R-2516-DR&E

October 1979

Acquisition Policy Effectiveness: Department of Defense Experience in the 1970s

Edmund Dews and Giles K. Smith

Allen Barbour, Elwyn Harris, Michael Hesse

A Report prepared for

OFFICE OF THE UNDER SECRETARY OF DEFENSE FOR RESEARCH AND ENGINEERING

Rand
SANTA MONICA, CA. 90406

The research described in this report was sponsored by the Office of the Under Secretary of Defense for Research and Engineering under Contract No. MDA903-77-C-0188.

Published by The Rand Corporation

R-2516-DR&E
October 1979

Acquisition Policy Effectiveness: Department of Defense Experience in the 1970s

Edmund Dews and Giles K. Smith
Allen Barbour, Elwyn Harris, Michael Hesse

A Report prepared for

OFFICE OF THE UNDER SECRETARY OF DEFENSE FOR RESEARCH AND ENGINEERING

Rand
SANTA MONICA, CA. 90406

PREFACE

This study originated in discussions between members of the Office of the Secretary of Defense (OSD) and members of the Rand staff concerning OSD's future development of defense acquisition policy. In these discussions it became evident that there was a lack of systematic, quantitative analysis aimed at identifying the strengths and weaknesses of existing policy. The present report is a contribution toward filling this analytical gap.

Part of the material presented here was reported earlier, in briefings and a working document, to the Office of the Undersecretary of Defense for Research and Engineering, which monitored the research performed under Contract No. MDA903-78-C-0188 in Rand's Acquisition Policy Program.

The findings reported here should be of interest to OSD and Service officials and others who are concerned with defense acquisition policy and management, the efficiency of the military requirements-development-production process, and problems of cost estimation and cost growth in military hardware acquisition programs.

SUMMARY AND FINDINGS

STUDY OBJECTIVE AND APPROACH

The primary objective of this study is to assist the Office of the Secretary of Defense in its current reassessment of defense acquisition policy by providing some quantitative insights into the effectiveness of the policy changes adopted at the beginning of the 1970s at the initiative of David Packard, then Deputy Secretary of Defense. Related objectives are (1) to identify policy areas where new initiatives seem desirable or further research would be profitable, and (2) to provide a set of organized, quantitative, cross-program data as a basis for future studies and comparisons.

The approach emphasizes quantitative analysis. The principal source of data is the Selected Acquisition Reports (SARs) issued quarterly for each major defense system being acquired. The most recent SARs analyzed in detail here are those for March 1978. Of the total of nearly 60 major systems now reported on in the SARs, some 30 were selected for study as being most representative of 1970s experience under the Packard guidelines. Among the systems excluded were those that had already entered full-scale development before 1969 and therefore presumably reflected earlier acquisition policies.

The report addresses five main questions:

- Has there been a positive response to the new policy guidelines established early in the 1970s?
- How have the results achieved in the 1970s acquisition programs compared with the goals established at the time the programs entered full-scale development?
- In terms of these result-to-goal comparisons, are the 1970s programs doing better than the 1960s programs?
- Is it now taking longer to develop and field systems than it did in the past? (The comparison is limited to fixed-wing aircraft.)
- What new initiatives and further research are suggested by these quantitative results?

The answers to these questions constitute the major findings of the study and are summarized below. An organized, quantitative, cross-program data base is presented in tables in the text and in Appendixes B and C.

RESPONSE TO THE PACKARD POLICY INITIATIVES

Of the 10 major elements in Mr. Packard's policy initiatives, 6 led to positive changes in organizational structure or standard operating procedures: (1) the Defense Systems Acquisition Review Council (DSARC) was established to provide systematic, high-level program reviews; (2) the Cost Analysis Improvement Group (CAIG) was established to provide OSD with independent cost estimates; (3)

"design-to-cost" was instituted, with a specific cost goal identified as a major program objective for each system; (4) responsibility for operational test and evaluation was shifted from the developing agencies to other, independent commands; (5) training courses and schools were established to prepare officers for program management; and (6) program managers were given written charters as a means of establishing their authority.

The remaining four elements required more discretionary responses, often involving program-by-program decisions at Service level; these responses were examined using a quantitative approach.

Our quantitative analysis of *program manager qualifications* suggests a trend in the direction of better-qualified managers, but the results depend on limited data and are generally not statistically significant. From interviews and other qualitative evidence we conclude that most program managers are now reasonably well qualified for the job, and some are very well qualified indeed. Compared with other groups for which data were available on *promotion experience,* program managers appear to have done very well on the promotion ladder in recent years, but questions can be raised about the composition of the groups compared, and we regard the results as suggestive rather than conclusive. Because of the inconclusive nature of these results, and because of the widely divergent views expressed by program managers and other program personnel about program management as a Service career, we believe OSD and the Services should not relax their attempts to attract superior officers to program management through favorable promotion opportunities and other incentives.

Job tenures for program managers have clearly been increasing, as called for in OSD policy, and are now between 2½ and 3 years on the average; but the increase had begun by the mid-1960s, well before the new guidelines were established. Length of tenure may now be in the right ballpark, but guidance may be needed concerning the timing of program manager assignments so as to coincide with natural break-points in program evolution.

The call for *early hardware testing* has had a strong positive response. Testing prior to both DSARC Milestone II (approval for full-scale development) and DSARC Milestone III (approval for production) increased markedly during the 1970s, so that by 1978 the hard data available at major decision milestones was much greater than it had been previously. The call for a *decrease in development/production concurrency* has also been answered, as shown by the high percentage of performance goals now achieved before DSARC Milestone III.

The response to Mr. Packard's call for *increased use of hardware competition* during development has also been positive, but not so clearly marked as in the case of hardware testing. About two-thirds of the programs that have reached DSARC Milestone II since 1973 involved significant use of hardware competition either before they entered full-scale development or subsequently. This change from the situation in the 1960s, when hardware competition in development was rare, was achieved in part because of the Advanced Prototyping Program, which provided direct dollar incentives for the Services to opt for an acquisition strategy involving hardware competition. However, for some programs that reached Milestone II in 1976 and afterward, favorable opportunities for hardware competition may not have been exploited. The Advanced Prototyping Program has not been continued, and there is as yet no strong commitment to hardware competition in OSD's formal policy documents, although there is a cross-reference to OMB's Circular A-109. The future of this key element of the Packard initiatives therefore appears somewhat in doubt, and a strong affirmation of OSD's commitment to hardware competition may be desirable, especially in view of the superior cost-growth record (discussed below) of the programs with hardware competition.

On balance, all policy elements being considered, the Packard guidelines appear to have been generally complied with. The result is an acquisition environment in the 1970s substantially different from that of the 1960s.

1970s EXPERIENCE: PERFORMANCE, SCHEDULE, AND COST

In comparing performance, schedule, and cost results with goals for the 1970s acquisition programs, the metric used was the ratio of results and goals, arranged so that in all cases the preferred outcome—higher performance, shorter schedule, lower cost—was represented by a ratio less than unity. The goals are those established at DSARC Milestone II when systems are approved for full-scale development. The results are those reported in the SARs through March 1978. The aggregate outcomes for the programs examined were as follows:

- For *system performance parameters*, the distribution of ratios was nearly symmetrical around unity, with a range from about 0.5 to 2.1, and a mean ratio of 1.0. On the average, performance goals were achieved for the parameters tested.
- For *scheduled program events* accomplished, the distribution of ratios was skewed slightly toward higher values (schedule slippage), with a range from about 0.8 to 2.1, and a mean ratio of 1.13. (These ratios reflect mainly experience in full-scale development, because the schedules established at DSARC Milestone II are heavily weighted toward development events and events early in the production phase.)
- For *program costs* as projected in March 1978, the distribution of ratios was skewed moderately toward higher values (cost growth), with a range from about 0.7 to 2.2, and a mean ratio of 1.20. The dollar-weighted mean ratio was 1.14, and the median ratio was 1.06. Thus *more than half of the programs had cost growth of less than 10 percent.* (In these comparisons, costs are calculated for the production quantity planned at DSARC Milestone II and are adjusted to eliminate the effects of inflation.)

Cost-growth ratios of the size found here for defense programs appear to be in the same ballpark as the cost-growth ratios observed for large nondefense projects involving new technology or other substantial uncertainties, although further research is needed to confirm this conclusion.

The sample of programs involving substantial hardware competition during or before start of full-scale development was characterized by considerably lower cost growth than the sample without hardware competition (a cost-growth ratio of 1.16 compared with one of 1.53). The sample with hardware competition also did somewhat better in terms of program schedules and system performance goals. The only program to pass DSARC III with negative cost growth (the UH-60) had full prime contractor competition through full-scale development. Although these samples are small, this result suggests that hardware competition deserves further attention, if only to identify more clearly the conditions in which it is likely to be advantageous.

As programs mature, the projected constant-dollar cost to complete them tends to increase, as might be expected. No program in our cost analysis sample of 31 programs had reached full term completion, but 17 had passed DSARC II by more than three years. For these 17 more mature programs, the mean cost-growth ratio was 1.34 compared with 1.20 for the whole sample including the younger programs. The average (linear) rate of cost growth for both the mature sample and the full sample was between 5 and 6 percent per annum. (This is somewhat greater than the annual cost-growth rates recently calculated by the Office of the Assistant Secretary of Defense (Comptroller), but the calculations are for different samples, and the OSD results are expressed in terms of compound rather than linear growth rates.)

Apart from inflation and changes in quantity, the major drivers of cost growth for the programs of the 1970s were schedule changes, engineering changes, and estimating errors. For the full 31 program cost analysis sample, schedule changes alone contributed about 40 percent of the total cost growth, or about $5 billion. There is a clear need to understand more concerning the underlying causes of schedule change.

The record strongly suggests that a substantial part of the cost growth is not within the area of control and responsibility of program managers, and in some cases it is even beyond the scope of control measures available to top level acquisition managers in the Services and OSD. Obviously this has important implications for OSD acquisition policy, and suggests that the search for better cost control should include consideration of changes in government policy and procedures outside the Department of Defense.

The conventional wisdom is that when programs experience difficulties, cost is the first constraint relaxed and schedule the second, but that performance goals are adhered to more rigorously. For 1970s experience, this view is supported by an examination of the result-to-goal ratios summarized earlier. But, for the 1970s at least, it must be added that constraints are relaxed (cost increases are accepted) for unit costs but not, generally, for total program costs. In the aggregate, total program costs in constant dollars have remained very close to the amounts projected in the Development Estimates (DEs) made at the time the programs entered full-scale development. For the 31 programs in our cost analysis sample, reductions in quantity almost precisely canceled out the sum of the cost changes due to the other variance categories. In other words, the real flexibility in the acquisition process is found in the quantities of units procured, not in the aggregate cost of acquisition programs.

This kind of flexibility raises important questions about the validity of the procurement quantities established in the requirements process and the manner in which quantity-quality tradeoffs are made.

1970s AND 1960s COMPARISONS

In terms of the degree to which program results approach program goals, the sample of 1970s programs shows improvement over the 1960s sample.

The 1970s programs are achieving their performance and schedule goals to at least the same degree as the 1960s programs did, and are probably doing slightly better.

The 1970s programs, moreover, are coming closer to their *cost* goals by some 10 to 20 percentage points. (The calculation is in terms of constant-year dollars and DSARC Milestone II production quantities.) This is a substantial reduction in cost growth. For the 31 1970s programs in our cost study the dollar sum corresponding to percentages of this magnitude would be from 9 to 18 billion 1979 dollars. Cost-growth avoidance is of course not the same as cost savings, but substantial cost savings are implied.

The average *annual linear rate* of program cost growth is also less—a rate of about 5 to 6 percent in the 1970s compared with 7 to 8 percent in the 1960s.

In this comparison of acquisition experience in the two decades, some caveats must be borne in mind: the somewhat different maturities of the 1960s and 1970s samples, the possibility of differences in program technical difficulty, and the influence of factors apart from OSD policy and beyond the control of program management, for example, the much higher rate of inflation in the 1970s. Nonetheless, we find it plausible that the changes in acquisition strategy and management introduced since 1969 have been the main contributors to the observed improvements. If the 1970s programs had not suffered from the unusually high rate of inflation they experienced, these improvements might well have been greater.

ACQUISITION INTERVALS: A SLOWDOWN IN THE DEVELOPMENT/PROCUREMENT PROCESS?

A recent study by the Defense Science Board identified lengthening acquisition intervals (slower fielding rates) as a critical defense issue. The DSB concluded that the times required for full-scale development had not changed appreciably, but that there had been some lengthening in the early phase of the acquisition process, before DSARC Milestone II, and also in the production phase, after DSARC Milestone III.

Because of the importance of this issue, we examined trends in aircraft fielding times, using a data base developed at Rand in connection with earlier studies. The sample included 34 U.S. aircraft acquired over a period of about 30 years. We lacked good data for the front end of the acquisition process, and therefore examined the time trends only for full-scale development (FSD) and production. The trend lines differed markedly for these two phases of the acquisition process.

The time taken to move from the start of development to first flight has changed little over the last 30 years, perhaps increasing very slightly. Total development time (measured from the start of development to the delivery of the first production item) also appears to have changed little (for the fighters in the sample), or even to have decreased somewhat (for the larger sample including bombers and transport aircraft). These results appear roughly consistent with the conclusions of the Defense Science Board.

The production phase, however, is taking much longer than it used to, as measured by the time between the delivery of the first and the 200th unit; this interval more than doubled in the course of 30 years. Again, this result is consistent with the DSB's findings. The cause of the lowered production rate is apparently fiscal rather than technical: higher production rates are generally quite feasible in terms of manufacturing capabilities and are often planned, but program funding rates for production have failed to keep pace with the increasing unit costs. The trend line for aircraft investment rates (constant-year dollars expended per month for the procurement of aircraft in the production phase) has remained almost level over time.

Even with the marked increase in production times, the net effect of the different trends in the successive phases of the acquisition process has been only a modest increase in total fielding times. The interval between the start of development and the delivery of the 200th production item has increased by less than 10 percent over the 30-year period—an average linear rate of increase of only a fraction of one percent per year. This does not, as explained earlier, take into account any lengthening that may be occurring in the pre-Milestone II phases of the acquisition process.

The results just summarized refer to a sample that excludes three recent aircraft programs each characterized by a distinct prototype phase preceding DSARC Milestone II—the A-10, the F-16, and the F-18. These aircraft were excluded from the trend analysis because of a conceptual problem concerning the proper timing for the start of development. Should Milestone II be the baseline date, or is it more realistic in these three programs to consider development as beginning earlier with the initiation of the prototype phase?

For these aircraft we examined both data points. If the development phase baseline is dated from the initiation of the prototype phase, the data points lie above the trend lines and thus suggest a continuing (or possibly accelerating) increase in total fielding times. If DSARC Milestone II is regarded as the correct development baseline, the data points for these aircraft generally fall below the trend lines and thus suggest either a reversal of the trend toward longer total fielding times, or some reduction in the historical rate of increase.

SUGGESTED POLICY INITIATIVES AND TOPICS FOR ADDITIONAL RESEARCH

Improve the Acquisition Information Data Base

Any systematic attempt to improve acquisition policy should be supported by an equally systematic attempt to improve the quality and extent of program data. The Selected Acquisition Reports already represent a major improvement in program data tracking compared with what was available before they were initiated in the late 1960s. However, because of their specialized and limited focus, the SARs are not a fully satisfactory source of data for analysis of broad acquisition policies.

A policy-oriented data base should be established in OUSDRE. Such a data base could utilize SAR information but should go beyond the present SARs in at least two areas. First, original baselines should be retained throughout the life of the program, together with a full documentation of all formally approved program changes. To the extent possible, the reasons for such changes in approved program goals should also be recorded (e.g., milestone slipped because of budget reduction, or technical difficulty) so that cause-effect relationships might be established. Second, to facilitate comparison of cost growth among many programs on an internally consistent basis, a different method of calculating cost variances should be used when there are changes in the buy size (see Section VI and Appendixes A and B for specific proposals).

Reduce the Instability in Program Funding and Scheduling

No major acquisition program can be planned and managed with high efficiency if it faces frequent and unpredictable changes in year-by-year program funding and production scheduling, even if total program funding eventually reaches the originally planned amount. Schedule slippage and cost growth are the closely related and mutually reinforcing effects of program funding instability. According to the SARs we examined, about 40 percent of program cost growth is attributable to schedule changes. Schedule changes, especially in operational testing and production, are a typical response to changes in annual program budgets. Presumably a large—but undetermined—share of this cost growth is therefore ultimately due to funding instability. We suggest three approaches to this problem:

- Provide what is now lacking: strong OSD policy guidance as to the desirability and means of reducing program budget fluctuations and schedule changes. For this purpose we offer a draft policy statement in Section VI.
- Institute a study of the relationship between annual funding instability, schedule slippage, and cost growth to quantify more definitively the effects of annual budget fluctuations on acquisition efficiency.
- As a part of the policy-oriented data base discussed above, methods should be established for routinely collecting information on changes in program budgets and the consequent changes in program structures so that the effects of budget fluctuations can be more accurately assessed and their causes identified.

Strengthen Guidance on Hardware Competition in Development

The evidence offered in Section III of this report presents at least a *prima facie* case in support of Mr. Packard's emphasis on hardware competition. However, in the latest OSD policy statements we have seen, hardware competition receives little attention; the topic is handled essentially through cross-references to OMB Circular A-109. As the Advanced Prototyping Program has not been continued, this indirect way of stating policy can be interpreted as a lessening of emphasis on hardware competition before and during full-scale development. If, as we believe, this interpretation is not intended, a partial solution can be achieved by means of a suitable statement inserted in DoD Directive 5000.1 and related documents, affirming OSD's commitment to competition beyond the paper proposal stage.

More than this affirmation appears to be needed, however. A general prescription in favor of competition where "beneficial" or "practical" is not enough. What is needed is guidance that will help the Services to decide when, under what circumstances, for what kinds of systems and contractors, and how far into development hardware competition appears desirable. Guidance of this kind should be based on experience. This suggests a need for a more detailed examination of program histories than could be attempted in this study. Recent samples of programs with and without hardware competition should be compared in detail.

Emphasize Production Quantity as an Element in the Requirements Process

This study did not directly examine the requirements process, but our results suggest that at the time the need for a new system is established the probability of attaining the planned production quantity may not receive sufficient management attention. As has been observed before and confirmed by this study, system performance goals and planned program costs are adhered to rather closely in the aggregate. For many reasons, however, acquisition costs per unit tend to rise above the cost goals. The eventual reconcilement with near-fixed total program costs is typically achieved by means of a substantial decrease in production quantity. This apparent flexibility as to the acceptable size of the operational inventory raises questions about the validity of the original requirement and suggests that production quantity and quantity-quality tradeoffs should receive greater emphasis in the requirements process.

Continue Incentives To Make Program Management an Attractive Service Career

Although there are indications that the status of program managers improved somewhat during the 1970s and that their promotion experience was favorable relative to some other groups of officers, the evidence is inconclusive and perceptions are mixed. The interviews suggest that many senior and middle-level officers now in the program management career field still have doubts about what it has to offer. Efforts to attract superior officers to program management should not be relaxed.

Examine the Timing of Program Manager Assignments

Average job tenures for program managers have been steadily increasing since the mid-1960s and may now be in the right ballpark. What is less clear is that program manager assignments are individually well timed with respect to natural transition points in program evolution. OSD policy is silent as to the preferred time phasing of assignments. Our impression is that there is insufficient understanding about what constitutes good timing in terms of program needs, and that this question deserves examination.

ACKNOWLEDGMENTS

For their help in identifying and assembling much of the data used in this study, we are grateful to many in the Office of the Secretary of Defense, the Defense Agencies, and the Services, including Mr. Robert Brandewie (Defense Manpower Data Center, Monterey, California), Mr. Gary Christle and Mr. Raymond Dominguez (Office of the Assistant Secretary of Defense (Comptroller)), Colonel Lauris M. Eek, Jr. (U.S. Army Materiel Development and Readiness Command, Alexandria, Virginia), Ms. Patsy Frogue (Naval Materiel Command, Arlington, Virginia), Mr. Michael H. Levy (Air Force Systems Command, Aeronautical Systems Division, Wright-Patterson Air Force Base, Ohio), and Captain J. D. Yamnicky (Office of the Undersecretary of Defense for Research and Engineering).

For their time and helpfulness in many stimulating sessions, we are grateful to the many officers and civil servants we interviewed, and especially the Program Managers and Deputy Program Managers, in the program offices of the IFV armored carrier, the Patriot missile, the Roland missile, the Hellfire missile, the Lance missile, the Advanced Attack Helicopter, the Aegis fire control system, the Harpoon missile, the Condor missile, the F-18 aircraft, the F-15 aircraft, the F-16 aircraft, the A-10 aircraft, and the PLSS target-location system.

Within Rand we acknowledge much help from those who critically read and commented on earlier versions of this report, including Brent Bradley, Mark Lorell, Gary Massey, and Michael Rich. The conclusions (and any deficiencies) are, of course, our own.

CONTENTS

Appendix

FIGURES

TABLES

I. INTRODUCTION

BACKGROUND

The Need for Quantitative Analysis

This study originated in discussions between members of the Office of the Secretary of Defense (OSD) and Rand concerning OSD's future development of defense acquisition policy. In these discussions it was noted that there appears to have been a lack of systematic analysis—especially of a quantitative kind—aimed at identifying the strengths and weaknesses of existing policy. It has therefore been difficult to assess various proposals for policy change. This study—part of a continuing program of acquisition studies at Rand—is a contribution toward filling that analytical gap.

Two Views of the Acquisition Process

The policy elements focused on here represent what may be termed the "second generation" of OSD acquisition policies. The first generation policies emerged during the early and middle 1960s when Robert McNamara was Secretary of Defense; these policies influenced most of the major defense systems developed in that decade.

The underlying assumption in the 1960s was that choices between technical alternatives could reasonably be made on the basis of design studies ("paper studies") and simulations, and that once a go-ahead decision was made, the actual development and procurement of a system would proceed more or less smoothly according to plan. Basically, system acquisition was regarded as a predictable activity, and, in accordance with this view, OSD attempted central management in detail.

The new policies introduced by Secretary Packard[1] at the beginning of the 1970s reflected a very different view of the uncertainties involved in the acquisition process. According to this view, development was a highly uncertain business requiring a cautious management style; paper studies were not enough. Prototyping and early hardware tests were encouraged as the means of selecting among alternatives; development was to be substantially completed before a production decision was made; management authority and responsibility were to be delegated to highly competent program managers; and system affordability and cost control were to be emphasized.

[1]David Packard was Deputy Secretary of Defense from 1969 to 1971, during which time he had primary responsibility for OSD acquisition policy.

The Packard Initiatives

More specifically, the Packard initiatives emphasized the ten major policy elements listed in Table 1. These policy elements were first outlined by Mr. Packard in a series of memorandums[2] and speeches, and (with one or two exceptions) they were soon codified in formal policy documents, particularly in Department of Defense (DoD) Directive 5000.1 of 1971 and in a series of supporting DoD Directives and Instructions issued soon afterward.

Table 1

THE PACKARD INITIATIVES: MAJOR POLICY ELEMENTS

1. Provide for systematic program reviews at important decision milestones by a group of senior officials in the Office of the Secretary of Defense (establish the DSARC--the Defense Systems Acquisition Review Council).
2. Improve program cost estimates and provide OSD with an independent source of such estimates by establishing a Cost Analysis Improvement Group (CAIG) within OSD.
3. Design to cost: establish a cost goal as one of the primary program objectives, equal to schedule and performance in importance; design with operation and support costs in mind as well as production costs (life cycle costing).
4. Increase testing objectivity by establishing agencies for operational test and evaluation (OT&E) independent of the Service commands responsible for development of new systems.
5. Improve the training of program managers by establishing military training courses and schools to prepare them for the job.
6. Strengthen the authority of program managers, especially by giving them a clear written charter.
7. Attract superior officers to program management, in part by providing them with superior promotion opportunities.
8. Reduce the turnover rate of program managers so that they have longer job tenure.
9. Resolve technological uncertainties during development, not during production (hence emphasize earlier and more complete hardware testing and reduce "concurrency"--the overlap between development and full-rate production).
10. Encourage competitive hardware developments to reduce risk and stimulate contractor efforts; where feasible, use prime-contractor competition through full-scale development to avoid developer monopoly at the time the initial production contract is negotiated.

The encouragement of competitive hardware developments was regarded by Mr. Packard as especially important, but for some reason this element of policy was not embodied in OSD's formal policy statements until the 1977 revision[3] of DoD Directive 5000.1, although it appeared earlier in some of the Service policy documents, notably those of the Army. To encourage increased use of hardware

[2]For example, the Packard memorandum of 28 May 1970, "Policy Guidance on Major Weapon System Acquisition."

[3]The 1977 revision of DoD Directive 5000.1 was a response to a government-wide acquisition policy document issued the previous year: Office of Management and Budget, Circular A-109, " Major Systems Acquisitions," 5 April 1976. This OMB circular itself owed much of its content to defense acquisition experience and practice, and it would be only a slight exaggeration to say that it represented a generalization of the Packard policy initiatives, adapting them to the acquisition of nondefense as well as defense systems.

competition, Mr. Packard adopted a pump-priming approach. He set up an Advanced Prototyping Program which was specially funded by the Congress. A pool of funds was established that could be drawn on by the Services only in support of prototype competitions. The Services were asked to propose candidates for competitive prototype development, several candidates were approved, and for these the prototype phase of development was supported from the special funds.[4]

Another element of the Packard policy that was not immediately embodied in formal policy documents was the call for longer program manager tenures; this did not appear until 1974.[5] It is clear, however, that from the beginning of the decade this and the other major policy elements listed in Table 1 received the serious attention of senior officials in OSD.

OSD's Current Reassessment of Defense Acquisition Policy

The acquisition policy changes initiated by Mr. Packard have been in effect for the greater part of a decade, and more than half of the major defense acquisition programs now under way have been conducted largely under their influence.[6] The data are becoming available for at least a preliminary appraisal of their effectiveness.

A review of defense acquisition policy by OSD would therefore be appropriate at this time in any case, but several considerations confirmed the need for such a review. First, there was the obligation to bring defense acquisition policy into conformity with the government-wide policy established by OMB Circular A-109. The needed changes concerned mainly the "front end" of the acquisition process, focusing on early, realistic statements of military requirements and formalized requirements procedures. These changes have been carried into effect recently, with the establishment of the Mission Element Need Statement (MENS) and the addition of a milestone "zero" in the defense acquisition process.

Second, there was growing concern about the length of time required to move a system through the entire acquisition process from program inception to the procurement of the final production item. Reasonably short "acquisition intervals" or "fielding times" are recognized as needed to capitalize on any lead times in technology the United States may have over its adversaries, and to sustain the qualitative superiority that has generally characterized U.S. military equipment since World War II. There is evidence, however, that U.S. fielding times have been increasing, and some observers have attributed this to the Packard policy that discouraged development/production concurrency and called for thorough testing before the commitment to production. Concern was heightened by the argument that increasing acquisition intervals contributed to increasing program costs, and by the possibility that the recent reform of requirements procedures would prolong the early part of the acquisition process.

---

[4]For more detail, see United States Senate, Committee on Armed Services, 92d Congress, 1st Session, *Hearings on Advanced Prototypes*, Washington, D.C., 1971, pp. 4-5, 35-37, and 40-41.

[5]In Department of Defense Directive 5000.23, "System Acquisition Management Careers," 26 November 1974.

[6]However, because of the long duration of major acquisition programs, few, if any, can be said to have been conducted under the Packard policies throughout a full program lifetime extending from program inception to the completion of the production phase.

This combination of additions to the Packard policy and criticisms of some of its major themes has recently led to an OSD review of defense acquisition policy as a whole. The present study was designed to support and contribute to that review.

OBJECTIVES

The main objective of this study is to assist OSD's current reassessment of defense acquisition policy by providing some quantitative insights into the effectiveness of the policy changes adopted at the beginning of the 1970s. Subsidiary objectives are (1) to identify policy areas where new initiatives seem desirable or further research would be profitable, and (2) to provide a set of organized, quantitative, cross-program data as a basis for future studies and comparisons, thus helping to strengthen "corporate memory" and facilitating future policy development.

In principle, the effectiveness of the Packard initiatives might be assessed by several different measures: for example, the degree to which the individual policy elements were adopted by OSD and the Services; the effect of the whole set of policy elements on acquisition program outcomes, as indicated by a comparison of program results and goals; or (ideally) the contribution of each policy element to the degree of success achieved by each program and by all programs in the aggregate. For several reasons it is not feasible in practice to employ measures of this third kind:

- There is no really satisfactory way of judging the contribution of a program to total defense effectiveness.
- Even if the question of overall defense effectiveness is sidestepped and each program is considered in isolation, there is little agreement about what constitutes "success" in program outcomes. (For example, it can be argued that some programs that were canceled before production began were nonetheless initially well conceived, well managed, and successful in meeting program goals during development.)
- Moreover, because of the small number of major programs and their great diversity, there is no satisfactory method of isolating cause and effect relationships for each of the policy elements.

Accordingly, this study focuses on measures of the first two kinds. The major emphasis is on the effect of the Packard initiatives as a whole, as measured by a comparison of observed results and stated goals for the acquisition programs of the 1970s.[7] We also present some quantitative measures of compliance for selected policy elements.

[7]We recognize, of course, that OSD's acquisition policy is only one set of factors affecting program outcomes. External influences (outside OSD and the Services) can occasionally exert important or even dominant influences on program management and outcomes. Within the executive department, the budget guidance of the Office of Management and Budget is always important, and the intervention of the President can be decisive. The Congress sometimes "manages" program details through funding decisions. The workload of the contractor, the health of the defense industry, and the general state of the economy can affect individual programs; in some years in the 1970s, high rates of inflation had important consequences. Foreign military sales place increasing demands on program management and can influence costs and schedules in unforeseeable ways. Substantial changes in the nature and sophistication of the military threat may occur when program lifetimes are long, thus leading to mid-program design alterations, expensive retrofitting, or even program cancellation.

DATA SOURCES AND DATA ADEQUACY

Because of the study's emphasis on quantitative analysis, its scope was largely determined by the data that were readily available to us or could be generated within the limits of study resources. We relied mainly on the quarterly Selected Acquisition Reports (SARs), which provide the only easily retrievable, systematic record of acquisition program data extending over the whole period of interest. The cutoff date for the quantitative data used in the analysis was May 1978; thus the March 1978 SARs were the last consulted in the comparison of program results and goals and the assessment of policy compliance.

Additional information was obtained from the Decision Coordinating Papers (DCPs) generated in the course of DSARC reviews, and from extensive interviews with program managers and management personnel in 13 program offices. The DCPs and interviews provided some information not available in the SARs and offered some useful insights into the interpretation of SAR data. For our examination of program manager career characteristics and promotions we obtained data from the Defense Manpower Data Center in Monterey, California. The data on program manager tenures came directly from the Services. Other data sources were also drawn on for certain aspects of the study, as noted in the text.

The SARs represent a major improvement in the collection and presentation of program information. Established in 1968, the SARs are prepared quarterly by the program managers and forwarded through service channels to the OSD and to the Congress. They provide a sparse but valuable compilation of data, two elements of which were especially useful for our study. First, the SAR series for each program records a program baseline, established at the beginning of full scale development (the DSARC II milestone), that describes the acquisition program in terms of the expected cost, schedule, and system performance. The baseline is used here as a reference point for examining how the program evolved. The second set of valuable information provides explanations of why the program varied from the baseline, expecially in terms of program cost variance.

The SARs are not designed specifically for the kind of management analysis conducted in this study. The level of detail, the information on cause and effect relationships, and some of the accounting procedures used are less than ideal for our purposes. Because project resources prevented an extensive independent data collection activity, we relied extensively on SAR data, although in some cases we recalculated certain elements of cost variance in a way that seemed more suitable for our study objectives. Those analysis methods, together with recommendations for additional data collection in support of acquisition policy analysis, are described in Sections III, IV, and VI of the text and in Appendixes A and B.

Systems Included in the Study

The study examines experience with "major" defense systems (programs).[8] In practice, these are the systems that are expensive, are subject to DSARC review, and are reported on in the SARs. Between 50 and 60 systems are now reported on

---

[8]A major system is one so designated by the Secretary of Defense. Typically, major systems are expected to exceed $75 million in development or $300 million in production cost.

in this way, and for one calculation (a comparison between our own and OSD cost-growth results),[9] we examined this full set of systems. But the basic sample examined here is limited to about 30 systems, selected as being representative of acquisition experience in the 1970s.

Three categories of systems were excluded in selecting this basic sample:

1. Systems that had started full-scale development before 1969.
2. Navy ship systems.
3. A few systems for which data were incomplete or ambiguous.

Systems that entered full-scale development before 1969 were excluded because they were regarded as having been influenced more by the acquisition policies of the 1960s than by the Packard initiatives. Navy ship systems were excluded for several reasons. They are a special type of acquisition, difficult to separate into conventional development and production phases. Moreover, at the time of the study, several ship systems were subject to intense scrutiny by both the executive and legislative branches of government, and some were involved in major litigation. Thus we were unsure of the completeness and timeliness of some of the ship system data and of our ability to find our way through areas of contention. The other excluded categories contain only a few systems, and their exclusion is unlikely to affect the results. The 32 systems remaining after the exclusion of these three categories are listed in Table 2 and constitute our primary data base. They represent acquisition programs totaling more than $100 billion in development, test, production, and initial support.

Table 2 lists the 32 programs examined—10 Army, 13 Navy, and 9 Air Force.[10] From this basic set of 32 programs, subsets were selected as appropriate for the analysis or as dictated by special data limitations. In some analyses, for example, we focused on the more mature programs, as in the examination of the amount of testing achieved by the time of the production decision (DSARC III Milestone). In other cases it was necessary to exclude one or more programs because the data were insufficient for our purpose. For example, the analysis of cost experience was limited to 31 systems because the baseline cost data were incomplete for the AIM-7F Sparrow missile. Such adjustments of the data set are explained at appropriate places in the text.

ISSUES NOT ADDRESSED HERE

The current debate over acquisition policy focuses in part on issues that have arisen only during the past few years. One of these, as already mentioned, concerns the requirements process: Milestone 0, the MENS, and indeed all the activities preceding the decision to proceed to full-scale development (DSARC II). The process of selecting what is to be developed is almost certainly as important as the process of managing the actual development and production of the system. However, this

[9]This comparison is discussed in Appendix A.

[10]For convenience, we list these programs by single Service according to the Service attribution adopted by the Office of the Assistant Secretary of Defense (Comptroller). However, some of these might be more properly described as joint-Service programs—for example, the ALCM and GLCM, which (like the Tomahawk SLCM) are managed out of the Joint Cruise Missile Project Office headed by a Navy officer.

Table 2

PROGRAMS EXAMINED
(Basic Sample, 32 Programs)

Programs	Calendar Year of DSARC II[a]	Calendar Year of DSARC III[b]	Program Office Interviewed in This Study?
Army (10 systems)			
UH-60A (Black Hawk) helicopter	1971	1976	
M-198 howitzer	1971	1976	
IFV (MICV) armored carrier	1971	---	Yes
Patriot missile	1972	---	Yes
Copperhead (CLGP) projectile	1975	---	
Roland missile	1976[c]	---	Yes
Hellfire missile	1976	---	Yes
YAH-64 (AAH) helicopter	1976	---	Yes
XM-1 tank	1976	---	
DIVAD gun	1977	---	
Navy (13 systems)			
Aegis fire control radar	1969	1978	Yes
CAPTOR torpedo-mine	1971	1975	
AIM-9L Sidewinder missile	1971	1976	
AIM-7F Sparrow missile	1973	1974	
Harpoon missile	1973	1975	Yes
Condor missile	1973	1976	Yes
LAMPS MK. III	1973	---	
SURTASS surveillance system	1974	---	
F-18 aircraft	1975	---	Yes
TACTAS surveillance system	1976	---	
Tomahawk (SLCM) cruise missile	1977	---	
5-in guided projectile	1977	---	
8-in guided projectile	1977		
Air Force (9 systems)			
F-15 aircraft	1969	1972[d]	Yes
B-1 aircraft	1970	1976	
AWACS (E-3A) aircraft	1972	1974	
A-10 aircraft	1973	1974	Yes
F-16 aircraft	1975	1977	Yes
DSCS III space system	1976	---	
ALCM cruise missile	1977	---	
GLCM cruise missile	1977	---	
PLSS target-location system	1977	---	Yes

[a]DSARC II is the milestone at which the DSARC recommends whether to continue the program into full-scale development (FSD). In some cases where the program had no formal DSARC II, the year shown is the date of program entry into FSD.

[b]DSARC III is the milestone at which the DSARC recommends whether to produce the system. Because of the cut-off date of this study, DSARC III dates in 1978 or 1979 are not included.

[c]Year when DSARC restructured the predecessor SHORAD program; assumed equivalent to DSARC II for the Roland program.

[d]Year when long-lead-time production items approved; full production approved early 1973.

phase of acquisition is still very sketchily documented, and there is as yet little experience regarding Milestone 0 and the MENS. Because of the lack of actual experience with these new policy elements, no attempt was made in the current study to evaluate them.

Another policy issue excluded from the study concerns the growing influence of foreign military sales (FMS) on acquisition management. Again we acknowledge the importance of this policy area and observe that there may be a good case for new OSD initiatives. However, the data currently available do not readily lend themselves to our quantitative approach.

Finally, we did not explicitly address the set of issues relating to the integration of the DSARC process and the Program, Planning, and Budgeting system. These issues are clearly of major importance; but since they were already being examined by several high level study groups,[11] we decided that our resources could be better used by examining other policy elements. We do, however, have something to contribute to the question of DSARC-budget coordination, as a result of an examination of program "stability" over time—especially program funding stability.

OUTLINE OF THE REPORT

In what follows, the main emphasis is on the overall effect of the Packard initiatives as measured by a comparison of program results and goals. We begin, however, by addressing the question of policy compliance: Have the Packard policy initiatives been carried out in practice during the 1970s? Evidence supporting a generally affirmative answer is presented in Section II.

Section III examines the degree to which, in the 1970s, results have approximated the goals for system performance, program schedule, and program cost. Section IV continues this analysis by comparing the degree of performance achievement, schedule slippage, and cost growth observed in the 1970s with the corresponding outcomes in the 1960s.

Because of the growing concern that the acquisition process proceeds too slowly from program initiation through development and production to the fielding of the system, we drew on data from earlier Rand studies, examined acquisition speeds for a large sample of military aircraft programs, and quantified trends in "fielding times" over a period of three decades. These results are shown in Section V.

Section VI discusses two final topics. The first is a brief review of program budget instabilities and their possible effects on cost growth. The second topic emerged as a by-product of the earlier analyses: an awareness of gaps in the data base and difficulties in using the existing types of data for improving policy through experience. Among our findings are some suggestions about how program record-keeping might be improved to provide a better basis for developing acquisition policy through institutional learning.

---

[11]See, for example, Donald B. Rice, *Defense Resource Management Study,* Final Report, a report requested by the President and submitted to the Secretary of Defense, February 1979, especially Chap. 1.

Appendix A describes the method used for calculating program cost growth when changes in production quantity occur and explains why that method was selected instead of the method used by OASD(C). Appendix B analyzes the basic causes of program cost variance. Recommendations are made on the kinds of cost variance data that should be collected for an OSD management information system designed to improve corporate memory and facilitate learning from experience. Appendix C provides brief system descriptions and program cost summaries for the 26 programs in our sample that experienced cost growth; these cost summaries are tabulated in a format that facilitates comparison of cost growth among programs that started in different years and experienced different degrees of inflation.

II. RESPONSES TO THE PACKARD INITIATIVES

FORMAL RESPONSES—POSITIVE

Of the 10 Packard initiatives listed in Table 1, the first 6 were followed by easily confirmed formal responses—positive changes in organizations or in standard operating procedures:

- The Defense Systems Acquisition Review Council (DSARC) was established within OSD. Since the early 1970s it has conducted systematic, high-level reviews at successive program-decision milestones. Similar system acquisition review councils were established within the Services.
- The Cost Analysis Improvement Group was established within OSD. It has contributed independent cost estimates and cost critiques for DSARC and other OSD uses.
- Design-to-cost was formally adopted as the norm in Service regulations, and since the early 1970s a cost goal has typically been stated at DSARC II and re-examined at subsequent milestones.
- Independent testing agencies have been established within the Services.
- Training courses and schools have been established to prepare officers for program management.
- Program managers have been given written charters confirming their authority and establishing their reporting channels.

There may be questions about the manner in which these actions have been carried out, and about their individual effectiveness; but it is clear that in each case there was a positive response to the new policy. The effectiveness of these and the other elements of the Packard policy, considered as a whole, will be assessed in Sections III and IV.

DISCRETIONARY RESPONSES—POSITIVE ON BALANCE

The four remaining policy elements listed in Table 1 are of a somewhat different nature. Rather than requiring a visible organizational change or a straightforward alteration in standard operating procedures, they call for results to be achieved by a change in emphasis—by an aggregate shift in largely discretionary decisions made by the Services. Some of these, such as the emphasis on early testing and hardware competition, lie at the heart of the Packard approach for dealing with the uncertainties in the acquisition process. On balance, as will be shown in the remainder of this section, these more discretionary responses have also been positive.

Program Manager Qualifications and Promotion

In 1969 a Defense Science Board task force concluded that a "major increase in the recognition, the status, and the opportunities in program management may be necessary to attract and retain a larger share of the most capable career officers" for system acquisition management.[1] In the following year the Blue Ribbon Defense Panel identified the status of program management as a weakness in defense acquisition.[2] And Mr. Packard, in his policy guidance memorandum of May 1970, observed that "program management in the Services will be improved only to the extent that capable people with the right kind of experience and training" are chosen as managers, and that "program managers must be given more recognition."[3] At about the same time, increased manager tenures (longer tours of duty) were identified as desirable by several study groups. These perceptions were briefly indicated or implied in DoD Directive 5000.1 of 1971, and developed more explicitly in DoD Directive 5000.23 of 1974.

Among other things, the 1974 directive required that:

- Career opportunities should be established to attract, develop, retain, and reward outstanding military officers and civilians employed in acquisition management.
- Promotion opportunities for military officers should be equal to those of their contemporaries in operational and command positions.
- The tenure of program manager assignments should be sufficient to ensure management continuity.[4]

In what follows we attempt to assess whether this guidance has been complied with.

Qualifications are difficult to reduce to numbers, but, in keeping with our attempt to provide quantitative assessments, we selected two indicators as proxies for officers' qualifications at the time of their appointment to be program managers: (1) years of formal education, and (2) years of service before promotion to grade. It is plausible that the better qualified officers would have more formal education and would have demonstrated qualities of leadership resulting in faster promotion. This choice of indicators was largely determined by the types of data maintained by the Defense Manpower Data Center.[5]

These two indicators were examined for program managers and other officers for two different years, 1972 and 1978. We sought to answer two questions:

- How did program managers compare with other officers in terms of these indicators?

---

[1]Defense Science Board Task Force on Research and Development Management, *Final Report on Systems Acquisition*, Washington, D.C., September 1969.

[2]Blue Ribbon Defense Panel *Report to the President and Secretary of Defense on the Department of Defense*, Washington, D.C., July 1970.

[3]David Packard (Deputy Secretary of Defense), "Policy Guidance on Major Weapon System Acquisition," Memorandum, May 1970.

[4]Department of Defense Directive 5000.23, "System Acquisition Management Careers," 26 November 1974.

[5]The data base of the Defense Manpower Data Center is excellent within its limits. It contains current and historical data for the entire officer population for all the Services, and it is readily accessible. In some respects, however, it is more highly aggregated than would have been desirable for our purposes. A more detailed analysis would require the use of data bases of individual Services; this was beyond the limited resources available to the present study.

- What was the trend of the indicators during the period?

The program manager group was compared with two other groups of officers: all officers of the same grade,[6] and the subset of officers of the same grade having occupational codes of executive officer, research and development coordinator, or general or flag officer. This subset of officers was chosen as representing a group roughly comparable to program managers in terms of previous career experience.

The results of the comparisons are summarized in Table 3. In terms of their absolute quantities, the indicators suggest that program manager qualifications improved over the period; program managers had a higher level of education in 1978 than in 1972, and they attained their current grade more rapidly. But very similar changes occurred for the other groups also.

In relative terms, the indicators show little difference between program officers on the one hand and "comparable" officers and all officers on the other. In both 1972 and 1978, the less senior program managers (grades O6 and O7) had a slightly higher average level of education than the same grades in the other groups, but, as shown in Table 3, the difference is statistically significant in only one instance. In 1972, program managers generally had been promoted not quite so fast as the other groups, but by 1978 they had caught up with the others and in fact slightly exceeded them in speed of promotion to current grade. Thus, although there is some evidence of a relative improvement over time in the qualifications of program managers, the change in this indicator appears to be too slight to support firm conclusions. However, from more subjective evidence and on the basis of our interviews, we conclude that most program managers are now well qualified for the job.

In our interviews with program managers and other senior program personnel, we found that many regarded their promotion opportunities to be fully equivalent to those of their contemporaries in operational, line, and command positions; but several admitted doubts about this, and a few of those who did so expressed the view that, while prospects for promotion had improved for program managers since 1970, these prospects were still inferior to those in some other career areas. Two remarked that they had advised younger officers to avoid the management area. Thus, at least among officers already in middle and senior program management positions, perceptions about this career ladder appeared mixed.

Although this matter of career ladder reputation is clearly important in attracting able and ambitious officers, in the present study we addressed it only incidentally; instead, we assessed actual promotion experience as a measure of compliance with policy. To do this, we compared the recent promotion experience of O6-grade program managers with that of the whole population of O6-grade officers, and with that of a more comparable group consisting of all O6-grade officers having occupational codes of executive officer or research and development coordinator.[7] The comparison examines the promotion experience during the years 1972 to 1978 of

---

[6]The relevant grades were O6, O7, and O8. Officers in grade O6 are colonels in the Army and Air Force, captains in the Navy; officers in grades O7 and O8 are general or flag officers.

[7]These are the occupational codes most frequently possessed by program managers; over 80 percent of the 1972 program managers had one or the other of these codes. By this criterion, the executive officer/R&D coordinator group and the program manager group should be reasonably comparable. We would have liked to make a direct comparison between the promotion experience of officers in the program management career option and that of officers in the field command career option, but the data base of the Defense Manpower Data Center was not structured to facilitate this comparison.

Table 3

Program Manager Qualifications Compared with Those of Other Officers, by Education and Length of Service Before Promotion to Current Grade

Characteristics	Program Managers: Grade Level 06	07	08	All Grades	Comparable Officers: Grade Level 06	07	08	All Grades	All Officers: Grade Level 06	07	08	All Grades
1972												
Average Education Level (Years)	17.4	17.5	16.0	17.3	16.7	17.3	16.8	16.8	16.7[a]	17.2	16.8	16.8
Average Length of Service before Promotion to Present Grade (Years)	23.0	25.5	29.7	24.4	22.7	26.7	26.0	24.0	22.6	26.9	26.2	22.8
1978												
Average Education Level (Years)	17.7	17.8	18.0	17.8	17.1	17.6	18.6	17.7	17.3	17.6	17.5	17.3
Average Length of Service before Promotion to Present Grade (Years)	20.8	24.1	26.0	22.1	21.3	25.8	25.8	22.8	20.9	25.8	25.8	21.2

SOURCE: Defense Manpower Data Center.

[a]The hypothesis that the program manager group is a random sample of the "comparable officers" group or the "all officers" group for the same grades can be rejected by the chi-square test only in this single case (significance probability ≤ 0.05).

the program managers and the other O6 officer groups as they existed in 1972 in all Services. The initial year 1972 was selected for several reasons: (1) it was convenient because a full list of program managers was readily available for that year, (2) it followed the Packard initiatives by enough time to allow the new policy to become known and begin to influence promotion decisions, and (3) it was early enough so that by 1978 substantial promotion experience had accrued. The results are shown in Table 4.

Table 4

PROGRAM MANAGER PROMOTION EXPERIENCE COMPARED WITH THAT OF OTHER OFFICER GROUPS

		Same Officers, March 1978	
Officer Groups	Number of O6 Officers in Group in 1972	On Active Duty in Same Grade or Left Service (Percent)	On Active Duty With Higher Grade (Percent)
Program Managers	18	61	39
Comparable Officers	1,784	95	5
All Officers	15,602	95	5

SOURCE: Defense Manpower Data Center.

Of the 18 O6-grade officers serving as program managers in 1972, seven officers —39 percent—had been promoted and were still on active duty in 1978. The corresponding figure for the other officer groups was only 5 percent. By this comparison, promotion opportunities during the period 1972 to 1978 appear to have been excellent for those who were already program managers in 1972. Thus there is support for the view that Service practice has been largely in compliance with the new policy guidance.

Two possible objections to this conclusion may be advanced. First, it may be argued that the program managers should be compared with different (more select) officer groups than those shown in Table 4, and that some of these other groups would exhibit substantially higher promotion percentages than the program managers. But a serious problem arises in defining these groups and obtaining suitable data for them. Second, it may be argued (and was, by several program managers we interviewed) that the experience of the 1972 group is atypical—that after an initial period of compliance with the new promotion policy in the mid-1970s, there has been a tendency to return to earlier practices with less favorable promotion opportunities for program managers.

Unfortunately, the data readily available were insufficient to enable us to test these arguments satisfactorily. The promotion of officers is based on a rich variety of factors, many of which are subjective, and repeated attempts by others to derive a quantitative model of promotion practices have met with failure. Regardless of the evidence offered here that promotion prospects are good in the program management area, the fact that many officers have a contrary impression should be sufficient to justify the continued attention of senior DoD officials to this important matter. It may be desirable to supplement our results by more detailed, Service-by-Service studies. If these confirm that promotion prospects in the program management area are indeed good, this fact should be made more widely known to young officers. If not, suitable actions should be taken to correct the situation.

Program Manager Tenure

By the end of the 1960s it had become apparent that acquisition programs often suffered from too rapid a turnover of program managers. Program duration sometimes exceeded 10 years, and program managers frequently served less than 2 years on the job.[8] The frequent leadership changes not only produced unnecessary shifts in program emphasis, they also led to loss of direction while the newly assigned program managers settled in and learned their jobs. The new policy guidance therefore called for increased management stability through longer tenures for program managers and overlapping assignments for the outgoing program manager and his replacement.

The limited data we have seen, supported by interview results, suggests that the Services usually schedule only a brief overlap (sometimes none) between successive program managers, seldom enough to provide a substantial transfer of program-specific knowledge and experience.[9] Because of problems of divided authority, there is a strong military tradition against command overlap, and this seems to be carried over into the area of program management. In this respect, practice does not appear to comply with the spirit of DoD Directive 5000.23. On the other hand, the deputy program manager is often a very experienced civil servant, as are some other senior people in the program office, and the Services rely on this civilian program staff to maintain management continuity. Most of the program managers we interviewed seemed to regard this method of achieving continuity as adequate, given that changes in leadership occurred infrequently and at natural breakpoints in the evolution of the program.

Longer tenure on the job has the advantage that it reduces the number of program leadership changes and increases the fraction of program lifetime in which the program manager is well equipped to handle his job.[10] The data on program manager tenures from 1961 to 1978 indicate a steady increase in tenure from an all-Service average of about 18 months in the 5 years centered on 1963 to about 32 months in the 5 years centered on 1976. This result is shown in Fig. 1. The steady upward trend[11] in the 5-year moving averages that was already established in the 1960s has continued in the 1970s. Since 1969, the 5-year moving

[8]In the period 1961-1965, for example, the *average* tenure for all program managers was 18 months; for Army program managers, the average was only 12 months.

[9]The principal exception to this is the occasional selection of new program managers from within the program office.

[10]Even an experienced program manager transferred to a new program must learn the background of the new program, master a great deal of technical data, and establish a network of contacts before he can be fully effective.

[11]The linear regression line in the figure accounts for over 91 percent of the variance in the data.

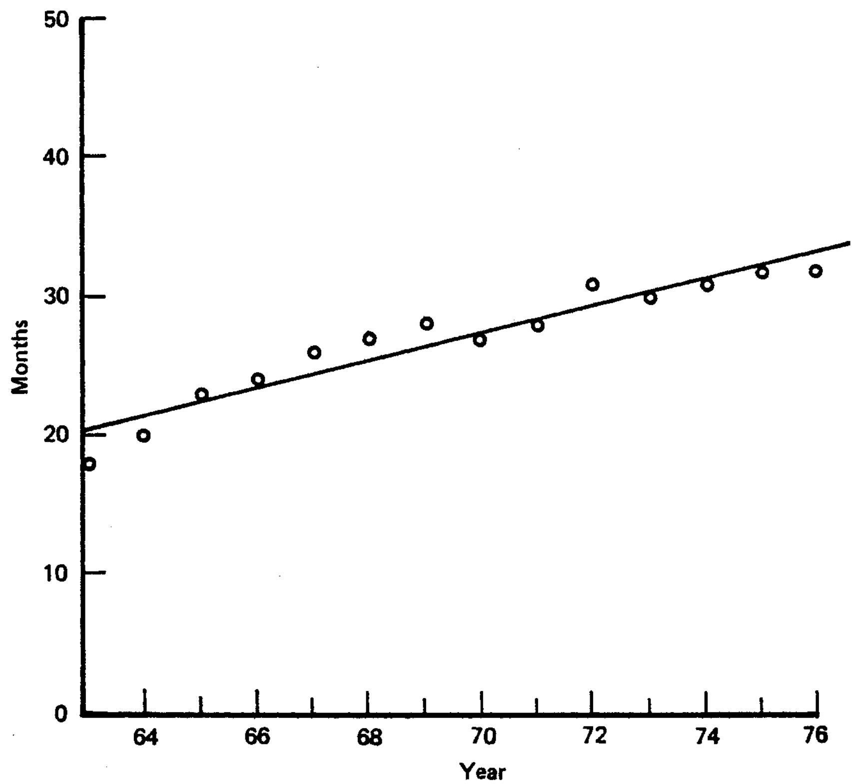


Fig. 1—Program manager tenure, five-year moving averages

NOTE: The period examined begins in 1961 and ends in 1978. The data points are five-year moving averages plotted at the middle year of each five year period.

average has lengthened from 26 months to 32 months, an increase of nearly one-fourth.

The data thus show a steady movement in the direction desired by Mr. Packard's guidance, and in this sense there has been compliance with OSD policy. But, as in so many instances, a direct causal connection between these elements of policy and practice cannot be established. The new policy may simply have affirmed a need for longer tenures already accepted and acted on by the Services. Another possibility is that we are observing one aspect of some broader movement toward longer tours of duty, carrying along program managers as part of a wider group of officers. Because of the aggregated data base at the Defense Manpower Data Center, we were not able to test this possibility. We suspect that the increased tenures observed are the combined result of many factors, including some general tendency toward longer tours of duty, independent Service perceptions of the need for greater program management continuity, and a significant reinforcement provided by OSD's policy guidance.

It seems clear that the tours of duty for program managers have frequently been too short, especially in the 1960s. What is not clear is how long these tours should be. Are they now about right, or should even longer tenures be sought for the future? The answer presumably depends on the duration of programs (which appear to be lengthening, at any rate in the production phase), and the number and timing of the "natural" program breakpoints at which it is convenient or desirable to bring in a new program manager. It has been suggested that there are two or three such natural transition points in a typical acquisition program. This implies no more than three or four program managers, and, if programs last about 10 years, an average tenure of 30 to 40 months—possibly somewhat less if allowance is made for occasional shortened tours due to program cancellations and replacements of misassigned personnel. Something like the current average of about 32 months might then be about right. However, if programs are typically longer than 10 years or have only one or two convenient breakpoints, a further increase in average tenures would be called for. Additional research seems to be required if OSD is to update its policy on tenure. In particular, more specific guidance about the time-phasing of program manager appointments appears desirable.

Early Hardware Tests

A key element in Mr. Packard's new policy guidance was the emphasis on the need for early hardware fabrication and testing. This was a return to a style of acquisition that had been largely abandoned in the 1960s, when "paper" designs together with studies and simulations often replaced early prototyping. The new guidance emphasized early hardware tests not only as a preferred approach for the developer, but specifically as a means of providing the hard data needed to improve DoD decisionmaking at important milestones in the acquisition process. Test results were desired to demonstrate the feasibility of the technical approach at the time of DSARC II (the decision to proceed to full-scale development) and to confirm system capability and producibility at the time of DSARC III (the decision to go into production).

Testing Before DSARC II. We inquired whether hardware test results had become increasingly available during the 1970s for use in DSARC II deliberations. There was no easy way to answer this question, because information on early (pre-DSARC-II) testing is not systematically recorded in summary documents such as the SARs. (Recall that the SAR series for a given program usually comes into existence only after DSARC II.) We therefore relied on a variety of sources of varying completeness, and when the information for a given program seemed ambiguous, we excluded that program from the analysis. Of our basic sample of 32 programs (see Table 2, above), we could categorize 27 as either having or not having some significant amount of full-scale hardware testing before DSARC II.[12]

When arrayed according to the year in which the DSARC II milestone was passed (see Fig. 2), these programs display a steady trend toward the greater use

[12]A "significant amount" of testing meant that at least one major element of the system was fabricated in full scale and subjected to "field" tests (that is, an aircraft or missile was flown, a vehicle was driven across appropriate terrain, etc.). The usual laboratory tests (wind tunnel, etc.) of scale models or developmental components do not satisfy the present criterion. The five programs we were unable to categorize to our satisfaction were the Army's M-198 howitzer, and the Navy's CAPTOR mine-torpedo, SURTASS and TACTAS surveillance-sonar systems, and Tomahawk cruise missile.

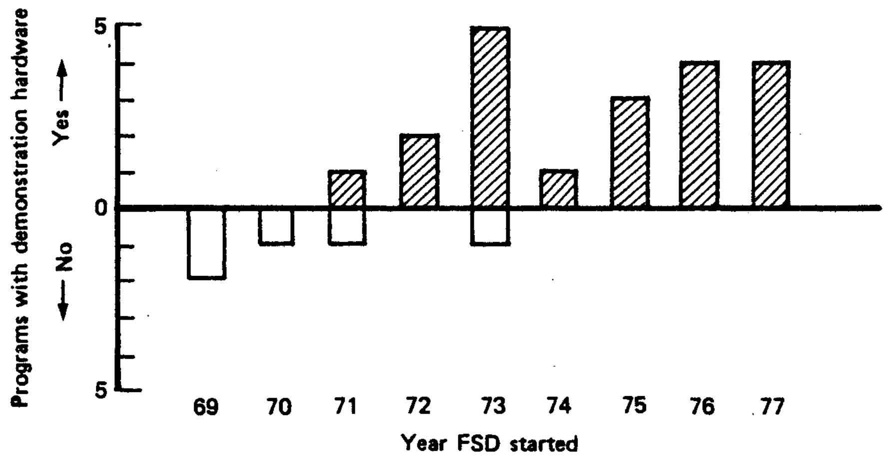


Fig. 2—Hardware testing prior to DSARC II

NOTE: Here two pairs of programs with FSD starting in 1977 (the 5-in. and 8-in. guided projectile programs, and the ALCM and GLCM cruise missile programs) are counted as if each pair was a single program. If each program in these two pairs had been counted separately, the bar for 1977 would be two units higher.

of hardware tests to demonstrate feasibility prior to full-scale development. Indeed, with two possible exceptions,[13] all the programs in our basic sample that reached DSARC II after 1973 could be categorized as including at least some full-scale hardware testing prior to DSARC II. Between 1969 and 1975, there was clearly an increase in the amount of pre-DSARC-II testing. In this instance, there is little reason to doubt that the result was a direct response to OSD's new policy guidance.

Testing Before DSARC III. The Packard policy innovations also called for comprehensive, independent testing of near-production hardware during FSD as a means of further reducing technical uncertainty and improving the cost, effectiveness, reliability, and other types of information available at DSARC III, when the production decision is considered.

We inquired, therefore, whether there had been an increase since 1970 in FSD hardware testing. Accepting the test parameters identified at the time of DSARC II as reflecting a reasonably comprehensive test plan, we examined the extent to which these parameters had actually been tested by the time of DSARC III, and, for the parameters tested, the degree to which the stated performance goals had been achieved. Obviously, both measures are important. The extent to which planned testing was accomplished by the time of DSARC III is a measure of compliance with DoD policy; the identification of performance successes and shortfalls is a major objective of testing and an important input to tradeoff decisions during FSD, as well as to the decision to produce a system.

Previously, in examining the availability of hardware test data at the time of DSARC II, we asked only whether some substantial amount of hardware testing had been accomplished prior to this decision point. Now, for DSARC III, we ask *how much* test information was available, relative to the full set of performance parameters listed for testing in the initial "approved program."

[13]The possible exceptions are the TACTAS and the Tomahawk, which we did not categorize.

The *initial* approved program is the approved program adopted at the beginning of full-scale development, that is, at the time of DSARC II or soon afterward. Unlike the DSARC II approved program "development estimate" or program cost goal, which is repeated with few if any changes in successive SARs, the approved program system-performance and program-schedule goals may change substantially from SAR to SAR as a result of successive OSD-approved program changes.[14] To provide a fixed basis for comparing performance and schedule results with goals, we made use of the goals adopted in the initial approved program (and usually stated in the first SAR issued after DSARC II). When performance or schedule or cost goals are mentioned below, the initial approved program goals are those referred to, unless otherwise indicated.

The test chronology and the data for comparing the performance results achieved by the time of DSARC III with the performance goals stated at the time of DSARC II were obtained by examining successive SARs, beginning with the initial SARs and concluding with those for March 1978. The program sample consisted of those systems listed in Table 2 that had reached DSARC III by March 1978, except for the two cancelled systems.[15] For each of these programs we obtained the following data from the SARs: the list of performance parameters,[16] the corresponding performance goals, the test results for each parameter, and the date when these results were reported in the SAR.

Figure 3 illustrates one type of result obtained, using the Harpoon program as an example. The percent of parameters subjected to test and the percent of goals met or exceeded are shown as a function of time measured from DSARC III.[17] Test results in the Harpoon program began to appear about 4 years before DSARC III. At the time of DSARC III, about 95 percent of the performance parameters had been subjected to test and over 85 percent of the performance parameters had met or exceeded the performance goals. For the 3 years following the Harpoon DSARC III, the SARs show no additional parameters as being subjected to test or achieving performance goals.[18]

Figure 4 is similar to Figure 3 but presents an average or composite picture of the programs in our sample that had entered production.[19] For these programs as

---

[14]Using the sequence of SARs, we examined the performance and schedule changes successively approved by OSD as the "approved programs" evolved over time. Such changes are not frequent, and they are only occasionally large, but in the aggregate they can be significant. By the time a program enters the production phase, the "approved program" as shown in the then-current SAR can be different in several important respects from the initial approved program adopted at the time of DSARC II.

[15]The B-1 and the Condor had been canceled; a rough check suggests that inclusion of these would not change the composite results significantly.

[16]Most performance parameters listed in the SARs are of a technical nature such as speed, range, and weight, but some parameters provide a more direct measure of system effectiveness or operability, such as missile accuracy or component reliabilty.

[17]We treated a performance goal as "met" when the test results came within 10 percent of the goal. In this illustration and in what follows, each parameter is equally weighted. Note that some of the performance parameters listed in the initial approved programs do not really require testing; their achievement can be confirmed by measurement (for example, the dimensions of a missile). When design features of this kind were deleted from the total list of performance parameters considered, the results were not significantly different. Thus the calculations reported here refer to the entire set of performance goals for each system in the sample.

[18]This may reflect the true status of the program, or it may be due to incomplete reporting in the SARs. We have no reason to believe that the latter is the case, but we acknowledge the possibility. As noted earlier, we have accepted SAR data without attempting to check them against other sources, except for occasional checks when the opportunity arose.

[19]Except, as already noted, for the two canceled programs (the B-1 and Condor). Figure 4 is derived on the basis of all the performance goals and test results as reported in the SARs for all the programs in the sample; the curves thus summarize more than 400 data points.

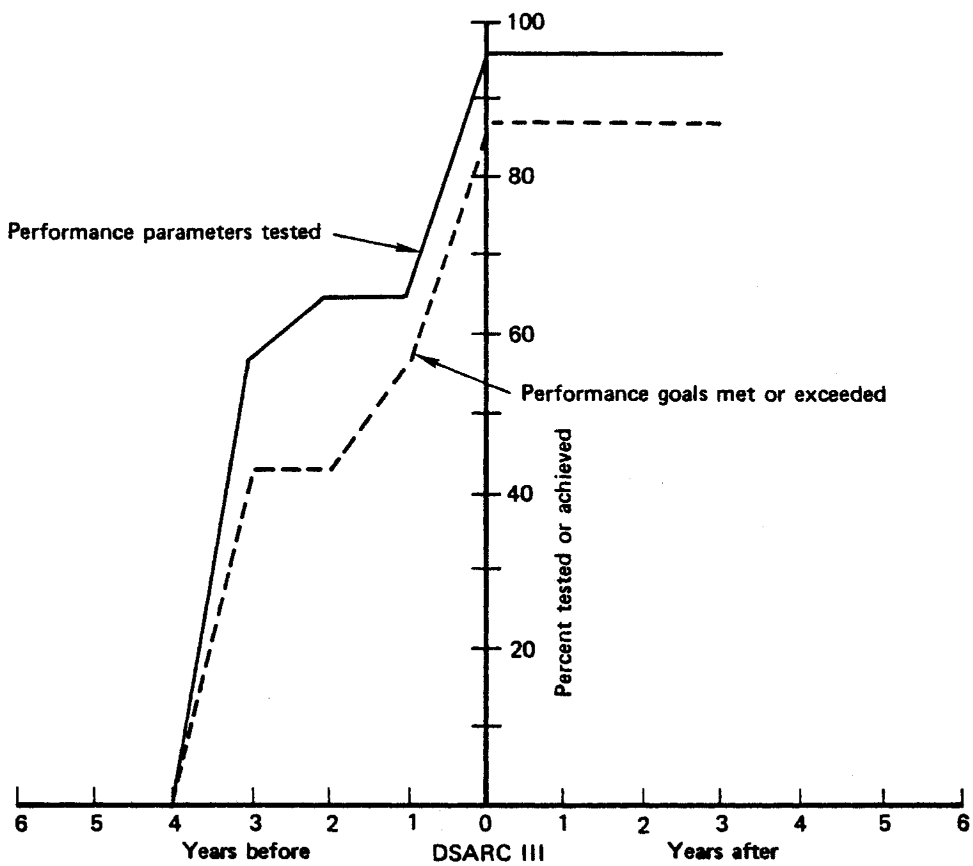


Fig. 3—Performance parameters tested and goals achieved before and after DSARC III, illustrative program (Harpoon missile)

a whole, only about 60 percent of the total performance parameters were tested by the time of DSARC III (solid curve), and not quite 50 percent of the performance goals were met or exceeded (dashed line). Not until some 3 years after DSARC III were 90 percent of the performance parameters subjected to test, and not until some 4 years after DSARC III were 90 percent of the performance goals achieved. These results might seem to suggest that there has been only a very modest degree of compliance with OSD's policy emphasis on thorough testing during full-scale development, before the decision to produce.

This composite picture, however, includes systems that reached DSARC III early in the 1970s. When the trend over time is examined for the same sample, as in Fig. 5, the evidence for compliance with the new policy appears much more favorable. Figure 5 shows test results as a function of the calendar date of the DSARC III milestone. If policy compliance increased over time, the curves should rise from year to year. This is exactly what is observed. Near the beginning of the period, only about 20 percent of a program's performance parameters had been tested by the time of its DSARC III; at the end of the period, some 90 percent of

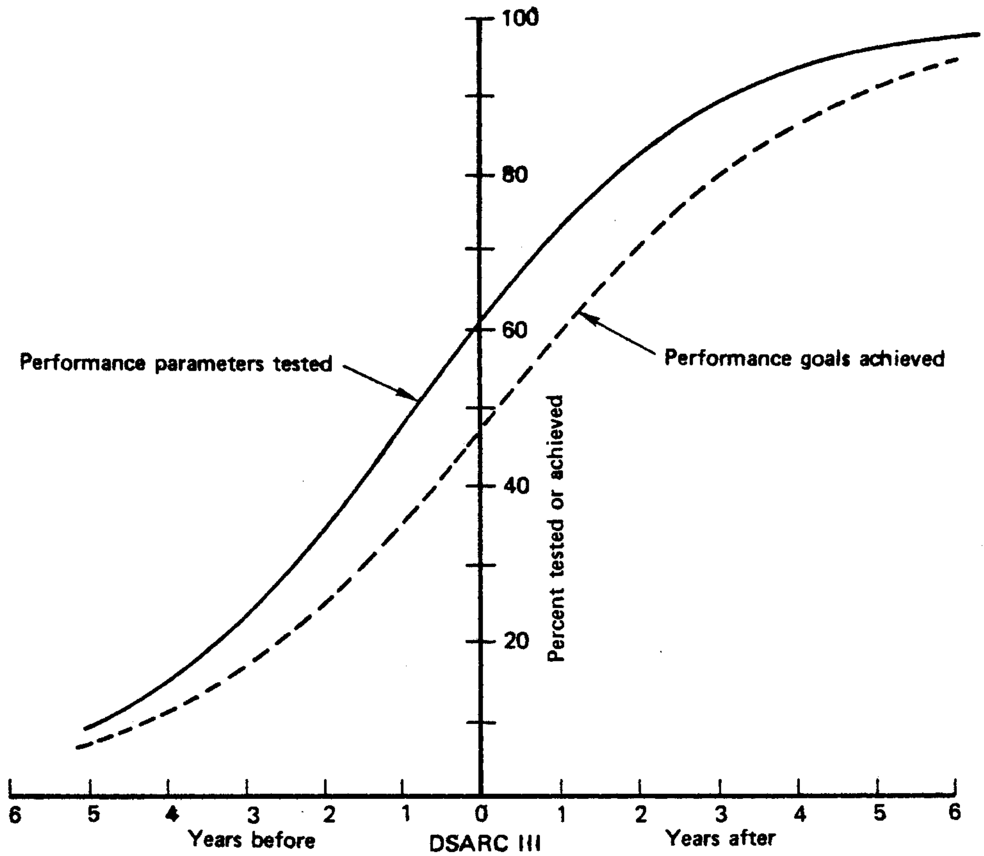


Fig. 4—Performance parameters tested and goals achieved before and after DSARC III, composite program

the performance parameters had been tested at DSARC III, and the trend is probably still upward. By 1978 the test information available at the time of the production decision was much greater than at the beginning of the decade, and probably greater than at any time in the 1960s or 1950s. This appears to be a clear affirmation of Service compliance with the DoD policy on testing—not instantaneous compliance but a positive response with progressive implementation.

Figure 5 also offers clear evidence of a reduction in development/production concurrency, as called for in the Packard initiatives. The curve showing performance goals achieved provides the relevant evidence. For programs reaching DSARC III in the late 1970s, not only had performance been tested for some 90 percent of the parameters, but the performance goals had been achieved for some 80 percent of the parameters. Thus for systems that went into production late in the 1970s, development appears to have been much more complete than for systems that went into production early in the 1970s, when less than 20 percent of the performance goals had been achieved by the time of DSARC III.[20]

[20]While the record clearly shows a trend toward greater achievement of *development* goals before onset of production, it is not clear that there is a corresponding increase in the demonstration of *operational suitablity* before, or even soon after, production go-ahead.

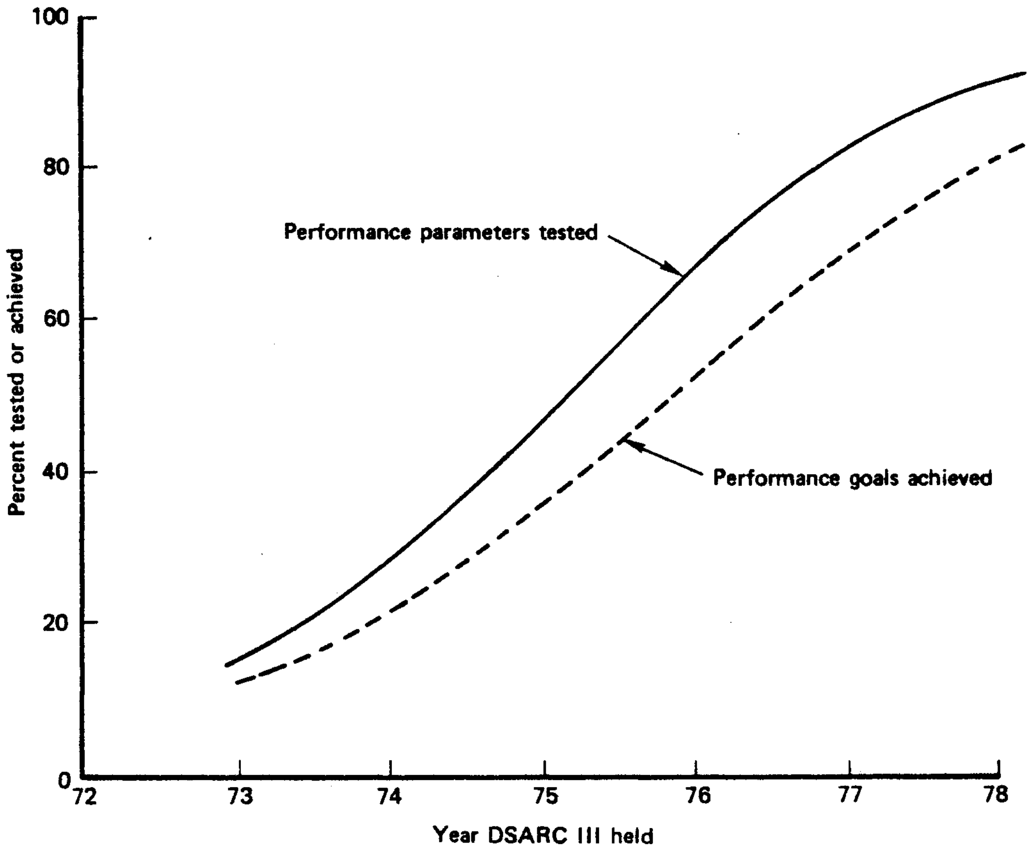


Fig. 5—Performance parameters tested and goals achieved at the time programs reach DSARC III, by calendar year

Competitive Hardware Development

As previously discussed, the early development and testing of hardware was one of the major elements in the Packard guidelines. And, as just shown, there has been a clear and steady trend toward compliance with this guideline. In closely related policy memorandums and speeches, Mr. Packard called for the increased use of hardware competition during the development phase of system acquisition—especially during feasibility demonstration before full-scale development, but also, where practicable, during full-scale development itself. As noted in Section I, this element of the Packard guidelines was not embodied in formal OSD policy documents until 1977 but was encouraged through the Advanced Prototyping Program with its provision of special funds for competitive prototyping.

To assess the incidence of hardware competition, we examined each of the 32 programs in our basic sample (Table 2) and attempted to categorize each program as having or not having some significant degree of hardware competition during development, either before or during FSD. Such a distinction is admittedly subjective; in some cases the determination was difficult; and in five instances we omitted the program because of lack of sufficient information.[21]

The interpretation of the results depends upon whether one looks at the 1970s sample as a whole or at the trends over time. For the sample as a whole, not quite half of the programs employed hardware competition before or during full-scale development. This might be regarded as a disappointing response, unless one recalls that the use of hardware competition in selecting systems for full-scale development and in deciding when they were ready for production was almost unknown in the 1960s.[22] Moreover, the trend during the 1970s is generally upward (although mixed), as shown in Fig. 6. In the years 1969 to 1973, only about one-fourth of the programs starting FSD involved hardware competition at some point in development. But the development plans of the systems reaching FSD in 1969 to 1973 were designed some time earlier, in many cases prior to the announcement of the Packard reforms. In the years 1974 to 1977, however, some two-thirds of the programs entering FSD involved hardware competition, typically before rather than during FSD.[23]
adopting the Packard guidelines on hardware competition, but nonetheless a positive response with eventually substantial implementation. By 1974, the position had been transformed in comparison with the 1960s.

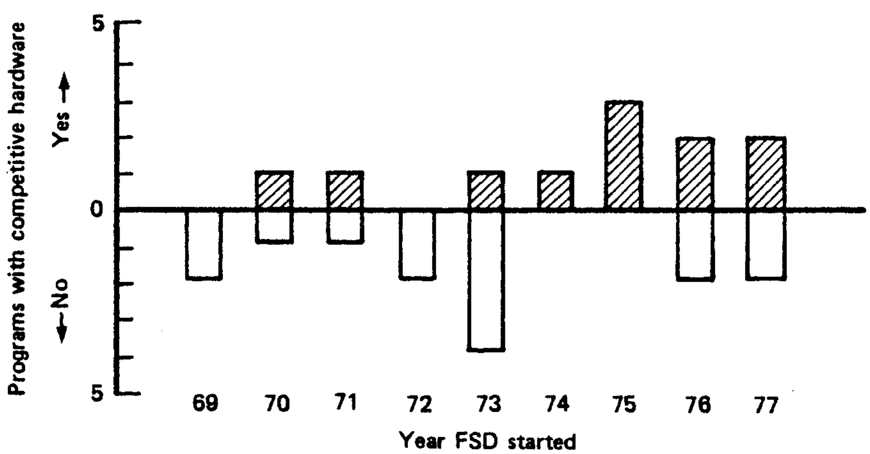


Fig. 6—Competition in hardware during development

NOTE: Here two pairs of programs with FSD starting in 1977 (the 5-in. and 8-in. guided projectile programs, and the ALCM and GLCM cruise missile programs) are each counted as a single program. We assessed the latter pair as involving competitive hardware and the former as not; hence, if these two pairs had been counted as four programs, the 1977 bar would have been extended one unit in each direction.

---

[21]SURTASS, TACTAS, Tomahawk, CAPTOR, and the M-198 howitzer. These are the same five systems omitted from the sample portrayed in Fig. 2.

[22]Competition was called for in OSD's basic 1960s policy directive on system acquisition: DoD Directive 3200.9. But DoDD 3200.9 could be read as referring mainly to "paper" competition, involving the description of a technical approach but not the building of hardware; at any rate, the directive was almost always so implemented.

[23]Figure 6 shows no results for 1978 because no program in our sample passed DSARC II during 1978 before our March cut-off date for SAR data.

However, for some programs that reached DSARC II in 1976 and 1977 (see Fig. 6), opportunities for hardware competition may have been missed. The Advanced Prototyping Program had by then ceased to provide direct dollar incentives for programs to adopt competitive prototyping as an acquisition strategy, and there was as yet no strong commitment to hardware competition in OSD's formal policy documents. Indeed, apart from cross references to OMB's Circular A-109, it can be argued that DoD directives still lack a clear call for competitive hardware.

SUMMARY

The overall picture that emerges is one of substantial compliance with the new acquisition policy established at the beginning of the decade.

Of the 10 major elements in Mr. Packard's policy initiatives, 6 led to positive changes in organizational structure or standard operating procedures. The remaining four elements required more discretionary responses often involving program-by-program decisions; these responses were examined using a quantitative approach.

The quantitative analysis of program manager qualifications was inconclusive, but from interviews and other qualitative evidence we conclude that most program managers are now reasonably well qualified for the job, and some are very well qualified indeed.

Compared with other groups for which data were available, program managers appear to have done well on the promotion ladder. But these comparisons are open to some question, and program managers and other senior program personnel have mixed views on the subject.

Job tenures for program managers have clearly been increasing, as called for in OSD policy, and are now between 2½ and 3 years on the average; but the increase had begun by the mid-1960s, well before the new guidelines were established. Length of tenure may now be in the right ballpark, but guidance may be needed concerning the timing of program manager assignments so as to coincide with natural breakpoints in program evolution.

The call for early hardware testing has had a strong positive response. Testing prior to both DSARC II and DSARC III has increased markedly during the 1970s, so that by 1978 the hard data available at major decision milestones was much greater than it had been previously. The call for a decrease in development/production concurrency has also been answered, as shown by the high percentage of performance goals now tested and *achieved* before the DSARC Milestone III decision to go into production.

The response to Mr. Packard's call for increased use of hardware competition during development has also been positive, but not so marked as in the case of hardware testing. About two-thirds of the programs that have reached DSARC Milestone II since 1973 have involved significant use of hardware competition either before they entered full-scale development or subsequently. This change from the situation in the 1960s, when hardware competition in development was rare, was achieved in part because of the Advanced Prototyping Program, which, for a time, provided direct dollar incentives for the Services to opt for an acquisition strategy involving hardware competition. In the absence of these incentives and without a strong OSD policy statement in favor of hardware competition, the future of this key element of the Packard initiatives appears somewhat in doubt.

III. 1970s EXPERIENCE: PERFORMANCE, SCHEDULE, AND COST

The previous section examined some measures of the degree to which OSD or Service actions in the 1970s complied with the new policy guidelines established at the beginning of the decade. This section focuses on program experience in the 1970s, in terms of system performance and program schedule and cost. The next section compares program experience in the 1970s with that in the 1960s.

1970s RESULTS VS. GOALS: OVERALL VIEW

The approach here is to assess the degree to which program goals are being achieved in the 1970s by comparing initial objectives with current results for performance, schedule, and cost. The data for this comparison are drawn from the SARs. Program performance and schedule goals are those stated in the initial approved program, and cost goals are those given in the development estimate (DE). Thus the goals are those defined at or shortly after the time of DSARC II, without any changes that may have been subsequently approved.

The results are taken from the March 1978 SARs. Performance results are those established by tests, as discussed in Section II. Schedule results are the actual times of occurrence of scheduled events that have already been accomplished. And cost results are the March 1978 "current estimates" (CEs) of total acquisition cost adjusted to remove the effects of inflation and any changes in procurement quantity since DSARC II, so that results can be compared with goals in terms of constant dollars and the initially projected buy size. The methods used here to make these quantity adjustments to the SAR cost data are described in Appendix A. The cost comparisons are for the 31 programs (from our basic sample of 32) for which adequate cost data were available (see Table 6, below). As will be explained, we also examine cost experience for certain subsets of these 31 programs. The performance and schedule comparisons are for the programs that had passed DSARC III by March 1978, that is, the programs for which there is a substantial track record of performance tests and scheduled events achieved.[1]

The comparison of 1970s results and goals was based on result-goal ratios. For program cost, the ratio is given by dividing the DE (goal) into the CE (current estimate of result), both costs being expressed in constant dollars for the DE production quantity. For program schedule, we calculated for each accomplished event the ratio of the number of months actually taken in its accomplishment to the number of months originally scheduled at the time of DSARC II.[2] For program

---

[1]This is the same sample as used for Figs. 4 and 5, above; two canceled programs (the B-1 and Condor) are omitted as before.

[2]Note that the schedule result-to-goal ratios reflect mainly experience in full-scale development, because the schedules established at the time of DSARC II are heavily weighted toward development events and events early in the production phase. In other words, a schedule result-to-goal ratio showing

performance, the ratio was calculated for each performance parameter, based on the reported test results. Note that, for consistency with the cost-growth and schedule-achievement ratios, the performance comparison is stated so that the preferred outcome is a ratio less than unity.[3]

The comparison of the 1970s program results and goals is shown in the three histograms of Fig. 7. The performance histogram is the only one that presents a near-symmetrical pattern: The schedule and cost histograms are clearly skewed to the right, cost being the more skewed. This appears to be a first-order validation of the conventional view that when programs begin to experience difficulties, cost is the first constraint to be relaxed and schedule the second, but performance goals are held to more rigorously. Even so, the achieved values of the performance parameters sometimes varied by factors of two from the initially approved goals, sometimes "better" and sometimes "worse."

The cost histogram shows that a few of the programs in the sample of 31 were experiencing modest underruns, but most exceeded the development estimate cost goal, and in a few cases the ratio of result to goal was in the vicinity of 2.1. The average cost-growth ratio—not weighted by size of program budget—was about 1.20. When weighted by program cost, the average cost-growth ratio for the 31 programs was about 1.14, reflecting somewhat lower cost growth in the high-value programs. As will be discussed later, ratios of this size, although significant in dollar terms, are not exceptional when compared with the growth experienced in many nondefense projects.

FAVORABLE EFFECTS OF HARDWARE COMPETITION?

As noted earlier, the increased use of *hardware* competition was one of the main elements of Mr. Packard's policy initiatives.[4] How have the programs employing substantial hardware competition before or during FSD fared in comparison with those that did not? For several reasons, only a tentative answer can be given to this question.

- The samples are small; only 13 programs among those examined here had passed DSARC III.
- The distinction between those with a significant degree of competition and those without is sometimes rather subjective; nearly every program can claim some instance of hardware competition, if only for a subcontracted component.
- Of the 13 programs past DSARC III, we felt reasonably confident about the classification of only 10: a set of 4 with substantial hardware competition, and a set of 6 without. Of the 4 with substantial hardware competition, only one carried this competition through FSD.
- "Other things" were not necessarily equal for the two sets of programs. Many factors apart from hardware competition could influence results.

---

little aggregate slippage is not necessarily inconsistent with a slippage in the mid- or late-production phase that contributes to significant cost growth.

[3]We inverted some performance ratios to make them consistent with the above description. This was necessary because, in the case of performance factors, a desirable outcome sometimes results in a result-to-goal ratio being greater than unity (missile range, for example).

[4]We refer to programs in which competitors produced and tested full scale versions of the system or major subsystem under development. We believe such activity is different in important respects from programs in which the competition is based only on paper design studies, scale model tests, etc.

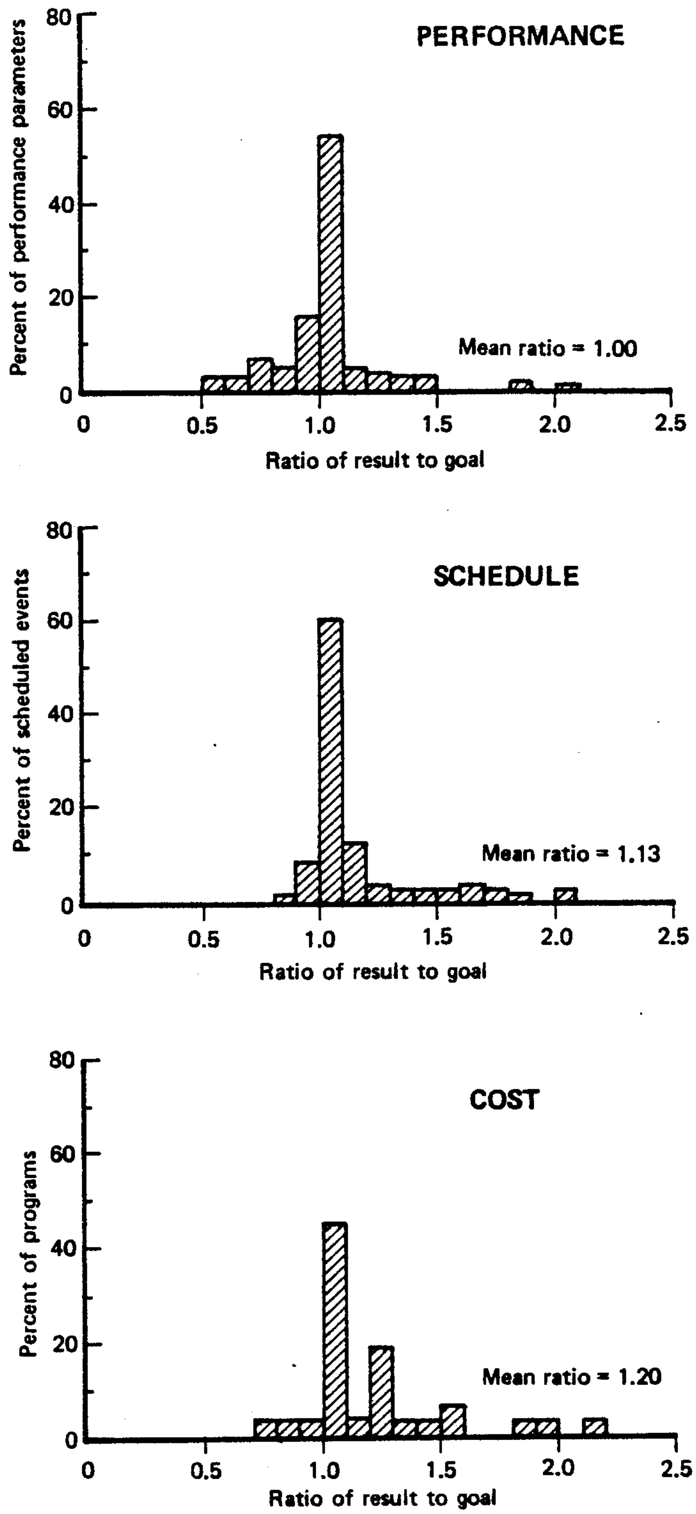


Fig. 7—1970s program results versus goals: performance, schedule, and cost

Nonetheless, we think a comparison of the two sets is at least suggestive, generally supporting the policy emphasis on hardware competition. As shown in Table 5, the competitive programs had slightly better performance and schedule ratios, and substantially less cost growth—their mean cost-growth ratio was only 1.16 compared with 1.53 for the programs with little or no hardware competition. Most of the programs in each sample had cost-growth ratios in the range 1.20 to 1.30, but the sample with competitive hardware had the only instance of negative cost growth, and the sample without competitive hardware had two instances in which cost had roughly doubled.

Table 5

EFFECTS OF HARDWARE COMPETITION

	Ratio of Results to Goals (smaller ratios preferred)	
Program Measure	Competitive Sample[a]	Non-competitive Sample[b]
SYSTEM PERFORMANCE (mean for all parameters)	.98	1.07
PROGRAM SCHEDULE (mean for all occurrences)	1.06	1.17
PROGRAM COST		
Range of program ratios	.87-1.27	1.24-2.12
Mean of program ratios	1.16	1.53

[a]Four programs: AWACS, A-10, F-16, UH-60.

[b]Six programs: F-15, Aegis, Harpoon, AIM-9L, CAPTOR, M-198.

Here we may also note another effect of hardware competition drawn from a study (not yet published) conducted by Rand for the U.S. Air Force. That study examined a series of programs in which full-scale prototype hardware had been tested before or during full-scale development. In three of these programs (the AX, the Lightweight Fighter/Air Combat Fighter, and the Army's Advanced Attack Helicopter), there is a widespread opinion that, for various reasons, the designs and contractors selected for final development after prototype hardware tests were not the ones that would almost certainly have been selected if only paper designs had been evaluated. Although the effects of such a shift cannot be quantified, it is reasonable to conclude that a "better" weapon system resulted from the development of competitive hardware before full-scale development began.

It is sometimes suggested that increased competition early in the acquisition process can have adverse effects on design and product quality, especially on reliability and maintainability. The argument goes that contractors, under the stress of competition, will cut corners where they can in order to keep costs low while meeting the stated performance goals. In theory this is conceivable, but in practice we would not expect it to be a serious problem in defense programs.

We know of no evidence that it has occurred in the competitive programs in our sample; on the contrary, in programs such as the UH-60 helicopter we are inclined to think that competition helped to improve quality across the board, including reliability and maintainability. With full-scale development contracts written on a "cost plus" basis, the contractors' incentives for such corner-cutting behavior during FSD appear to be slight or nonexistent. And the buyer should be able to avoid or minimize the problem by adequate testing before the decision to procure and, if necessary, by broadening the statements of desired performance characteristics. Moreover, hardware competition, certainly if it is carried into the FSD phase, has the "quality" advantage over noncompetitive developments that it provides the buyer with a choice of designs at a later time in the acquisition process, when he is better able to assess the precise nature of the threat to be countered and the means of countering it.

DETAILED ANALYSIS OF COST VARIANCE

Methods and Definitions

Acquisition cost variance, as used here, is the difference between the baseline Development Estimate (DE) of a program's total cost,[5] generated as a part of the DSARC II review process, and the updated Current Estimate (CE) as of March 1978. In this study, the change in cost is adjusted to nullify the effects of production quantity changes so that the cost variance is stated in terms of the procurement quantity that was approved at DSARC II. The method used here for these adjustments is described in Appendix A.

Cost data are typically expressed in base-year constant dollars or in then-year inflated dollars. Unfortunately, neither of these provides a convenient means for making cost growth comparisons among several programs. Although base-year constant dollars express real cost growth, with each passing year they become more difficult to relate to the familiar current-year dollar amounts. Moreover, the costs of different programs can be compared directly only with those of other programs having the same base year.

Program costs expressed in then-year dollars include inflation and are sensitive to the particular spend-out pattern (time-stream of expenditures) of each program. Thus even when they have the same base year, the costs of two programs are usually not comparable when summed in then-year dollars. Moreover, sums of then-year dollars have the added fault of seeming quite large when compared (as they always are) with today's prices and the base-year dollar estimates. To eliminate the effects of inflation and to provide a consistent medium for comparing the "real" costs of the various acquisition programs, we express our costs in FY 1979 constant dollars.[6] A format including base-year (constant), current-year (constant), and then-year (inflated) dollar program costs is suggested for adoption in the pro-

[5]Development, test, procurement, military construction, peculiar support, and initial spares.

[6]These were computed on the basis of the base-year dollar projections in the SARs, inflated with the OSD price indexes of 30 June 1978.

posed policy-oriented acquisition data base and is used in Appendix C to display the basic cost data for programs in our cost-analysis sample.

Table 6 presents the baseline and March 1978 cost projections for the 31 programs (out of the 32 in Table 2) for which we had adequate cost data, giving totals and breakdowns by development, procurement, and military construction. Dollar costs are shown as well as cost-growth ratios (CE/DE) for each of these categories, adjusted to eliminate cost variance that simply reflects changes in output quantity. Programs suffering from high cost growth are sometimes cut so as to remain within funding limits. Other programs may have the buy size increased above the number of units originally planned for. Because it would be misleading to compare the total cost variance of programs having increased production quantity with those whose production output was unchanged or reduced, the cost variance attributed to quantity changes was deleted. The program costs are then expressed in terms of constant (baseline) production quantity as well as constant dollars.

The programs included in our sample are by no means homogeneous. All three military departments are represented. There are various equipment types—aircraft, missiles, tanks, communications equipment, and others. Programs of widely differing cost magnitudes are included. Different states of the art are represented—among aircraft, for example, both the very advanced F-15 and the simpler A-10. New developments such as the UH-60 are included, as well as follow-on developments such as the AIM-9L and IFV. There is an example of technological transfer to the United States (Roland) and an example of a U.S.-developed aircraft being coproduced in Europe (F-16). There are examples of short and long periods of FSD, from the one year for the A-10 to many years for development of the MICV/IFV, Aegis, and Patriot. Finally, there are programs such as the YAH-64, A-10, and F-16, which featured prototype hardware in their advanced development, and there are those that relied more on paper studies (F-15). Two of the programs included in the group were canceled: the Condor missile and the B-1 bomber.

The Amount of Cost Growth

The grand total, in FY 1979 dollars, of the baseline estimates for the 31 programs in our cost study sample (Table 6) amounts to $89.6 billion. Development costs account for about one-quarter of this total. There is a sprinkling of military construction costs, but procurement accounts for most of the remaining three-quarters. Excluding production quantity variance and inflation, the current estimate of acquisition costs for these programs had risen to $102.4 billion as of March 1978, resulting in an aggregate cost-growth ratio of 1.14 (that is, 14 percent cost growth). Development evidenced a slightly higher cost-growth ratio than procurement—1.18 for development versus 1.13 for procurement.

Of these 31 programs, 14 were less than three years past DSARC II. Of these younger programs, five had no cost growth at all and only one, Roland, had a cost-growth ratio exceeding 1.07. The Roland missile's cost-growth ratio of 1.53 placed it fourth in the list of programs having the greatest relative cost growth.

In the whole sample of 31, the program with highest cost-growth ratio was the CAPTOR ASW encapsulated torpedo system, the acquisition costs of which had more than doubled since it began FSD. The development cost of this system was

Table 6

PROGRAM COSTS: GOALS (DEVELOPMENT ESTIMATES AT DSARC II) AND RESULTS (CURRENT ESTIMATES AS OF MARCH 1978)
(Costs in FY 1979 $ Millions for Development Estimate Quantity)

	Development Estimate (DE)				Current Estimate (CE)				Cost-Growth Ratio (CE/DE)			
	Dev (1)	Proc (2)	Constr (3)	Total (4)	Dev (5)	Proc (6)	Constr (7)	Total (8)	Dev (9)	Proc (10)	Constr (11)	Total (12)
ARMY												
Patriot	1,722.9	5,131.2	68.4	6,922.4	2,339.2	4,916.6	65.0	7,320.8	1.36	.96	.95	1.06
Hellfire	268.9	386.0	---	654.9	282.2	383.9	---	666.1	1.05	1.00	---	1.02
UH-60	597.2	2,703.8	---	3,301.0	633.8	2,244.1	---	2,877.9	1.06	.83	---	.87
YAH-64	973.6	2,081.8	---	3,055.4	1,017.7	2,065.5	---	3.083.2	1.05	.99	---	1.01
IFV	54.8	284.6	---	339.4	183.1	429.9	---	613.0	3.34	1.51	---	1.81
XM-1	675.2	3,239.0	---	3,914.1	670.4	3,516.0	---	4,186.3	.99	1.09	---	1.07
Roland	204.8	878.2	---	1,083.1	293.6	1,368.6	---	1,662.1	1.43	1.56	---	1.53
Copperhead (CLGP)	134.1	956.3	---	1,090.4	149.2	981.6	---	1,130.9	1.11	1.03	---	1.04
DIVAD Gun	173.0	2,167.7	---	2,340.7	173.0	2,201.2	---	2,374.2	1.00	1.02	---	1.01
M-198 Howitzer	49.4	131.8	---	181.2	70.6	174.4	---	245.0	1.43	1.32	---	1.35
NAVY												
F-18	1,838.1	8,501.2	21.4	10,360.8	1,991.4	8,638.5	22.4	10,652.4	1.08	1.02	1.04	1.03
LAMPS III	473.7	1,739.0	---	2,212.7	701.7	2,429.3	10.5	3,141.5	1.48	1.40	∞[a]	1.42
Aegis	693.3	---	---	693.3	860.3	---	---	860.3	1.24	---	---	1.24
CAPTOR	142.9	368.3	4.2	515.4	147.9	933.8	13.3	1,095.0	1.04	2.54	3.17	2.12
Harpoon[b,c]	380.8	1,122.6	---	1,503.3	537.7	1,321.5	---	1,859.2	1.41	1.18	---	1.24
Sidewinder (AIM-9L)[d]	22.4	322.2	---	344.6	94.1	586.5	---	680.6	4.20	1.82	---	1.98
Tomahawk	889.6	1,160.3	---	2,049.9	889.6	1,160.3	---	2,049.9	1.00	1.00	---	1.00
5-in. Guided Projectile	107.4	288.8	---	396.2	107.4	288.8	---	396.2	1.00	1.00	---	1.00
8-in. Guided Projectile	78.9	106.1	---	185.0	78.9	106.1	---	185.0	1.00	1.00	---	1.00
SURTASS	75.9	189.8	---	265.8	103.9	299.3	---	403.3	1.37	1.58	---	1.52
TACTAS	69.6	444.0	---	513.6	103.5	435.8	---	539.3	1.49	.98	---	1.05
Condor[a]	419.8	204.6	---	624.5	381.4	181.8	---	563.1	.91	.89	---	.90
AIR FORCE												
A-10	495.8	2,652.1	---	3,147.9	611.2	3,380.9	---	3,992.1	1.23	1.28	---	1.27
B-1	4,275.8	13,243.0	---	17,518.8	4,848.9	15,882.9	---	20,731.7	1.13	1.20	---	1.18
F-15	2,910.8	7,730.8	---	10,641.6	3,350.5	9,876.7	---	13,227.2	1.15	1.28	---	1.24
F-16	739.8	4,921.5	---	5,661.2	951.2	6,229.6	---	7,180.9	1.29	1.27	---	1.27
E-3A (AWACS)	1,338.5	2,479.7	---	3,818.2	2,075.1	2,537.3	---	4,612.5	1.55	1.02	---	1.21
PLSS	222.1	547.3	---	769.4	219.1	547.3	---	766.4	.99	1.00	---	1.00
DSCS III	152.6	563.2	---	715.8	155.8	405.6	---	561.4	1.02	.72	---	.78
ALCM	791.1	2,620.4	140.5	3,552.0	791.1	2,620.4	140.5	3,552.0	1.00	1.00	1.00	1.00
GLCM	85.0	1,051.5	59.2	1,195.8	85.0	1,051.5	59.2	1,195.8	1.00	1.00	1.00	1.00
Subtotal, programs three years past DSARC II	14,528.0	44,181.1	72.6	58,781.7	18,039.8	52,406.4	88.8	70,534.9	1.24	1.19	1.22	1.20
Grand total, all programs	21,057.9	68,216.5	293.7	89,568.1	24,898.4	77,195.8	310.9	102,405.1	1.18	1.06	1.13	1.14

SOURCE: *Selected Acquisition Reports*, March 1978, and Appendix C.

NOTE: **Programs italicized are "mature programs" at least three years past DSARC II.**

[a]Ratio is infinite because the military construction DE was zero.

[b]For consistency, these "Development Estimates" for Harpoon and Condor reflect their Current Estimate projections made at the time of DSARC II. The DEs that appear in the SARs for these two programs are based on an earlier baseline (Condor) or on a baseline established after the DSARC II decision to proceed with FSD (Harpoon). See Appendix C.

[c]Distribution between Development and Procurement approximated.

[d]Navy and Air Force programs combined.

nearly on target, but procurement was estimated at about 2.5 times its baseline projection.

The second highest cost-growth ratio was attained by the AIM-9L (Sidewinder) missile, with a cost projection in March 1978 of almost twice the baseline estimate. For this missile the cost of development estimated at DSARC II turned out to be low by a factor of 4, but since this was a follow-on development to an existing weapon, these development costs were a relatively minor part of the total. Procurement costs were somewhat less than twice the baseline estimate.

In third place was the Army's infantry fighting vehicle (IFV), which represents a restructuring of the earlier mechanized infantry combat vehicle (MICV) program. The IFV benefited from the earlier development efforts, but partly because of the program restructuring, the development costs of this system rose by a factor of more than 3. Procurement costs had reached 1½ times the original estimate prior to the large production cutback. (It should be recalled that the figures in this table are stated in terms of the quantity approved in DSARC II.)

The Roland program, in fourth place, has already been mentioned. Its high cost growth is especially notable because it occurred so soon after its DSARC II review. The program with the fifth largest cost-growth ratio is the Navy's SURTASS surveillance system, with 1.52. However, SURTASS is the third smallest program in the study, and its effect on the growth ratio of the sample as a whole is small. Later in this section we will identify the major reasons given for the cost growth of these systems.

The variance figures given above measure cost change as a ratio of the baseline cost projection without regard to the dollar amounts involved. But a moderate cost growth in a large (high-dollar) program such as the B-1 has a much greater budgetary impact than a large growth in a relatively small program such as the AIM-9L or CAPTOR. According to its SAR, the cost-growth ratio of the B-1 had risen to 1.20 by the time of its cancellation; this is not particularly high, especially for programs that push the state of the art, but it involved an increase of $3 billion above its DE. In contrast, the CAPTOR program's cost-growth ratio of 2.12 represented a dollar increase of $0.5 billion; the AIM-9L with a ratio of 1.98 had a $0.3 billion increase.

The cost histogram in Fig. 7, repeated in Fig. 8 (top), summarizes the cost variance of these 31 acquisition programs. It indicates that, although a few programs had substantial cost growth, more than half had cost-growth ratios of less than 1.10. The mean cost-growth ratio is 1.20 (sum of the individual cost-growth ratios, divided by 31). The dollar-weighted mean is 1.14. The median is 1.06.

If we exclude the 14 programs that are less than 3 years past their DSARC II go-ahead dates, thereby eliminating several programs that had not yet experienced noticeable cost growth, we find that the remaining 17 more mature programs present a somewhat different picture. The histogram for these older programs, shown also in Fig. 8 (bottom), reveals a sharp drop in the number of programs in the 1.00 to 1.10 range compared with the previous histogram, with a shift of the distribution to the right, toward higher cost-growth ratios. The mean cost-growth ratio, found by summing the growth ratios of the individual programs and dividing by 17, is 1.34. The dollar-weighted mean is 1.20, and the median is 1.24. Again it should be noted that, although these programs are more mature, none has reached completion; the costs are still only the current estimates of full-term costs.

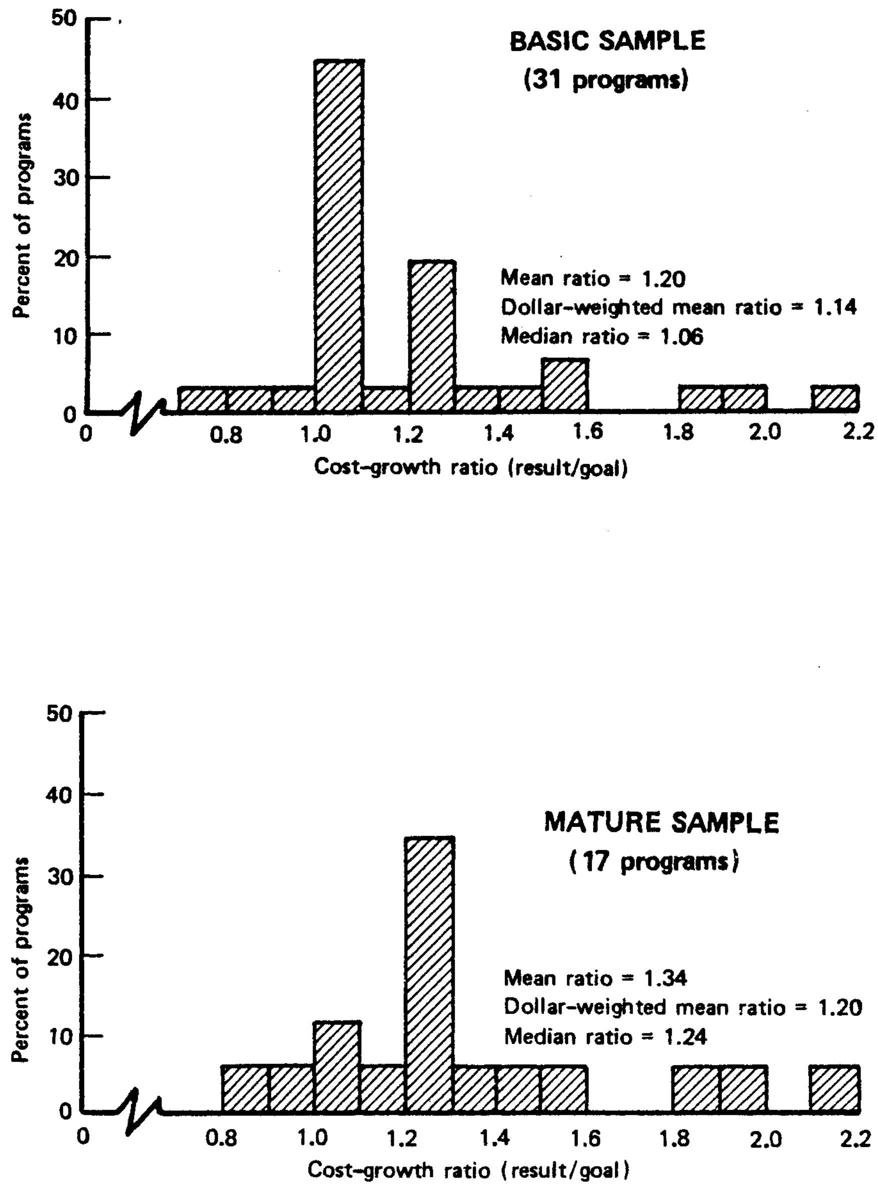


Fig. 8—1970s cost experience: basic sample and mature sample

Comparison with Nondefense Projects

Cost-growth ratios in this range—from, say, 1.1 to 1.4—are by no means trivial in terms of their implications for defense acquisition expenditures. But they do not appear to be especially large in comparison with the cost growth experience of many nondefense projects. Comparisons are difficult, because nondefense projects vary enormously in the nature of the uncertainties they have to face and in many other characteristics. Ideally, one would like to compare our sample of 31 defense programs with a representative sample of nondefense programs that involved major development efforts, continued into serial production of several hundred units, and required from 5 to 15 years to complete. The cost-growth ratios for this nondefense sample should, of course, be adjusted to eliminate the effects of inflation and changes in production quantity.

Unfortunately, data for a closely comparable set of nondefense programs appear to be unavailable. But a recent Rand review of cost estimation and cost growth in new technologies, prepared for the U.S. Department of Energy, certainly does not suggest that defense programs are characterized by exceptionally large cost-growth ratios compared with high-technology nondefense projects.[7]

Table 7 gives the cost growth results for one sample of 10 nondefense construction projects.[8] For this sample, the median cost-growth ratio is 1.37 after adjustment for inflation and changes in scope. If we treat the Trans-Alaska Oil Pipeline as exceptional and omit it from the sample, the median cost-growth ratio is 1.34 and the mean ratio is 1.54.

Further research is required before comparisons of this kind can be more than suggestive. But on the basis of the evidence we have seen, we are inclined to think that the constant dollar cost growth of defense systems in the 1970s can be characterized as rather modest—especially when one recognizes the substantial advances in technology that most defense projects entail. The widespread contrary impression appears to be due to several factors: a failure to appreciate the inherent nature of the cost uncertainties present at the time, early in development, when the baseline cost estimates are made; memories of the higher cost growth ratios observed in the 1950s and 1960s; and the high inflation of the 1970s and the tendency to characterize growth in terms of progressively inflated then-year dollars rather than in terms of cost growth ratios or percentages calculated on a constant dollar basis.

Measurement of Cost Growth over Time

As already noted, none of the 31 programs in the cost analysis sample is a complete, full-term program; program cost growth is calculated on the basis of the SAR current estimates rather than a final accounting of actual costs. Many of the programs are quite young and have experienced little cost growth.

---

[7]Edward W. Merrow, Stephen W. Chapel, and Christopher Worthing, *A Review of Cost Estimation in New Technologies: Implications for Energy Process Plants*, The Rand Corporation, R-2481-DOE, July 1979, pp. 86-90. See also David Novick, "Are Cost Overruns a Military-Industrial-Complex Specialty?" The Rand Corporation, P-4311, March 1970; and General Accounting Office, *Financial Status of Major Federal Acquisitions, September 30, 1978*, GAO Report B-182596PSAD-79-14, January 1979.

[8]The selection criteria for this sample are not known to us, however.

Table 7

COST GROWTH IN MAJOR U.S. NONDEFENSE CONSTRUCTION PROJECTS, 1956-1977

Project and Date of Initial Estimate	Final Cost ($ Millions)	Ratio of Final Cost to Initial Estimate[a]
Trans-Alaska Oil Pipeline, 1970	7700	4.25
New Orleans Superdome, 1967	178	3.22
Cooper Nuclear Station, Nebr. Pub. Power Dist., 1966	395	1.75
Dulles Airport, Washington, D.C. 1959	108	1.49
Toledo Edison's Davis-Besse nuclear power plant, Ohio, 1971	466	1.40
Rayburn Office Building, Washington, D.C., 1956	98	1.34
Rancho Seco Nuclear Unit No. 1, Sacramento, 1967	347	1.24
Frying Pan-Arkansas River Project, Colorado, 1962	54	1.24
Second Chesapeake Bay Bridge, 1968	120	1.10
Bay Area Rapid Transit Authority, 1962	1640	1.04
MEDIAN		1.37

SOURCE: W. J. Mead et al., *Transporting Natural Gas from the Arctic*, American Enterprise Institute for Public Policy Research, Washington, D.C., 1977, pp. 88-89, quoted in Edward R. Merrow, Stephen W. Chapel, and Christopher Worthing, *A Review of Cost Estimation in New Technologies: Implications for Energy Process Plants*, The Rand Corporation, R-2481-DOE, July 1979, p. 38.

[a]After correction to remove effects of inflation and change of project scope.

Several explanations for the lower cost-growth ratios of the younger (more recently started) programs can be suggested. Some explanations point to possible differences between the younger and older programs in the sample. The younger programs may reflect improved cost estimating, or a more rigorous management of cost growth, or they may constitute a set of technically more "conservative" programs involving lesser advances in the state of the art.

Although these factors may offer at least a partial explanation for the observed cost differential between the younger and the older programs, we tend to favor a fourth explanation that associates cost growth with program maturation over time. A program's cost growth does not occur overnight; it accumulates over the span of the whole acquisition process. If we trace the year-by-year cost growth experienced by the older programs in our sample, we find a clear tendency for programs to grow in cost during their advance through the acquisition process, this being the result of unforeseen technical problems, of seemingly inevitable changes in program scope and system performance, of schedule accommodations to meet funding and other constraints, and of cost estimating refinements as more information becomes available.

Intuitively, we would expect the time track of a program's cost-growth ratio to resemble an S-shaped curve. This would reflect four distinct phases: (1) initially a period of little or no cost increase following the DSARC II approval, (2) near the middle of the development phase, relatively large increases in projected costs as problem areas are uncovered and more costly solutions are found to be required to meet the performance specifications, and as realism replaces earlier, more optimistic assumptions, (3) by the time of the decision to enter production, most technical problems would be resolved, engineering changes would decrease in number and scale, and the rate of cost growth would diminish, and (4) finally, in the production phase toward the end of the program, cost growth would level off.

In an attempt to test this hypothesis we tracked the year-by-year cost growth of the small number of ongoing programs in our sample that had passed the DSARC III milestone.[9] The results appear in Fig. 9 where the cost growth is measured vertically, and program maturity (years beyond DSARC II) horizontally. The dashed lines in Fig. 9 indicate a lack of program cost data in constant dollar terms for the intervening years. Prior to 1974, the SAR cost projections were shown in then-year dollars and in some cases we were unable to convert them into constant dollars. And no SARs were prepared for the M-198 howitzer until DSARC III. In these cases we interpolated from unity (zero cost growth) at DSARC II to the first data point. The prominent dot on each line indicates the year of DSARC III, separating the FSD and procurement phases.

This small sample includes the two programs with the highest cost-growth ratios (CAPTOR and the AIM-9L) and the one with the lowest (the UH-60).

As already mentioned, many of the programs lack data points for the early years of FSD. The dashed-line interpolations obscure the possible presence of start-up lags before cost growth accelerates. Only a few programs, Harpoon and possibly CAPTOR and AIM-9L, seem to have a significant rate of cost growth from the start. For the others, a period of slow, or even negative, growth seems to characterize the beginning of FSD.

For the programs shown in Fig. 9, the period of rapid growth is not limited to the FSD phase. This is shown more clearly in Fig. 10, where the cost-growth ratios are normalized to the costs at DSARC III, the beginning of the production phase; that is, we recalculated the cost-growth ratios for these mature systems, using the current estimates projected at DSARC III as the baseline. The results do not reveal any consistent reduction in the upward trend of cost-growth ratios after the production go-ahead. Most of the programs exhibited growth in both the development and production phases, and for some programs cost growth even accelerated in the production phase. A few of the tracks do suggest some leveling off at a later point.

The persistence of cost growth after DSARC III can be traced to two principal causes: schedule slippage and efforts to increase system performance.[10] These can

[9]This sample excludes the following systems that had passed DSARC III by 1978: B-1, Condor, Aegis, E-3A (AWACS), and AIM-7F. The B-1 and Condor were canceled before production began, the E-3A was just beginning low-rate production, and Aegis's costs cover development only. The AIM-7F program was omitted because we were unable to convert its early then-year dollar projections into constant dollar form.

[10]For a combat aircraft, for example, engineering changes typically continue throughout almost all its service life. After the aircraft enters service, this activity is referred to as "modifications."

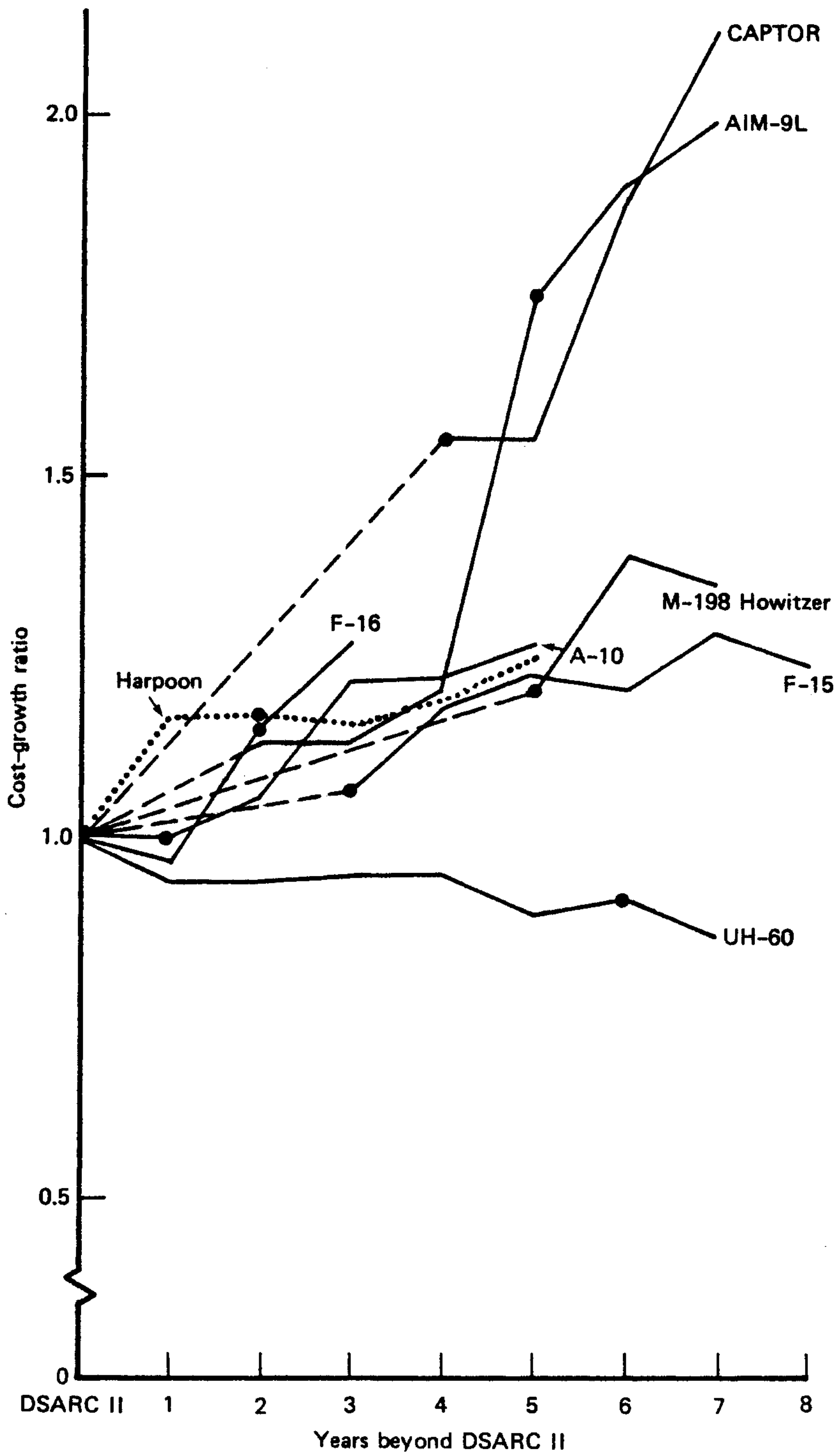


Fig. 9—Cost-growth tracks for programs that have passed DSARC III

NOTE: Harpoon cost growth (dotted line) is based on its Current Estimate at DSARC II (see Appendix C). Dashed lines represent multiyear interpolation between data points because of lack of intervening annual data. Heavy dots show date of DSARC III.

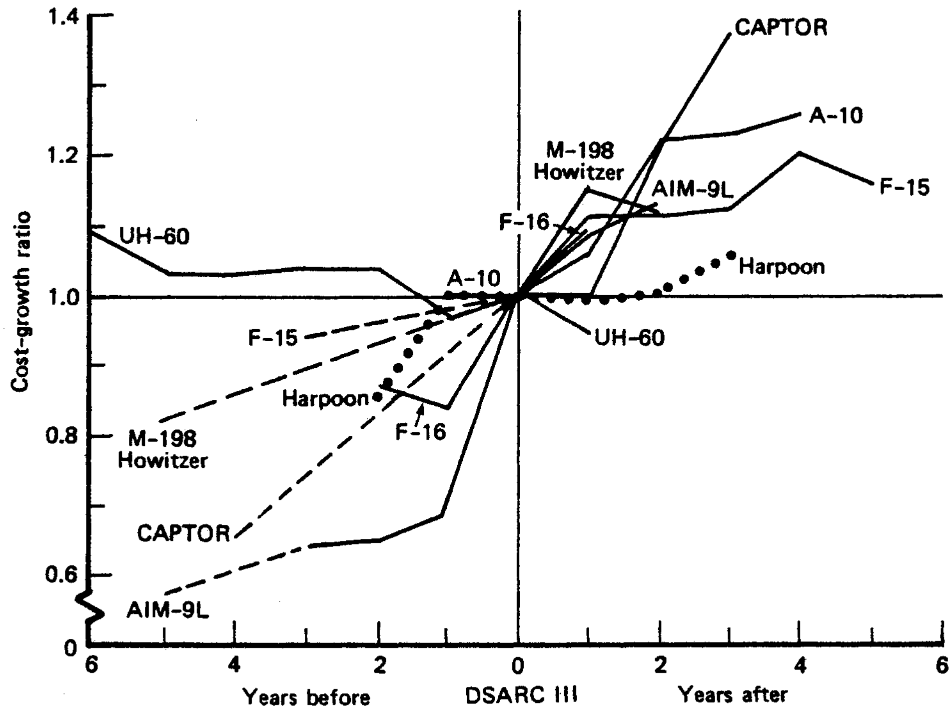


Fig. 10—Cost growth: development phase compared with production phase

NOTE: In this figure, the cost-growth ratio for each data point is calculated by dividing the Current Estimate for the given year by the Current Estimate made at the time of DSARC III. The earliest point on each curve corresponds to the DSARC II date and represents the ratio of the Development Estimate to the Current Estimate at DSARC III (except for Harpoon, the treatment of which is explained on pp. 126-127 in Appendix C). The dashed lines connect data points for which some of the intervening data were unavailable.

occur at any time in the accquisition cycle, and their effect is sometimes even greater in the production phase, for example, when production rates are reduced (procurement is stretched out) to comply with year-by-year funding constraints. Thus there is reason to question the usefulness of the S-curve hypothesis for describing typical trends in cost-growth ratios. What Figs. 9 and 10 show is a general tendency for cost-growth ratios to rise over time. The UH-60 helicopter program, however, appears to be an exception. Perhaps significantly, this is the only one of these programs in which full prime contractor hardware competition was sustained throughout full-scale development.

To derive a measure of the average rate of cost growth over time for our 1970s sample of 31 programs, we plotted their individual cost-growth ratios (as of March 1978) versus years beyond DSARC II (see Fig. 11).[11] Lacking statistical support

[11]For some programs the approval of the baseline cost estimate does not coincide exactly with the recorded DSARC II date, but the differences are not great. For programs without a DSARC II review, the date of the baseline costs approximates the initiation of FSD.

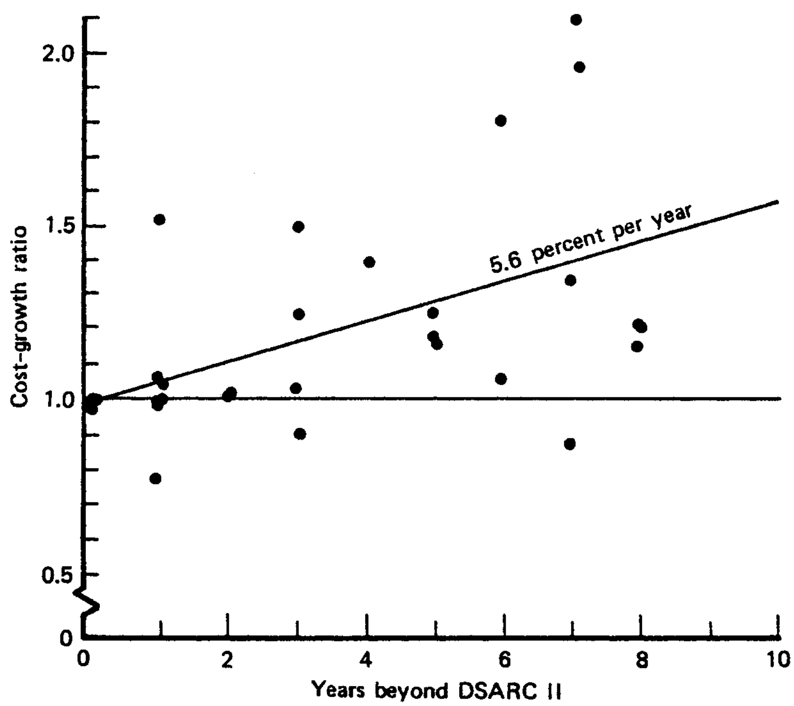


Fig. 11—Cost-growth over time, 1970s programs

NOTE: The data here have already been adjusted to eliminate the effect of inflation; hence the 5 to 6 percent linear annual growth rate represents real growth, above whatever inflation prevailed.

for any particular shape of curve, we simply performed a linear regression of the data, specifying the origin of the curve (at DSARC II) as unity. The result indicates a rather weak scalar relationship with a constant (linear) growth rate of about 5.6 percent a year.[12] Considering the dispersion of the data points, we prefer to characterize the growth rate as somewhere in the vicinity of 5 or 6 percent a year. This growth rate is for the set of programs as a whole, and should not be used to project the cost growth of individual programs.

REASONS FOR COST GROWTH IN THE 1970s

In what follows we attempt to illuminate the factors responsible for the cost growth in the 1970s programs. The basic source of our information is the cost

[12]Recent analysis by the Office of the Assistant Secretary of Defense (Comptroller) shows a somewhat lower annual growth rate—about 3.6 percent. Part of the reason for the difference is methodological: OSD adjusts for quantity variance differently and its growth rate is expressed in terms of compound, rather than linear, growth (See App. A). The primary reason, however, is the difference in samples. The OSD sample for March 1978 includes many more systems—all of the Congressional SAR programs (except the IFV) plus 5 non-Congressional SAR programs, for a total of 57, compared with our sample of 31.

variance section of the SARs.[13] Eight categories are used in the SARs to differentiate the causes of program cost variance in terms of constant dollars.[14] The categories are summarized below, together with a discussion of the problems involved in using SAR data for the cross-program comparison being conducted in the present study. A more complete discussion of cost variance analysis appears in Appendix B.

- *Schedule:* Cost effects of revisions in procurement delivery schedules or in the completion dates of tests and intermediate milestones of the major equipment item.
- *Engineering:* Cost effects of alterations in the physical or functional characteristics of the major equipment item.
- *Estimating:* Refinements or corrections of gross estimating errors in the baseline cost projection for the original major equipment.
- *Quantity:* Program cost changes attributed to changes in the number of units of the major equipment to be produced, as compared with the production quantity on which the development estimate was based.
- *Support:* Each of the previous variance categories relates only to the cost of the major equipment item. Cost changes in the support area (e.g., support and training equipment and initial spares) are shown in a single total.
- *Cost Overrun/Underrun:* Cost changes attributed solely to the performance of the contractors. This category involves subjective appraisals of the contractor's ability to perform in a reasonable and efficient manner.

The two remaining variance categories are usually rather small; we describe them separately below, but in our tables we group them together under the single heading "Other."

- *Contract Performance Incentives:* The net cost effect of contractor performance where the contract contains incentive provisions to reward better-than-predicted contractor achievement—such as delivery and value engineering goals—or to penalize underachievement.
- *Unpredictable:* One might expect this variance category to be used frequently, as almost all variance could in one sense be blamed on a failure to predict circumstances that lead to the cost change. But in practice the use of this category is so circumscribed that it has rarely been used. Only acts of God, work stoppages, law changes, and totally unexpected circumstances that are without precedent and are random in nature seem to fulfill the requirements for this variance category. *Failure of Congress to approve anticipated funding levels is such a routine event that it is expressly ex-*

[13]The information in this section concerning OSD's treatment of cost variance is based on the DoDI 7000.3 *Selected Acquisition Reports,* and the guidelines for preparing the data given in DoD Guide (draft) 7000.3-G, *Preparation and Review of Selected Acquisition Report (SAR), Cost and Economic Information,* both documents issued by OASD (Comptroller).

[14]A ninth category, economic variance, accounts for inflation revisions due solely to the operation of the economy. Its main effect is on then-year dollar estimates, although it may have an indirect effect on Schedule and Estimating if they change as a result of incorrectly gauging the magnitude of inflation during the budget year. That is, if inflation is greater than budgeted for, but the work is accomplished anyway, at no additional then-year dollar cost, then the cost in real terms was originally overestimated. If less work was accomplished than scheduled because of inflation, some diseconomies may result if there is schedule slippage due to budget constraints.

cluded from the Unpredictable category, and is generally reported as schedule slippage—the effect produced, not the underlying cause.

This last observation introduces one of the primary limitations of the SAR cost variance categories when used to assess the effects of acquisition policy: In the SAR the emphasis is on effects or intermediate causes rather than on basic causes. For example, the Schedule variance category indicates the cost effect of altering the development and production schedules. But from the policy point of view one is primarily interested in the reasons that led to the schedule revisions. Was the schedule slipped because of unforeseen difficulties that made the original schedule unattainable? Or was it a response to a shortage of funds? If the latter, was the underfunding due to underestimates in the affected program or to an overrun in another program of higher priority? Was the funding shortfall the immediate result of Service, or OSD, or Congressional decisions? Was it the result of unexpected inflation?

Like the Schedule category, the Engineering, Estimating, and Support categories each combine under a single heading elements of cost growth due to a variety of causes. For policy-oriented analysis it would be desirable to have additional detail to permit greater insight into cause-effect relationships. Much of the needed information is almost certainly available but it has not been collected in any uniform and convenient format. Therefore, although the SAR cost variance categories are less definitive than would be desired for the present study, the analysis reported here is necessarily based primarily upon these SAR "effect oriented" categories. Supplementary information where available is used to aid in interpretation.

Table 8 describes the contribution to constant-dollar cost growth (or savings) of the different cost variance categories reported in the SARs. The effect of each variance category is expressed as a percentage of the all-program sum of the development estimates (DEs) for the 31 programs shown in Table 6, broken down, as in that table, for the development, production, and military construction budgets, and for the acquisition budget as a whole. Since they passed DSARC II these 31 programs, taken as a whole, have experienced a constant-dollar cost growth of about 1 percent (Table 8, Col. (9)). *This superficially very favorable result is due mainly to a large cutback in production quantity.* If the quantity adjustment is made—adding back into the total the 13 percent quantity-induced cost saving shown in Col. (8)—this group of programs has a cost growth of 14 percent, or a cost-growth ratio of 1.14 as shown at the bottom of Col. (12) in Table 6. This 14 percent growth is the sum of the percentages of the variance categories other than Quantity. As shown by the percentages in Table 8, Schedule and Engineering changes are the greatest contributors to cost growth apart from quantity-induced cost variance. The Schedule category contributes (5.6)/(14.3) of total cost growth (Table 8, Cols. (1) and (7)); this is almost 40 percent of the total, or about $5 billion.[15]

The cost-growth changes in the Development and Procurement phases and in Military Construction differed considerably, as shown in the table. If we exclude the 14 programs that are less than 3 years past their DSARC II go-ahead dates, and analyze the total cost variance of the remaining 17 more mature acquisition programs (see Table 9), the cost growth percentages are generally higher, and, again,

[15]For the 31 program sample, the difference between the sum of the CEs and the sum of the DEs is about $12.8 billion; see Table 6.

Table 8

Aggregate Percentage Cost Growth, 1970s Programs, by SAR Variance Categories

Acquisition Budget Affected (31-Program Aggregate)	SAR Variance Categories and Corresponding Percentage Cost Changes[a]								
	Schedule (1)	Engineering (2)	Estimating (3)	Support (4)	Overrun/ Underrun (5)	Other (6)	*Total (Sum of Preceding Columns)* (7)	Quantity (8)	Total (Sum of Columns (7) and (8)) (9)
Development	5.4	5.3	1.0	0.6	0.7	5.2	*18.2*	-0.8	17.4
Procurement (production)	5.6	3.2	2.5	1.5	0.2	0.1	*13.1*	-17.0	-3.9
Military construction	0	0	-1.0	6.9	0	0	*5.9*	-17.5	-11.7
TOTAL ACQUISITION BUDGET	5.6	3.7	2.1	1.3	0.3	1.3	*14.3*	-13.2	1.1

SOURCE: Selected Acquisition Reports (SARs); Table 6.

[a]The cost-change percentages shown here are all-program aggregates for the 31 programs listed in Table 6. For each row in the present table (Development, Procurement, Military Construction, and Total Acquisition Budget), the basic cost is the corresponding Development Estimate (DE) grand total given in Table 6. The cost change due to each cost variance category is expressed as a percentage of the appropriate DE grand total. For example, from Table 6 the 31-program grand total DE for Development is $21,058 million. The total cost growth attributed to Schedule in the Development phase is $1,137 million, or 5.4 percent, as shown in Col. (1) of the present table. Because of rounding, the entries may not sum to the totals in Cols. (7) and (9).

Table 9

Aggregate Percentage Cost Growth, Mature 1970s Programs, by SAR Variance Categories

Acquisition Budget Affected (17-Program Aggregate)	SAR Variance Categories and Corresponding Percentage Cost Changes[a] Schedule (1)	Engineering (2)	Estimating (3)	Support (4)	Overrun/ Underrun (5)	Other (6)	*Total (Sum of Preceding Columns)* (7)	Quantity (8)	Total (Sum of Columns (7) and (8)) (9)
Development	7.2	7.5	0.5	0.9	0.5	7.6	*24.2*	-1.2	23.0
Procurement (production)	7.9	4.9	2.9	2.5	0.3	0.2	*18.7*	-31.9	-13.3
Military construction	0	0	-5.5	27.8	0	0	*22.3*	-70.9	-48.6
TOTAL ACQUISITION BUDGET	7.7	5.6	2.3	2.1	0.3	2.0	*20.0*	-24.4	-4.4

SOURCE: Selected Acquisition Reports (SARs); Table 6.

[a]The cost-change percentages shown here are all-program aggregates for the 17 programs that have progressed at least three years past DSARC II, as listed in Table 6. For each row in the present table (Development, Procurement, Military Construction, and Total Acquisition Budget), the basic cost is the corresponding 17-program Development (DE) subtotal given near the bottom of Table 6. The cost change due to each cost variance category is expressed as a percentage of the appropriate DE subtotal. For example from Table 6 the DE subtotal for Development is $14,528 million. For the 17 programs, the aggregate cost growth attributed to Schedule in the Development phase is $1,051 million, or 7.2 percent, as shown in Col. (1) of the present table. Because of rounding, the entries may not sum to the totals in Cols. (7) and (9).

Schedule and Engineering are the greatest causes of cost growth. (The "Other" category has become important for Development, but this was due almost entirely to the Navy's cancellation of its participation in the development of the F100 engine, which left the F-15 with a large "Unpredictable" cost increase.)

Table 10 shows the cost variance categories for each of the individual programs in the sample of 31 programs. Appendix C presents a more detailed narrative description of each program's experience, but even in the summary figures in Table 10 it is apparent that there is considerable variation in the reasons given for their cost growth. Excluding quantity variance, 14 programs had cost growth that exceeded 20 percent. For these 14, Estimating contributed most in 6 programs, Engineering in 4, Schedule in 3 (all Air Force), and Support in 1.

For the 6 programs with the greatest cost growth, the Estimating category contributed most for CAPTOR, AIM-9L, Roland, and SURTASS. Engineering contributed most for IFV and LAMPS III.

In attempting to push the analysis beyond these "effect-oriented" variance categories so as to get at more fundamental causes, we examined other information in the SARs and in Congressional hearings. This attempt was only partly successful. Some additional explanations were usually provided for the major cost changes, but cost breakdowns seldom were given in usable, constant dollar form.

Although its effect on cost growth in dollar terms cannot be accurately assessed from the data we have seen, inadequate annual funding was one of the underlying causes most frequently mentioned for the Schedule cost variance category.[16] The implicit reasoning is that a well designed acquisition plan embodies a time-phased series of events with a stream of expenditures providing for an adequate supply of test items, and an efficient production rate relative to the planned buy size. Funding cutbacks in terms of "real" resources (even if funding is nominally sustained in terms of then-year dollars) are disruptive of time-meshed activities, reduce labor productivity due to fluctuations in the workforce, open up contracts for renegotiation (seldom to the government's advantage, if only because of the delays involved), and often lead to insufficient testing and inefficient production rates, thus increasing total program costs in real terms as well as in then-year dollars. More than one-third of the programs in the basic sample had to cut production below planned levels at one time or another in response to constrained annual funding.

The information available did not indicate the relative importance of the various possible causes for the funding shortfalls, but it was clear that unexpectedly high inflation rates beginning in the mid-1970s were among the top-ranking influences. The effect of unpredictable funding and program schedule slippage will be discussed in more detail in Section VI, below.

For Engineering cost variance, unanticipated technical difficulties were identified as an underlying cause in 11 of the 31 programs, and an increase in performance beyond that required in the original specifications was mentioned in 12 programs. (Six programs attributed Engineering cost growth to both reasons.) In some programs, for example, the Patriot, Condor, and A-10, cost reductions were

[16]The point is not so much that *total* program funding summed over the whole program lifetime is inadequate, although this happens, but, rather, that the *annual rate* of funding is sometimes reduced unpredictably so that it becomes too low to permit activities to proceed efficiently as planned.

Table 10

INDIVIDUAL PROGRAM PERCENTAGE COST GROWTH,[a] 1970S PROGRAMS, BY SAR VARIANCE CATEGORIES

Program	SAR Variance Categories and Corresponding Percentage Cost Changes								
	Schedule (1)	Engineering (2)	Estimating (3)	Support (4)	Overrun/ Underrun (5)	Other (6)	*Total (Sum of Preceding Columns)* (7)	Quantity (8)	Total Sum of Columns (7) and (8) (9)
ARMY									
Patriot	5.5	-13.1	10.2	2.6	0.6	---	*5.8*	-24.5	-18.7
Hellfire	1.2	1.0	0.2	-0.6	---	---	*1.7*	---	1.7
UH-60	-3.4	-1.3	-1.9	-6.7	0.5	0.1	*-12.8*	-1.0	-13.8
YAH-64	1.4	---	---	-0.5	---	---	*0.9*	---	0.9
IFV	5.6	51.8	15.3	5.0	3.3	-0.4	*80.6*	-121.6	-41.0
XM-1	4.1	---	2.3	0.6	---	---	*7.0*	66.3	73.2
Roland	---	2.3	44.9	-0.9	7.2	---	*53.5*	2.3	55.8
Copperhead (CLGP)	-1.9	0.8	3.8	0.9	---	0.2	*3.7*	-11.3	-7.6
DIVAD Gun	---	---	1.4	---	---	---	*1.4*	2.7	4.1
M-198 Howitzer	2.5	1.2	29.1	2.3	---	---	*35.2*	-21.8	13.3
NAVY									
F-18	2.1	0.1	1.1	-0.5	---	---	*2.8*	---	2.8
LAMPS III	1.4	15.8	9.6	15.2	---	---	*42.0*	-11.6	30.3
Aegis	8.3	12.4	---	3.4	---	---	*24.1*	---	24.1
CAPTOR	12.3	35.6	41.0	23.6	---	---	*112.5*	-2.1	110.4
Harpoon	2.2	17.4	2.6	1.4	---	---	*23.7*	-21.3	2.4
Sidewinder (AIM-9L)[b]	15.4	13.4	53.3	16.0	---	-0.6	*97.5*	54.7	152.3
Tomahawk	---	---	---	---	---	---	*0*	---	0
5-in. Guided Projectile	---	---	---	---	---	---	*0*	---	0
8-in. Guided Projectile	---	---	---	---	---	---	*0*	---	0
SURTASS	-0.4	17.9	28.1	2.6	3.5	---	*51.7*	---	51.7
TACTAS	4.5	---	-0.3	0.7	---	---	*5.0*	-35.2	-30.2
Condor	12.2	-4.7	-13.2	-4.9	0.8	---	*-9.8*	-12.6	-22.4
AIR FORCE									
A-10	17.1	8.1	-1.3	1.6	---	1.3	*26.8*	---	26.8
B-1	6.6	11.4	2.0	-2.5	---	0.8	*18.3*	-87.1	-68.8
F-15	11.3	4.3	-0.8	-0.9	1.1	9.3	*24.3*	---	24.3
F-16	---	6.1	-1.4	21.8	---	0.3	*26.8*	67.4	94.3
E-3A (AWACS)	27.8	1.2	-6.7	-0.9	-0.1	-0.5	*20.8*	-2.9	17.9
PLSS	---	---	-0.8	0.4	---	---	*-0.4*	---	-0.4
DSCS III	---	---	-21.6	---	---	---	*-21.6*	---	-21.6
ALCM	---	---	---	---	---	---	*0*	---	0
GLCM	---	---	---	---	---	---	*0*	---	0

NOTE: Programs italicized are at least three years past DSARC II.

[a]The cost-growth percentages for each program were derived by dividing the program's total Development Estimate into the cost variance attributed in its March 1978 SAR to each category (Schedule, Engineering, etc.). Breakdowns by Development, Procurement, and Military Construction are given for each program in Appendix C.

[b]Navy and Air Force programs combined.

achieved by accepting a lower level of performance than called for in the original specifications.

For some systems, improving performance is a continuing activity throughout their operational lives. This is especially true of combat aircraft that must contend with an increasingly hostile threat environment. In cases where the need for these improvements could not have been foreseen at the time of DSARC II but later became essential for mission effectiveness, some consideration should be given to treating these added costs in a less pejorative way than is now common. Added costs for improved performance do sometimes buy added capabilities that are badly needed but for which the need could not have been foreseen.

Cost growth attributable to the Estimating category was traceable to two major factors: omission of significant system elements and lack of appropriate costing data. Some programs omitted training and depot equipment from the baseline. The LAMPS III baseline costs failed to include ship system support equipment costs. Lack of adequate technical data from the developers was identified as the main cause of the Roland[17] cost growth, and also figured importantly in other programs, especially those pushing the state of the art. In some cases only rough approximations could be made initially for some system components. These figures were refined as the system components later became "definitized." The CAPTOR SAR blamed much of its Estimating variance on the assumption of an overly optimistic rate of cost reduction as output increased (too steep a learning curve slope).

Table 11 presents an attempt to identify the primary underlying causes of acquisition cost variance for the 31 programs included in our cost analysis. Although we could not assign dollar values, the table distinguishes between causes of large variance (L) and small variance (s). An "r" indicates a small cost reduction.

SUMMARY

Performance, schedule, and cost results were compared with goals for the 1970s acquisition programs, the data being derived from the Selected Acquisition Reports (SARs). The metric used was the ratio of result to goal arranged so that in all cases the preferred outcome—higher performance, shorter schedule, lower cost—was represented by a ratio less than unity. The aggregate outcomes for the programs examined were as follows:

- For *system performance parameters*, the distribution of result-to-goal ratios was nearly symmetrical around unity, with a range from about 0.5 to 2.1, and a mean ratio of 1.0. On the average, performance goals were achieved for the parameters tested.
- For *scheduled events* accomplished, the distribution of result-to-goal ratios was skewed slightly toward higher values (schedule slippage), with a range from about 0.8 to 2.1, and a mean ratio of 1.13.
- For *program costs* as projected in March 1978, the distribution of result-to-goal ratios was skewed moderately toward higher values (cost growth), with a range from about 0.7 to 2.2, and a mean ratio of 1.20. The dollar-

[17]Roland, it will be remembered, is a non-U.S. development.

Table 11

PRELIMINARY ATTEMPT TO IDENTIFY THE UNDERLYING CAUSES OF PROGRAM COST VARIANCE

Program	Inadequate Funding	Unexpected Technical Difficulties	Changed Performance	Estimating Errors	Unpredictable
ARMY					
Patriot	s	s	r	s	
Hellfire	s		s		
UH-60					
YAH-64	s				
IFV		L	L	L	
XM-1		L			
Roland				L	
Copperhead (CLGP)					
DIVAD Gun					
M-198 Howitzer		s		L	
NAVY					
F-18					
LAMPS III		s	L	s	
Aegis	s		s		
CAPTOR	s		L	L	
Harpoon	s		L		
Sidewinder (AIM-9L)		L	L	L	
Tomahawk					
5-in. guided Projectile					
8-in. guided Projectile					
SURTASS			L	L	
TACTAS	s				
Condor	s	s	r	r	
AIR FORCE					
A-10	L		s		s
B-1	s	s	s		
F-15	s	s	s		s
F-16		s	s		
E-3A (AWACS)	L	s			
PLSS					
DSCS III					
ALCM					
GLCM					

Key: L = cause of large increase.
s = cause of small increase.
r = cause of small reduction.

> weighted mean ratio was 1.14, and the median ratio was 1.06. Thus more than half of the programs had cost growth of less than 10 percent. (In these comparisons, costs are calculated for the original DE production quantity, and adjusted to eliminate the effects of inflation.)

Cost-growth ratios of the size found here for defense programs appear to be in the same ballpark as the cost-growth ratios observed for large nondefense projects involving new technology or other substantial uncertainties, although further research is needed to confirm this conclusion.

The sample of programs involving substantial hardware competition was characterized by considerably lower cost growth than the sample without hardware competition (a cost-growth ratio of 1.16 compared with 1.53). The sample with hardware competition also did somewhat better in terms of program schedules and system performance goals. The only program to pass DSARC III with negative cost growth (the UH-60) had full prime contractor competition through full-scale development.

As programs mature, the projected constant-dollar cost to complete them tends to increase, as might be expected. No program in our cost analysis sample of 31 programs had reached full term completion, but 17 had passed DSARC II by more than 3 years. For these 17 more mature programs, the mean cost-growth ratio was 1.34 compared with 1.20 for the sample as a whole. The average (linear) rate of cost growth for the full sample was between 5 and 6 percent per annum. (This is somewhat greater than the annual cost growth rates calculated by the Office of the Assistant Secretary of Defense (Comptroller), but the calculations are for different samples, and the OSD results are expressed in terms of compound rather than linear growth rates.)

The major drivers of cost growth for the programs of the 1970s were schedule changes, engineering changes, and estimating errors. For the full 31 program cost analysis sample, schedule changes alone contributed about 40 percent of the total cost growth, or about $5 billion. The need to understand more about the underlying causes of schedule change is obvious, and the point will be addressed again in Section VI.

What has been said so far in this Summary refers to costs in constant dollars for programs costed as if they were to be completed with the original production quantity. The conventional wisdom is that when programs experience difficulties, cost is the first constraint relaxed and schedule the second, but that performance goals are adhered to more rigorously. For 1970s experience, this view is supported by an examination of the result-to-goal ratios summarized earlier. But, for the 1970s at least, it must be added that constraints are relaxed for unit costs but not, generally, for total program costs. In the aggregate, total program costs in constant dollars have remained very close to the amounts projected in the Development Estimates (DEs) at the time of DSARC II. For the 31 programs in our cost analysis sample, reductions in quantity almost perfectly cancelled out the sum of the cost changes due to the other variance categories. In other words, the real flexibility in the acquisition process is found in the quantities of units procured, not in the aggregate cost of acquisition programs.

This kind of flexibility raises important questions about the validity of the procurement quantities established in the requirements process and the manner in which quantity-quality tradeoffs are made, but these questions are outside the scope of the present study.

IV. COMPARISON OF 1960s AND 1970s EXPERIENCE

One way of judging the success of the new acquisition policies adopted by OSD early in the 1970s would be to make comparisons between representative samples of 1970s and 1960s programs. For the reasons mentioned in Section I, no fully satisfactory comparison of this kind appears possible. Influences external to the programs have not been constant over time, and the criteria of program success are situation-dependent and hence vary from program to program. We can, however, compare the degree to which samples of 1960s and 1970s programs met their own internal goals for performance, schedule, and cost.

The 1960s sample is that previously studied at Rand by Perry, Smith, Harman, and others,[1] and described here in Table 12, derived from their 1971 report. The 1960s sample is generally more mature than our 1970s sample, and for consistency in the interdecade comparison of cost-growth ratios, we limited the comparison to the more mature programs—the 17 1970s programs that were at least 3 years past DSARC II (identified in Table 10), and the 13 1960s programs for which we had cost data and that had progressed at least 3 years beyond the start of engineering development (identified in Table 12). These two "mature" samples are listed together in Table 13. In the performance and schedule comparisons, the difference in program maturities of the two samples is probably not significant, because the 1970s programs in these comparisons were limited to those that had already passed DSARC III, and in any case the data for results are always "actuals," representing performance test outcomes or scheduled events that have been accomplished.

As Table 12 suggests, the data available in the 1960s, before the introduction of the Selected Acquisition Reports, were spotty at best. Lacking the detailed program information that is now collected by program management offices from their various contractors and consolidated into coherent, standardized reports, the Rand analysts had to collect their 1960s data by means of literature surveys, questionnaires, follow-up letters, and phone calls. They converted the costs to constant dollars using the wholesale price index, and they developed learning curves to correct for quantity changes in the data they were able to assemble. Without the benefit of an allocation of cost growth among selected cost variance categories—a feature of the current SARs—the analysts could only speculate in a very general way about the probable causes of 1960s cost growth, schedule slippage, and performance shortfalls. Nevertheless, the work was carefully done and was internally consistent. So long as the performance, schedule, and cost figures in the earlier study are treated as somewhat rough approximations, they provide a basis for comparison with the 1970s sample.

Both samples include Army, Navy, and Air Force programs; both include mis-

[1]Robert Perry et al., *System Acquisition Experience*, The Rand Corporation, RM-6072-PR, November 1969; A. J. Harman and S. Henrichsen, *A Methodology for Cost Factor Comparison and Prediction*, The Rand Corporation, RM-6269-ARPA, August 1970; Robert Perry et al., *System Acquisition Strategies*, The Rand Corporation, R-733-PR/ARPA, June 1971.

Table 12

1960s PROGRAM SAMPLE

Program	Type of Data Available		
	Cost	Schedule	Performance
ARMY			
Pershing I	X	X	X
Pershing IA	X	X	X
OH-6A (Hughes)	X	X	X
Sheridan		X	X
Cheyenne		X	X
Lance		X	X
NAVY			
OV-10A	X	X	X
DIFAR	X	X	X
A-7E[a]	X	X	
SQS-26AX	X	X	
SQS-26CX	X	X	
MK-48 Mod 0		X	X
A-7A		X	X
MK-48 Mod 1		X	
AIR FORCE			
F-111	X	X	X
C-5A	X	X	X
C-141	X	X	X
Titan III-C	X	X	X
Minuteman II Airborne Command Post	X	X	X
Minuteman II Guidance and Control	X	X	X
A-7D[a]	X	X	
XC-142		X	X
Sprint		X	
SRAM			X

SOURCE: Robert Perry, Giles K. Smith, Alvin J. Harman, and Susan Henrichsen, *System Acquisition Strategies*, The Rand Corporation, R-733-PR/ARPA, June 1971, p. 3.

[a]For consistency, these A-7 programs were excluded from our cost analysis because they were less than three years beyond the start of what was then called engineering development (equivalent to full-scale development today).

Table 13

COST GROWTH COMPARISONS, 1960s AND 1970s
MATURE SAMPLES

1970s (17 Programs) Program	Cost-Growth Ratio[a]	1960s (13 Programs) Program	Cost-Growth Ratio[b]
UH-60	.87	Titan IIIC	1.06
Condor[c]	.90	Pershing 1A	1.07
Copperhead (CLGP)	1.04	OH-6A (Hughes)[d]	1.09
		OV-10A[d]	1.10
Patriot	1.06	MM II ACP[d]	1.12
B-1[c]	1.18	Pershing I[d]	1.12
E-3A (AWACS)	1.21	C-141[d]	1.16
Aegis	1.24	C-5A	1.36
Harpoon	1.24	SQS-26CX[d]	1.55
F-15	1.24	MM II G&C[d]	1.60
A-10	1.27	DIFAR	2.05
F-16	1.27	F-111	2.07
M-198 Howitzer	1.35	SQS-26AX[d]	2.34
LAMPS III	1.42		
SURTASS	1.52		
IFV	1.81		
AIM-9L	1.98		
CAPTOR	2.12		
Mean	1.34		1.44
Mean (weighted by program dollars)	1.20		1.47
Median	1.24		1.16

[a]Costs in constant dollars, ratio of March 1978 Current Estimate to DSARC II Development Estimate (for Harpoon and Condor, DSARC II Current Estimate).

[b]Costs in constant dollars, ratio of December 1969 estimate (or completed program actual cost) to original, approved estimate.

[c]Cancelled.

[d]Completed at time sample compiled.

siles and other systems as well as aircraft; and both include some examples of "high technology" developments pushing the state of the art. It is not clear, however, that the samples as a whole represent the same degree of technical difficulty. Moreover, the external influences in the two decades appear to have been somewhat different, for example, the nature of the foreign military threat, and the size and frequency of externally imposed program funding changes. We recognize that such differences may affect the outcomes, but we do not attempt to assess their overall influence.

PERFORMANCE AND SCHEDULE

The interdecade performance and schedule comparisons are shown graphically in Figs. 12 and 13, which repeat the 1970s performance and schedule results shown above in Fig. 7; the 1960s data are taken from the 1971 Rand Report previously mentioned. Note that, as before, the performance record is stated so that outcomes better than the goal are on the low side, at the left of the diagram, as with schedule and cost.

Figures 12 and 13 tell much the same story. The 1960s and 1970s histograms are generally similar in appearance. But, as would be expected if management in the 1970s has become "tighter" and more uniform, the 1970s ratios are concentrated in a narrower range with their mean values slightly closer to unity. Generally the picture appears to be one of modest improvement over time.

COST

As already mentioned, the 1960s sample was the more mature. Many of the 1960s programs were completed within the decade, and for these completed programs, actual (final) costs were available for use in place of current estimates.

To facilitate the interdecade cost growth comparison, the two sets of programs in Table 13 are ranked by their cost-growth ratios. As observed in Section III, the overall average cost-growth ratio for the 1970s mature sample, weighted by program value, is 1.20. The comparable figure for the 1960s is 1.47. In dollar terms, both sets are dominated by a few large aircraft systems. In the 1960s, the F-111 and C-5A accounted for more than half the total program costs in the sample, and the large cost growth of these aircraft raised the overall average. In the 1970s, the B-1, F-15, F-16, and F-18 aircraft programs accounted for 51 percent of total costs.

The mean of the 1970s cost growth factors for individual programs (unweighted by dollar size) is smaller than the mean for the 1960s: 1.34 compared with 1.44. The 1970s median is somewhat larger than the 1960s median (1.24 versus 1.16), but we do not attach much significance to this, for reasons suggested by an inspection of Table 13. The median 1960s program is immediately followed by one with more than twice as much cost growth—a cost-growth ratio of 1.36 compared with a ratio of 1.16 for the median program. The 1970s median program (a cost-growth ratio of 1.24) is flanked by programs with similar ratios (1.24 and 1.27). The comparison of cost-growth ratios in Table 13 is displayed graphically in Fig. 14.

The average annual *rates* of cost growth for these 1960s and 1970s mature

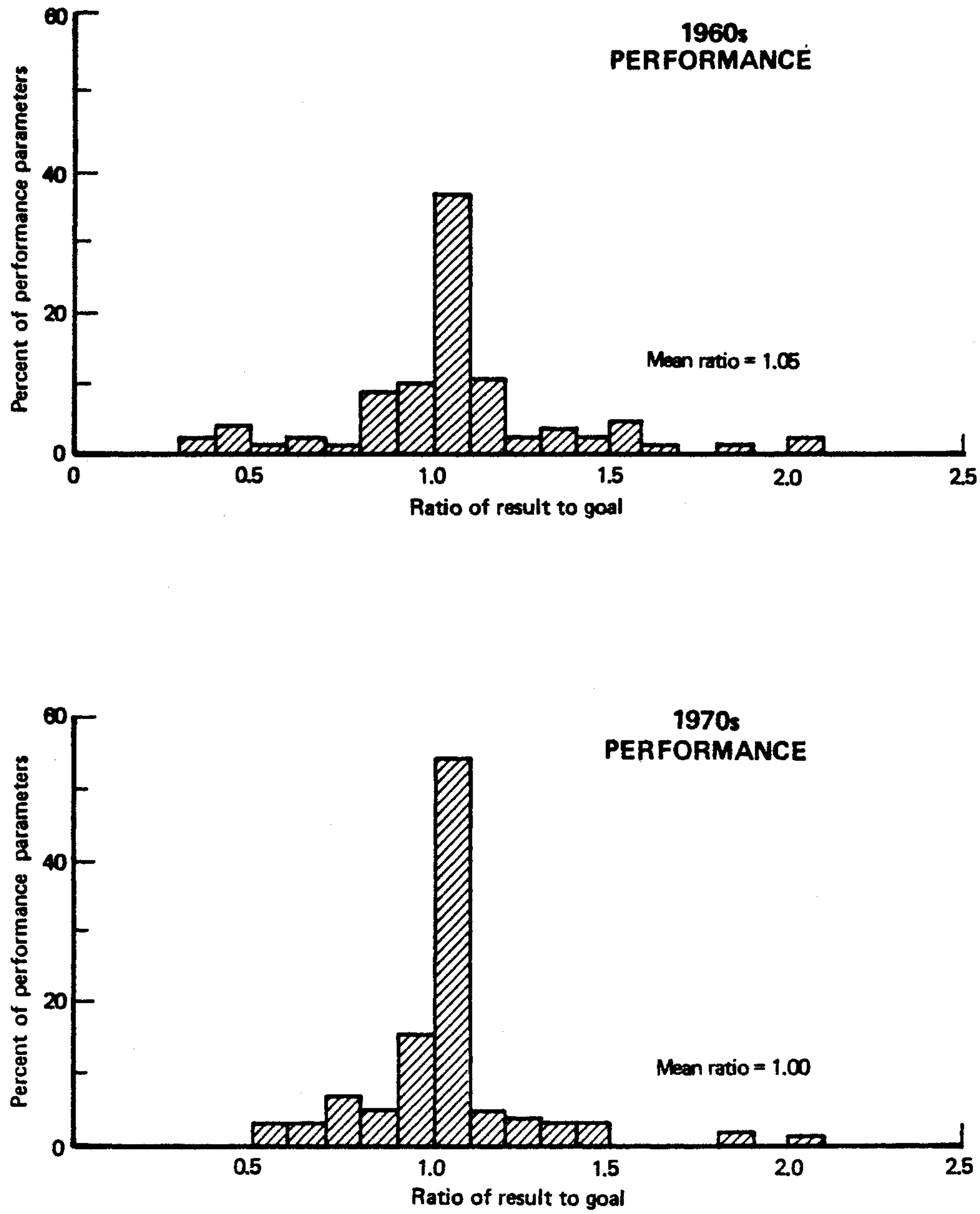


Fig. 12—Performance comparisons, 1960s and 1970s samples

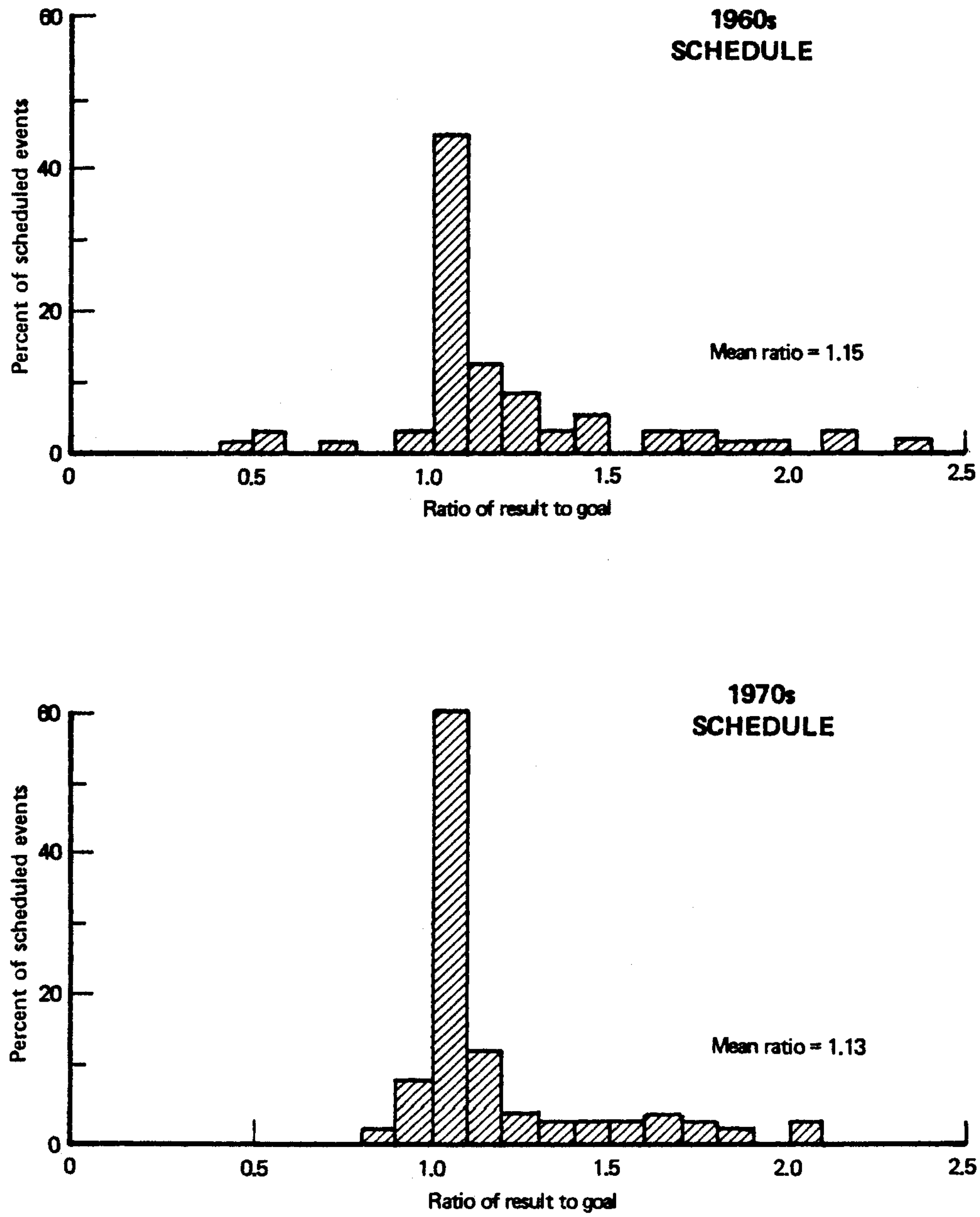
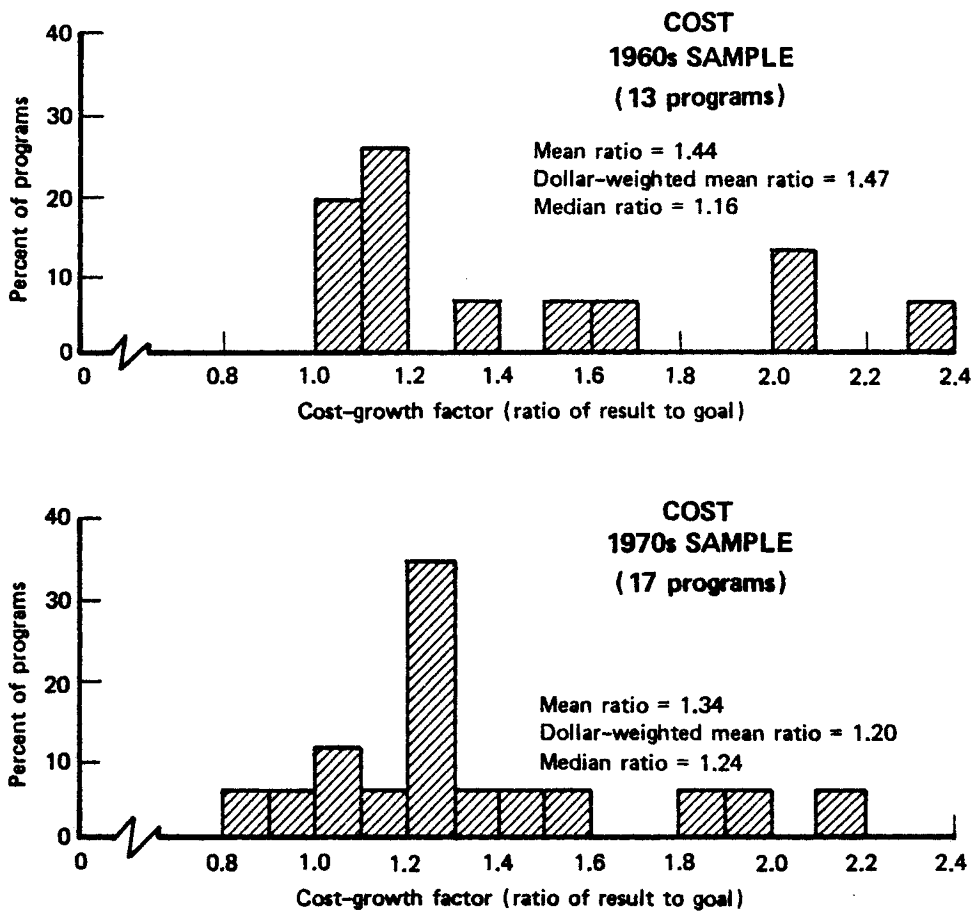


Fig. 13—Schedule comparisons, 1960s and 1970s samples



SOURCE: Table 13

Fig. 14—Cost-growth comparisons, 1960s and 1970s mature samples

samples were calculated in the same way as was done for the 1970s 31-program cost analysis sample (Fig. 11). The regression line for the 1960s displays the steeper slope, with a linear cost growth rate of 7.6 percent per year as compared with 5.8 percent per year for the 1970s.[2] But these average growth rates are simply central measures of quite dispersed data points, the 1960s data having even greater dispersion than the 1970s data. Because of the overlapping of data points and the rather poor statistical fit of the data,[3] we hesitate to attribute much precision to the size of the indicated improvement (reduction) in the growth rate in the 1970s. To indicate this uncertainty, we characterize the 1960s growth rate as 7 to 8 percent, and the 1970s growth rate as 5 to 6 percent. A reduction of 1 to 3 percentage points in the annual rate of cost growth, when sustained over a program life of some 10 years, would, of course, lead to a substantial reduction in total program cost growth.

The effect of these lower annual cost-growth ratios on total acquisition costs might, however, be partly counterbalanced by the apparent trend toward increasing program duration.[4]

The samples for both decades include instances of cost containment, and both have outliers with soaring growth. It is interesting to note, however, that one of the programs in the 1960s that exhibited a very high growth rate, the F-111, also was the greatest in dollar value. There is nothing similar in the 1970s sample. It is plausible that the Packard initiatives, including the "fly before buy" philosophy, the increase in hardware testing, and the discipline of the DSARC reviews, plus the visibility afforded by the SAR reporting process, now serve to give earlier warning when programs are heading into trouble and lead to earlier corrective actions.

The causes of cost growth appear to be somewhat different in the two periods: For the 1960s sample, the 1971 Rand analysis cited earlier identified changes in scope (increased system performance) as the biggest factor. Inflation was not the problem in the 1960s that it has become, and schedule slippage was not identified as a significant factor. Cost estimating errors were thought to be of minor significance, but we would be surprised if they were in fact any less significant than they are today.

As already discussed, schedule slippage and engineering changes are the primary reasons for cost growth in the 1970s sample, with cost estimating errors (underestimates) an important factor in a few cases. Inflation has been consistently underestimated, and compensatory schedule slippage as the response to the resulting funding squeeze has been a significant cause of program cost growth in the 1970s. Without this effect of inflation, it is plausible that schedule slippage and cost growth in the 1970s might have been more successfully controlled, and the cost growth comparison would presumably then have been even more favorable to the 1970s.

Obviously, cost growth avoided cannot be fully equated with savings achieved. In comparing results with goals, a lower cost-growth ratio may be due to a higher

---

[2]The linear cost growth rate calculated for the full cost-analysis sample of 31 1970s programs was 5.6 percent a year (see Sec. III).

[3]The following are measures of curve fit for the two data sets:

Samples	Coefficient of Determination (r^2)	Coefficient of Correlation (r)	Standard Error of Estimate
1960s	.455	.674	47.27
1970s	.516	.718	34.22

[4]For trends in program completion times, see Sec. V.

denominator as well as to a lower numerator—or to both. Goals have the nature of predictions, and a lower ratio may simply reflect an improvement in the skill or objectivity with which predictions are made. If we observe a reduction in cost growth between two periods of time, we cannot be certain whether this is due to improved accuracy or greater realism in cost estimation, or even to some degree of conscious overestimation[5] in setting the cost goals—or whether it is due to improvements in acquisition strategy, or to greater management effectiveness in controlling cost growth. This comment is not intended to downplay the value of more realistic cost goals. On the contrary, realistic cost goals contribute to improved acquisition management by permitting more reliable projections to be made of what can be accomplished with the programmed funds. This helps to avoid the schedule slippages and other dislocations later in the program that exert such a strong upward push on acquisition cost growth.

SUMMARY: IMPROVED RESULTS IN TERMS OF GOALS

Table 14 summarizes the performance, schedule, and cost comparisons of the 1960s and 1970s samples. By almost every measure the comparison favors 1970s experience.

Table 14

SUMMARY COMPARISON OF 1960S AND 1970S SAMPLES: RESULTS AND GOALS FOR PERFORMANCE, SCHEDULE AND COST

Program Measure and Sample	1960s	1970s
Ratio of results to goals (small values preferred)		
System performance	1.05	1.00
Program schedule	1.15	1.13
Program cost growth		
Basic sample (31 programs)		
Mean	n.a.	1.20
Dollar-weighted mean	n.a.	1.14
Median	n.a.	1.06
Mature sample (13 programs for 1960s, 17 for 1970s)		
Mean	1.44	1.34
Dollar-weighted mean	1.47	1.20
Median	1.16	1.24
Average annual cost growth, linear rate (percent)	7 to 8	5 to 6

NOTE: n.a. means not applicable.

[5]Although conscious overestimation is theoretically possible as an explanation, the bureaucratic incentives appear to be strongly in the other direction—toward "optimistic" low-side estimations.

A plausible description of what has been happening is that the 1970s programs are achieving their performance and schedule goals to at least the same degree as the 1960s programs did, and are probably doing slightly better. The 1970s programs, moreover, are coming closer to their cost goals by some 10 to 20 percentage points. This is a substantial reduction in cost growth. For the 31 1970s programs in our cost analysis sample, the dollar sum corresponding to this reduction would be from $9 billion to $18 billion, although, as discussed earlier, cost growth avoidance is not the same as cost savings. The average annual *rate* of program cost growth is also less in the 1970s than in the 1960s—about 5 to 6 percent compared with 7 to 8 percent.

In this comparison of acquisition experience in the two decades, some caveats must be borne in mind: the different maturities of the 1960s and 1970s samples, the possibility of differences in technical difficulty, and the influence of factors apart from OSD policy and beyond the control of program management.

Nonetheless, we find it plausible that the changes in acquisition strategy and management since the 1960s have been the main contributors to the observed improvements shown in Table 14. If the 1970s programs had not suffered as a result of the much higher rate of inflation they experienced, these improvements might well have been greater.

V. IS IT TAKING LONGER TO ACQUIRE SYSTEMS?—EVIDENCE FROM AIRCRAFT PROGRAMS

One measure of acquisition effectiveness is the time required to complete the acquisition process. Other things being equal (cost and performance, in particular), a shorter acquisition time is usually better than a longer one because the item can be fielded sooner. This gives the system a longer useful life before it becomes obsolescent in terms of adversary systems and hence increases its overall contribution to defense. In some instances, time is of the essence: the rapid fielding of a new system is sometimes called for, to counter a new threat or overcome a newly perceived deficiency.

There is a growing belief that the United States is taking too long to develop and field new weapon systems. A recent study by the Defense Science Board[1] identified long acquisition intervals (long "fielding times" or slow "fielding rates") as a critical defense issue. The study suggested that while the time required for full-scale development has remained essentially unchanged, some lengthening has occurred both in the production phase and in the "front end" (from program initiation to start of full-scale development). Because of the importance of this issue, we examined data on fielding times collected at Rand in the course of earlier acquisition studies.

Each development program is unique, beset by its own special problems and influences, some of which are completely external to the project itself (for example, changes in the perceived priority of need for the system). Thus it is impossible to say whether any individual program took the "correct" amount of time in the acquisition process. Instead, we can only examine historical trends to see if there have been changes over time. If a change is observed, it can then be decided if the trend warrants corrective action.

Three phases of acquisition were noted above:

- The "front end," prior to DSARC II
- Full-scale development (FSD)
- Production

For most programs the nature and timing of the important decisions in the front end of the acquisition process have not been systematically recorded, and even good narrative histories are hard to find for that phase. In our quantitative analysis, we were therefore limited to an examination of the times required to complete the FSD and production phases of acquisition.[2]

---

[1]Defense Science Board, *Report of the Acquisition Task Force*, Defense Science Board Summer Study Group, published by the Office of the Under Secretary of Defense for Research and Engineering, Washington, D.C., March 1978.

[2]Additional research has been started to better understand and describe historical trends in that part of the acquisition interval devoted to pre-DSARC II program activities.

AIRCRAFT DATA, 1944 TO THE PRESENT

Aircraft programs were selected for this analysis of fielding times, simply because they represented the only class of numerous programs for which suitable data were already available at Rand for a period spanning several decades.

The 34 aircraft in the data base are listed in Table 15. These include most of the U.S. military aircraft that have been produced (not just developed) in the last 30 years: 5 Navy and 13 Air Force fighters, 5 Navy and 1 Air Force attack aircraft, and 10 other types of aircraft including bombers and transports. For each aircraft, dates were identified for the following milestones:

- Start of full-scale development. For most of the recent aircraft, this corresponds to DSARC II.[3] For earlier aircraft, contract dates or, occasionally, source selection dates were used.
- First flight of the initial configuration produced under the development contract, even though it was not necessarily the configuration that finally went into production.
- First acceptance of the production version that was procured for operational inventory (interpreted here as the end of the development phase).
- Delivery of the 200th production item (if achieved or scheduled).

The time from start of full-scale development to each of the subsequent milestones is plotted in Figs. 15, 16, and 17, as a function of the development start date. Some difficulty in data interpretation occurs with the recent programs having a prototype phase. Did the program start when the prototype phase was initiated, or not until the subsequent commencement of formal full-scale development (Milestone II)? Three recent programs of this type (A-10, F-16, F-18) are shown by dual entries in Table 15. In the figures, each dual set is shown by a light dashed line connecting the two data points; the higher point in each set is timed to the start of the prototype phase, while the lower point is timed to the start of formal full-scale development. There is an argument in favor of each interpretation. For the other (earlier) aircraft programs with a prototype phase (roughly one third of the sample), the programs were assumed to start at the beginning of this phase. However, in these earlier prototype programs there was greater overlap between the prototype and the full-scale development phases than in the more recent programs. We leave the proper interpretation to the reader.

Figure 15 displays the intervals from the beginning of FSD to first flight of the aircraft, as a function of the year when development started. The least-squares regression line fitted to all the data points *except* for the A-10, F-16, and F-18 is close to the horizontal, suggesting that prior to the A-10 development there had been only a slight increase over the years in times to first flight. The data points for the three recent prototype programs fall close to the trend line if one measures the time to first flight from the beginning of formal full-scale development. On the other hand, if one measures from the beginning of the prototype phase, the times to first flight of the FSD configuration for these three programs are about double those of the trend line.

Figure 16 gives a rather similar picture for total development time (the interval

[3]As will be discussed in the text, the A-10, F-16, and F-18 are possible exceptions.

Table 15

ACQUISITION INTERVALS FOR U.S. AIRCRAFT SYSTEMS, 1944-PRESENT

Aircraft Model	FSD Start Date	First Flight Date	*Months to 1st Flight*	First Item Accepted	*Months to 1st Delivery*	200th Item Delivered	*Months to Produce 200 Acft*	*Total Months, FSD Plus Production of 200 Acft*
F-84	11/44	2/46	*15*	7/47	*32*	4/48	*9*	*41*
B-47	10/45	12/47	*26*	4/51	*66*	6/52	*14*	*80*
F-86	11/45	10/47	*23*	12/48	*37*	10/49	*10*	*47*
F3D	4/46	3/48	*23*	8/50	*52*	4/53	*32*	*84*
F-89	6/46	8/48	*26*	9/50	*51*	1/54	*40*	*91*
B-52	7/48	4/52	*45*	1/55	*78*	8/57	*31*	*109*
F-94	10/48	7/49	*9*	12/49	*14*	—[a]	—	—
F4D	12/48	1/51	*25*	5/55	*77*	8/57	*27*	*104*
A3D	3/49	10/52	*43*	1/55	*70*	6/60	*65*	*135*
C-130	7/51	8/54	*37*	12/55	*53*	2/59	*38*	*91*
F-102	9/51	10/53	*25*	6/55	*45*	1/57	*19*	*64*
F-100	11/51	5/53	*18*	9/54	*34*	7/55	*10*	*44*
F-101	1/52	9/54	*32*	3/57	*62*	5/58	*14*	*76*
KC-135	5/52	7/54	*26*	1/57	*56*	1/59	*24*	*80*
A-4	6/52	6/54	*24*	8/55	*38*	12/57	*28*	*66*
F-105	9/52	10/55	*37*	5/58	*68*	4/61	*35*	*103*
B-58	2/53	11/56	*45*	11/59	*81*	—	—	—
C-133	2/53	4/56	*38*	6/57	*52*	—	—	—
F-104	3/53	2/54	*11*	1/57	*46*	12/58	*23*	*69*
F-106	5/55	12/56	*19*	4/59	*47*	4/60	*12*	*59*
F4H	5/55	5/58	*36*	6/60	*61*	10/62	*28*	*89*
A-5	6/56	8/58	*26*	2/60	*44*	—	—	—
A-6	1/58	4/60	*27*	4/62	*51*	2/67	*58*	*109*
P-3	4/58	11/59	*19*	8/62	*52*	12/66	*52*	*104*
C-141	4/61	12/63	*32*	5/64	*37*	4/67	*35*	*72*
F-111	12/62	12/64	*24*	2/67	*50*	12/69	*34*	*94*
A-7	3/64	9/65	*18*	3/66	*24*	1/68	*22*	*46*
C-5	10/65	6/68	*32*	12/69	*50*	—	—	—
F-14	2/69	12/70	*22*	8/72	*42*	7/76	*47*	*89*
S-3A	8/69	1/72	*29*	3/73	*43*	—	—	—
F-15	12/69	7/72	*31*	11/74	*59*	7/77	*32*	*91*
A-10	12/70[b]	2/75[c]	*50*	10/75	*58*	5/79	*43*	*101*
A-10	1/73[d]	2/75[c]	*25*	10/75	*33*	5/79	*43*	*76*
F-16	4/72[b]	12/76[c]	*56*	8/78	*76*	1/81	*29*	*105*
F-16	1/75[d]	12/76[c]	*23*	8/78	*43*	1/81	*29*	*72*
F-18	4/72[b]	11/78[c]	*79*	5/80	*97*	—	—	—
F-18	11/75[d]	11/78[c]	*36*	5/80	*54*	—	—	—

[a]A dash — means not applicable or not yet completed or scheduled.

[b]Date if FSD is regarded as starting with the prototype phase.

[c]Date of first flight of the aircraft developed in formal full-scale development: aircraft fabricated in the prototype phase flew before the beginning of formal full-scale development.

[d]Date if FSD is regarded as starting only when formal full-scale development began, that is, after the Milestone II decision.

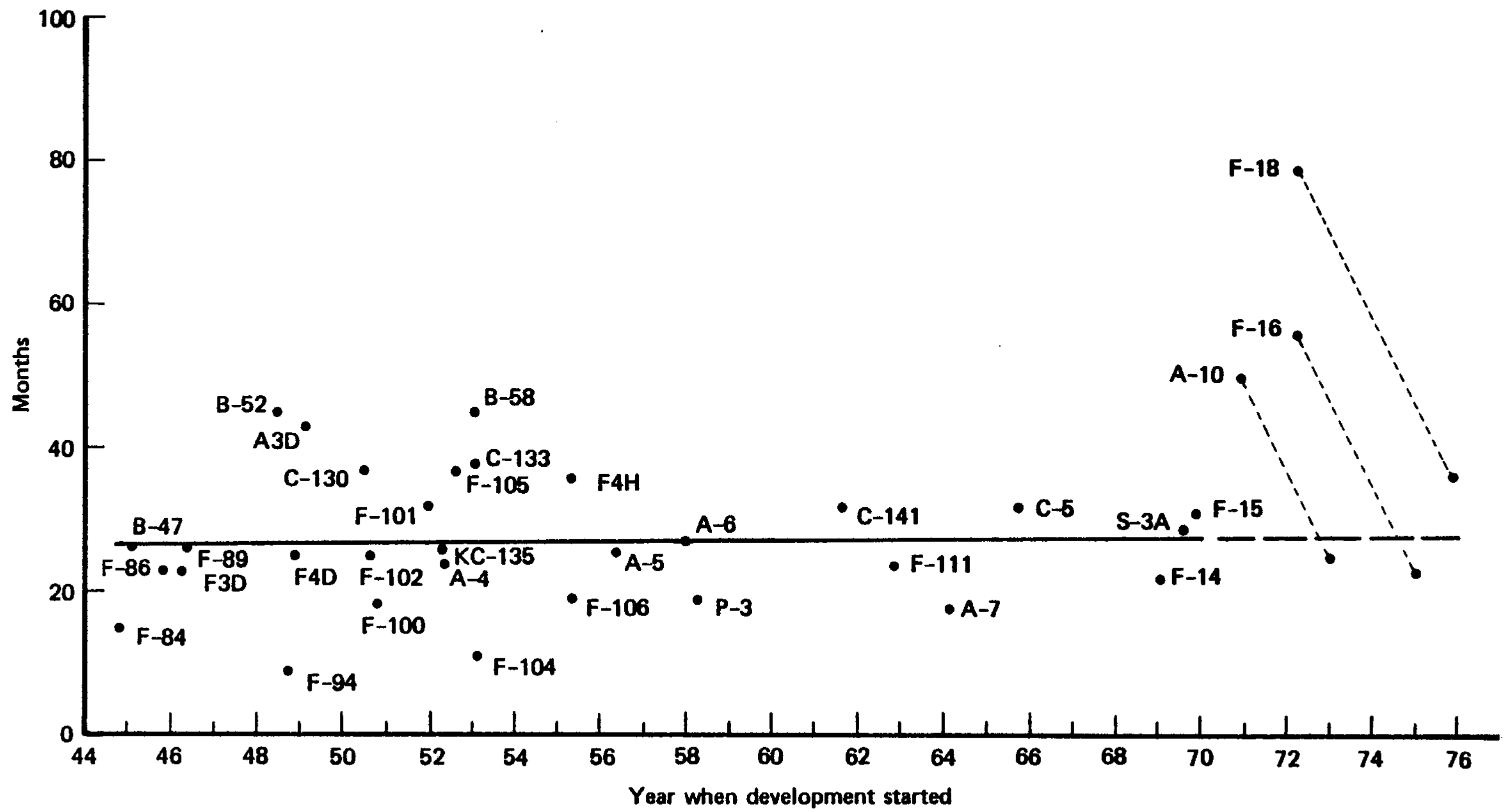


Fig. 15—Time from development start to first flight

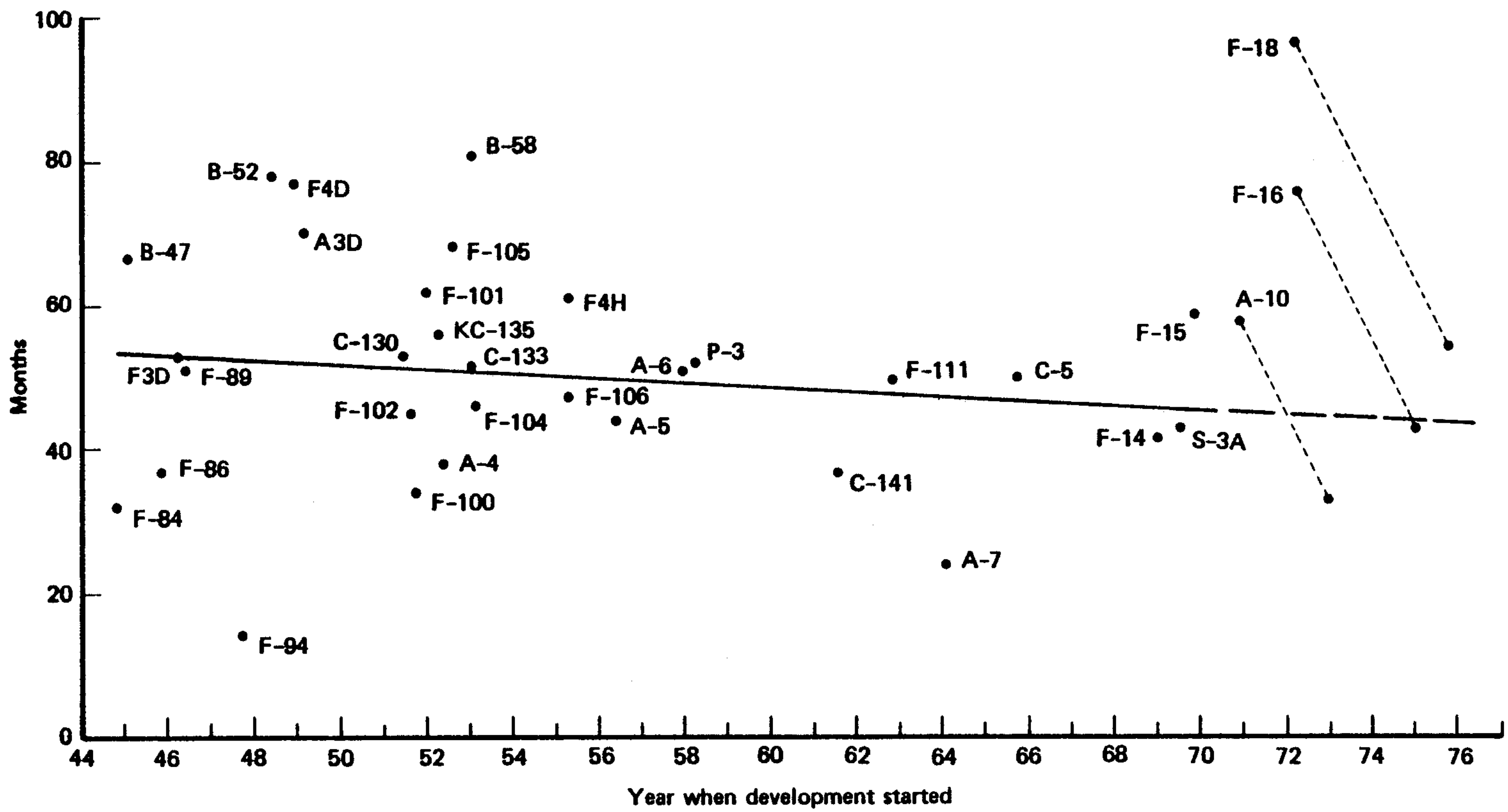


Fig. 16—Time from development start to first production delivery

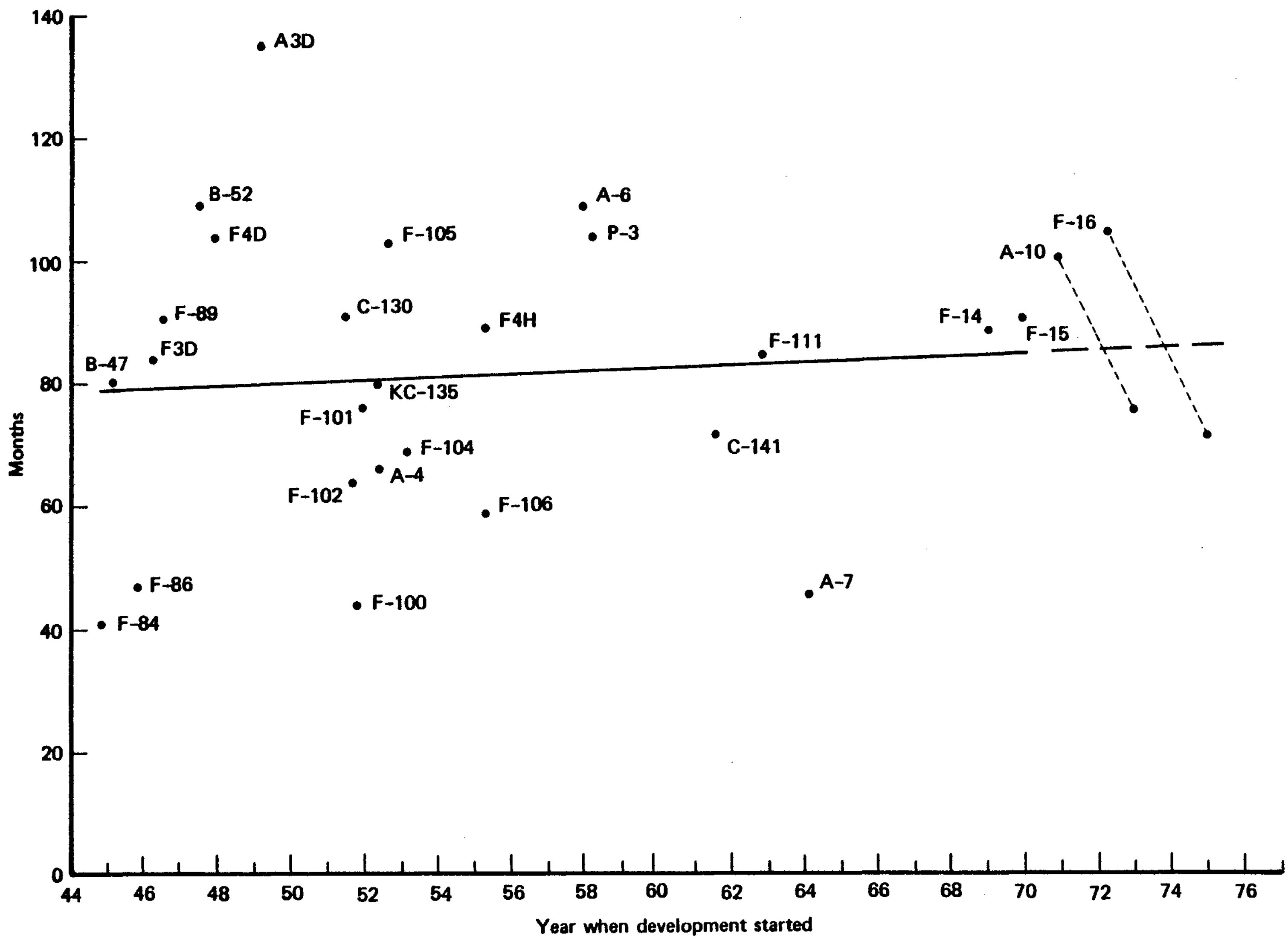


Fig. 17—Time from development start to 200th delivery

from the start of development to first production delivery), except that the trend line shows a decrease of about 20 percent over the 30 year period. As before, the three recent prototype programs were excluded in the derivation of the trend line. And again, the data points for these three programs fall in the vicinity of the trend line if time begins to run only at the start of formal full-scale development, but they lie well above the trend line if time begins to run at the beginning of the prototype phase.

The sample in Table 15 consists mostly of small aircraft (fighter and attack models). Examination reveals that some of the larger aircraft took an exceptionally long time to bring to production status in the earlier years. When these early, large aircraft are excluded and a more homogeneous sample (limited to fighters and attack aircraft) is examined, a somewhat different picture emerges, without the implication of a long term decrease in total development times. The time from start of development to first production delivery is shown in Table 16 for fighters and attack aircraft only. The models are clustered in 5-year groups depending on the date of first acceptance, and the average number of months to first delivery is shown for each group. The total development time increased markedly through the 1940s and 1950s, but since the 1950s the averages have been relatively stable except for the prototype programs in the late 1970s, the latter being characterized by either long or short times to first delivery, depending on the choice of development start date.

TOTAL ACQUISITION INTERVAL OR "FIELDING TIME"

Probably a more meaningful measure of acquisition interval or fielding time is the time required to develop the aircraft and equip the force with an operationally significant number of vehicles. We selected a quantity of 200 aircraft as significant. The fielding times for the aircraft models having 200 actual (or scheduled) deliveries are plotted in Fig. 17; the F-18 is omitted because no date has been scheduled for delivery of the 200th item.

Again a least-squares linear regression line was calculated, omitting the dual data points for the A-10 and F-16. The resulting trend line (see Fig. 17) shows a modest increase in fielding times of about 10 percent from the mid-1940s to the early 1970s, or an average linear rate of increase of about one-third of one percent per year. The dual data points for the A-10 and F-16 straddle the trend line, with the data points being above the line if fielding times are calculated from the beginning of the prototype phase and below the line if fielding times are calculated from the start of formal full-scale development.

DIMINISHING PRODUCTION RATES AND NEAR-LEVEL PROGRAM PROCUREMENT FUNDING

The time required for the production phase alone (production of the first 200 items) is shown in Fig. 18. An increase in the time to produce 200 units—that is, a decrease in average production rate—is clearly shown by the least squares

Table 16

TIME TO FIRST PRODUCTION DELIVERY:
FIGHTERS AND ATTACK AIRCRAFT ONLY

Year of First Delivery	Months to First Delivery	Average Months to First Delivery
1945-1949		
F-84	32	
F-86	37	28
F-94	14	
1950-1954		
F-89	51	
F-100	34	46
F3D	52	
1955-1959		
F4D	77	
F-101	62	
F-102	45	
F-104	46	58
F-105	68	
F-106	47	
A-4	38	
A3D	70	
1960-1964		
F4H	61	
A-5	44	52
A-6	51	
1965-1969		
F-111	50	37
A-7	24	
1970-1974		
F-14	42	51
F-15	59	
1975-1979		
F-16	76[a]	67[a]
A-10	58[a]	
F-16	43[b]	38[b]
A-10	33[b]	

[a]Measured from the beginning of the prototype phase.

[b]Measured from the beginning of formal full-scale development at Milestone II.

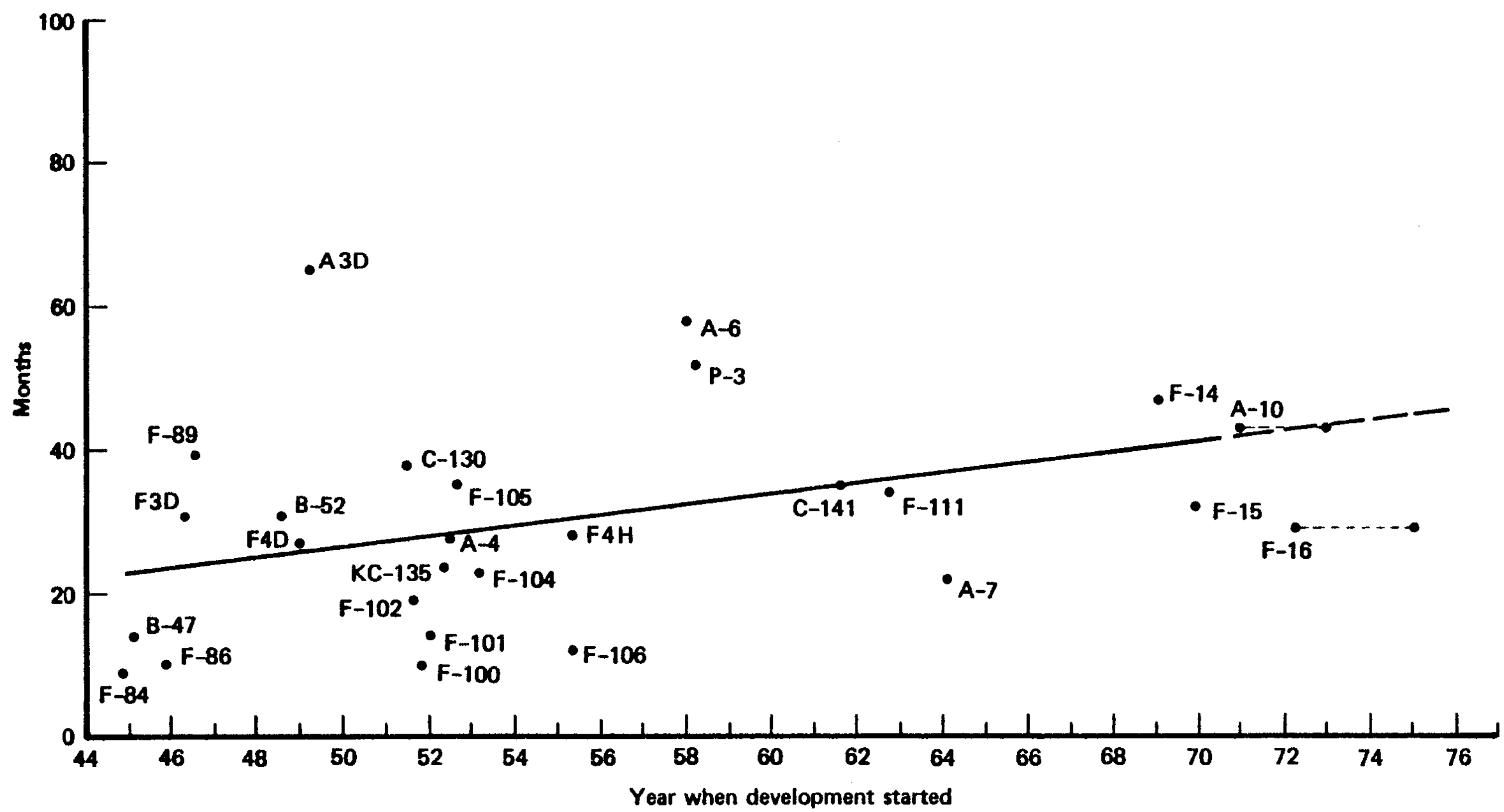


Fig. 18—Production time for first 200 units

linear trend line.[4] From the 1940s to the 1970s, the production time for the first 200 units of an aircraft about doubled, with an average linear rate of increase of about 4 percent per year. The data points for the A-10 lie close to the trend line, but those for the F-16 lie well below it. The F-16's higher production rate may reflect the multinational nature of F-16 procurement.

One explanation for the decrease in production rates is the typically higher unit costs of the more modern aircraft. To explore the relation between production budgets and production rates, the average unit cost of each aircraft in the sample was estimated, the actual monthly production rate for each model was determined, and the corresponding monthly investment rate (expressed in 1975 constant-year dollars) was determined for each aircraft model.[5] These investment rates are plotted in Fig. 19. The least-squares linear regression line for the whole period (omitting the A-10 and F-16) shows an almost flat trend, but the data points are quite scattered, especially in the first 5 years of the period. When the first 5 years are eliminated from the calculation (thus removing the extreme outliers among the data points), the resulting (dot-dash) trend line has an upward but very shallow slope, with an increase in the constant-dollar investment rate of less than 1 percent per year for successive aircraft models.[6]

As is well known, the constant dollar unit price of successive aircraft has generally risen much more rapidly than this. It seems plausible, therefore, that the production rates indicated in Fig. 18 are due largely to a combination of steadily increasing constant dollar unit prices and annual program production funds that (again in constant dollars) have risen only slightly over the years for successive aircraft programs.

SUMMARY

Chronological data for the "front end" of the acquisition process (events before the decision to begin full-scale development) are neither uniformly recorded nor readily accessible. The present study therefore examined acquisition intervals beginning with DSARC II as the baseline. With this baseline, the data for aircraft programs over the last three decades support the view that there has been an increase in the acquisition intervals (fielding times) for new systems.

The trend lines differ for different phases of the acquisition process. The time taken to move from the start of FSD to first flight has changed little over the last 30 years, perhaps increasing very slightly. But total development time (measured from the start of FSD to the delivery of the first production item) appears to have remained about the same (for the fighters in the sample), or even to have decreased

[4]In calculating the trend line, the data points for the A-10 and F-16 were again excluded; the data points for the F-18 were not shown in Fig. 18 because the delivery of the 200th unit had not been scheduled.

[5]These data all refer to the first 200 units.

[6]Note that the "investment rate" referred to here is the average monthly rate of expenditure for the first 200 production units *for each aircraft that was procured;* it does not refer to the aggregate amount spent monthly for all aircraft being procured at that time by the Department of Defense. The two trend lines shown in Fig. 19 were calculated from data that included A-10 and F-16 production experience. This was done because in this case the least-squares regressions were quite insensitive to the choice of development start date for these two aircraft. The trend lines shown were calculated for the Milestone II develoment start dates for these two aircraft.

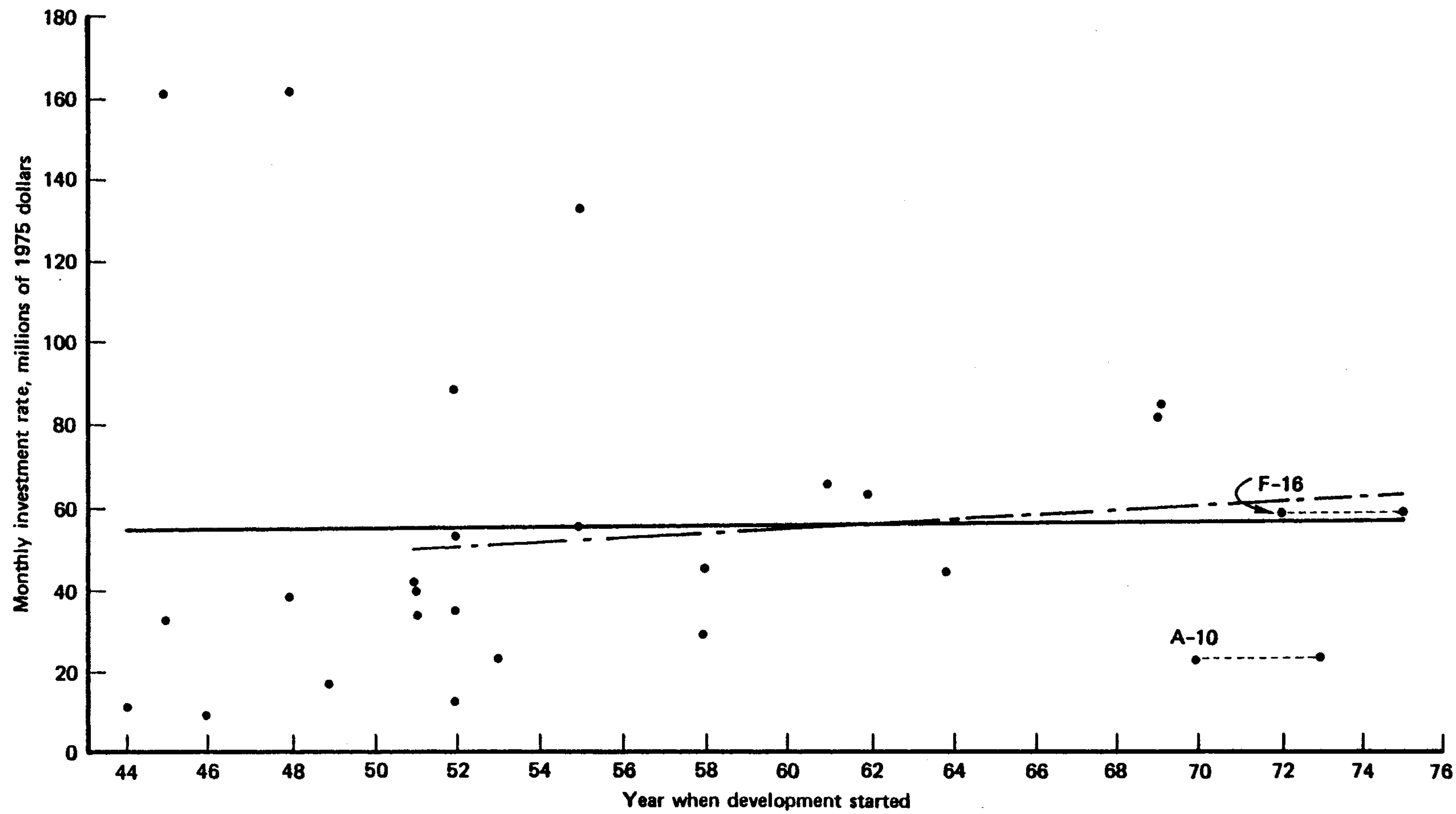


Fig. 19—Monthly procurement investment rate, aircraft systems, 1944-1975

somewhat (for the larger sample including bombers and transport aircraft). This result appears roughly consistent with the conclusions of the Defense Science Board mentioned earlier.

On the other hand, the production phase is taking much longer than it used to, as measured by the time between the delivery of the first and the 200th unit; this interval about doubled in the course of 30 years. Again, this result is consistent with the findings of the DSB. The cause of the lowered production rate is apparently fiscal rather than technical: higher production rates are generally quite feasible in terms of manufacturing capabilities,[7] but program funding rates for production have failed to keep pace with increasing unit costs.

Even with the marked increase in production times, the net effect of the different trends in the successive phases of the acquisition process has been only a modest increase in total fielding times. The interval between the start of FSD and the delivery of the 200th production item has increased by less than 10 percent over the 30 year period—an average linear rate of increase of only a fraction of one percent per year. This does not, as explained earlier, take into account any lengthening that may be occurring in the pre-Milestone II phases of the acquisition process.

The results just summarized refer to a sample that excludes three recent aircraft programs each characterized by a distinct prototype phase preceding Milestone II—the A-10, the F-16, and the F-18. These aircraft were excluded from the trend analysis because of ambiguity concerning the proper baseline for the beginning of FSD. Should Milestone II be the baseline date, or is it more realistic in these three programs to consider development as beginning earlier with the initiation of the prototype phase? In Figs. 15 through 19 both dates are shown for the three aircraft.

The result is that the data points for these aircraft generally straddle the trend lines. If the baseline is dated from the initiation of the prototype phase, the data points lie above the trend lines and thus suggest a continuing (or possibly accelerating) increase in total fielding times (see Fig. 17). On the other hand, if Milestone II is regarded as the correct baseline, the data points for these aircraft generally fall below the trend lines and thus suggest either a reversal of the trend toward longer total fielding times, or some reduction in the historical rate of increase.

---

[7]Not only are higher production rates generally feasible, they might well lead to reduced unit production costs.

VI. OTHER OBSERVATIONS

PROGRAM INSTABILITY: THE EFFECT OF FUNDING AND SCHEDULING CHANGES

The DoD- and Service-wide policy documents set forth an extensive set of guidelines, constraints, and procedures that shape and control the acquisition process. In all of these, cost control is a major concern. But, with an exception noted later, it appears that these policy statements say little or nothing about one important aspect of cost control, that is, the effect of frequent changes in a program's budget and schedule.

Major acquisition programs are complex endeavors, spanning many years and requiring the integration of numerous activities and organizations, including, of course, development and production contractors. A master schedule must be prepared to coordinate these many elements and provide for their material support over time. Assuming that the original schedule was reasonably well designed for the particular program, and that work has started and commitments have been made (staff assembled, material ordered, facilities allocated), then any significant change in that schedule will almost certainly introduce inefficiencies and increase program cost.

Some schedule changes can originate within the program, as when unexpected technical problems arise, accidents occur, etc. Experience has shown that such problems almost inevitably do arise within the program, and prudent managers add some slack in the schedule to accommodate them.

Other changes in program schedule are imposed from outside, usually in the form of a near term budget reduction below the level planned. To accommodate this program budget reduction, schedule changes are usually required so as to reduce near term spending; the result is schedule stretchout, with some activities postponed to later years. Almost inevitably this leads to some degree of disruption in program activities: a loss of efficiency with higher unit costs and lengthened fielding times.

This phenomenon has of course been widely recognized. It is given prominence in the present study because of the frequent comments made by the program managers and their staffs during the interviews we conducted. When they were asked to identify the most serious problems they had observed in the acquisition process, one of the problems most frequently mentioned was the numerous schedule stretchouts imposed for budget reasons, and the even more frequent "budget exercises" required of program management to explore the consequences of suggested or "threatened" budget changes. In some programs these exercises have occurred several times in a year, and have involved heavy commitments of time from senior program personnel, diverting effort from other management activities. In our interviews, the problem was sometimes described by program personnel as "program turbulence" or "budget whiplash,"

To understand the nature of this problem, we reviewed the schedule and budget histories of several Air Force acquisition programs.[1] A sample of the results is shown in Fig. 20. Here we show 4 successive schedules, at 2-year intervals, for the production phase of the F-15. Figure 20a shows the production schedule as envisioned in 1973, the year production started. Tooling was purchased to support this rate. By 1975 (Fig. 20b) it had been decided to hold production at 9 aircraft per month for several years before eventually (and briefly) achieving the original goal of 12 per month. By 1977 (Fig. 20c) the higher rate had been abandoned, and a rate of 9 or 10 per month was scheduled to extend over a period of 5 years. However, by 1979 (Fig. 20d) another stretchout had been imposed, with the rate scheduled to drop to 5 per month. It is not possible here to give the detailed budget history associated with these changes but it may be noted that the budget projections for the F-15 during this period changed substantially from year to year.

To illustrate what can happen, Fig. 21 displays the projections made in earlier years for a single budget year in each of two Air Force programs; one (Fig. 21a) with the reference year near the middle of the *production* phase, and the other (Fig. 21b) with the reference year near the middle of the *development* phase. In these examples, the actual budget for the reference year is quite poorly approximated by the projections for that year in the programming documents prepared several years earlier.

We did not perform the comprehensive survey necessary to establish that the data shown in Figs. 20 and 21 are typical of the scheduling and budgeting problems faced by program managers. However, our review of the data (together with the comments of the program staff interviewed) strongly suggests that these figures do illustrate a common occurrence: turbulence or instability in program schedules, often resulting from program changes in annual program budgets as a consequence of decisions external to the program.

This leads to two questions: is this effect important, and can anything be done about it?

We suspect that funding-induced schedule instability is indeed an important contributor to cost growth, but we could not rigorously test this hypothesis using the available data. It will be recalled from Section III that, for the 31 programs in the full cost analysis sample, the SARs attributed about 40 percent of total cost growth (about $5 billion) to schedule changes. But this is an aggregate figure for schedule changes due to all causes, not just the changes arising from budget instability.

One would expect most of the cost growth to have occurred in the more mature programs, and we therefore examined separately the 17 programs that were at least 3 years beyond DSARC II. Of these, 12 exhibited both positive cost growth attributed directly to schedule change, *and* net positive cost growth taking into account all cost variance elements.[2] For this smaller sample of 12, the cost growth attributed to schedule changes amounted to about $4.6 billion. This is 44 percent of the total cost growth for this sample, and, on the average, more than $0.3 billion per program.

---

[1]The necessary programming documents for the Air Force programs were already available at Rand. Time did not permit a similar historical search of Army and Navy programming documents, but there is no reason to believe the experience of those Services is much different from that of the Air Force.

[2]The effects of inflation and changes in production quantity being eliminated, as before.

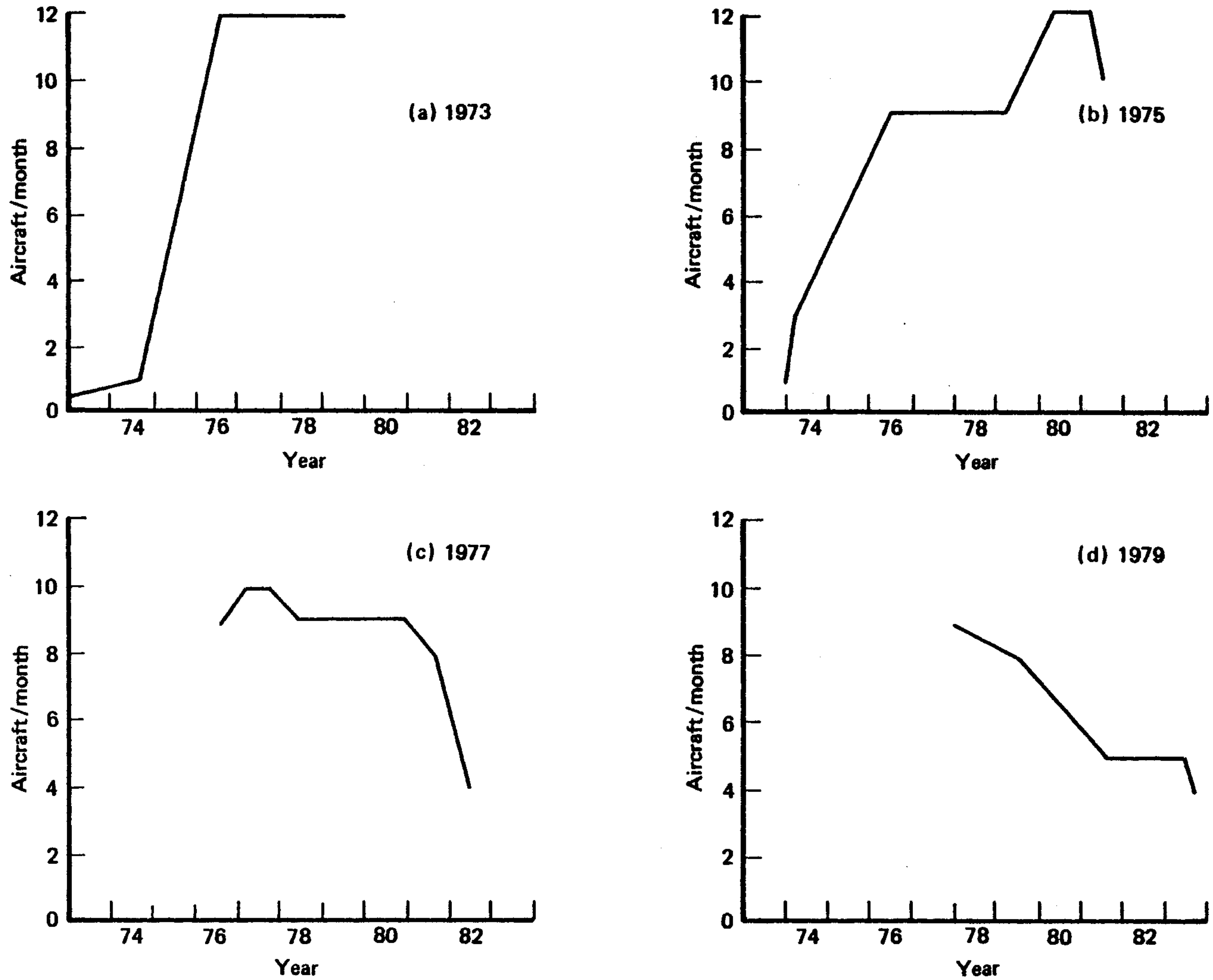


Fig. 20—F-15 programmed production rates, various program years

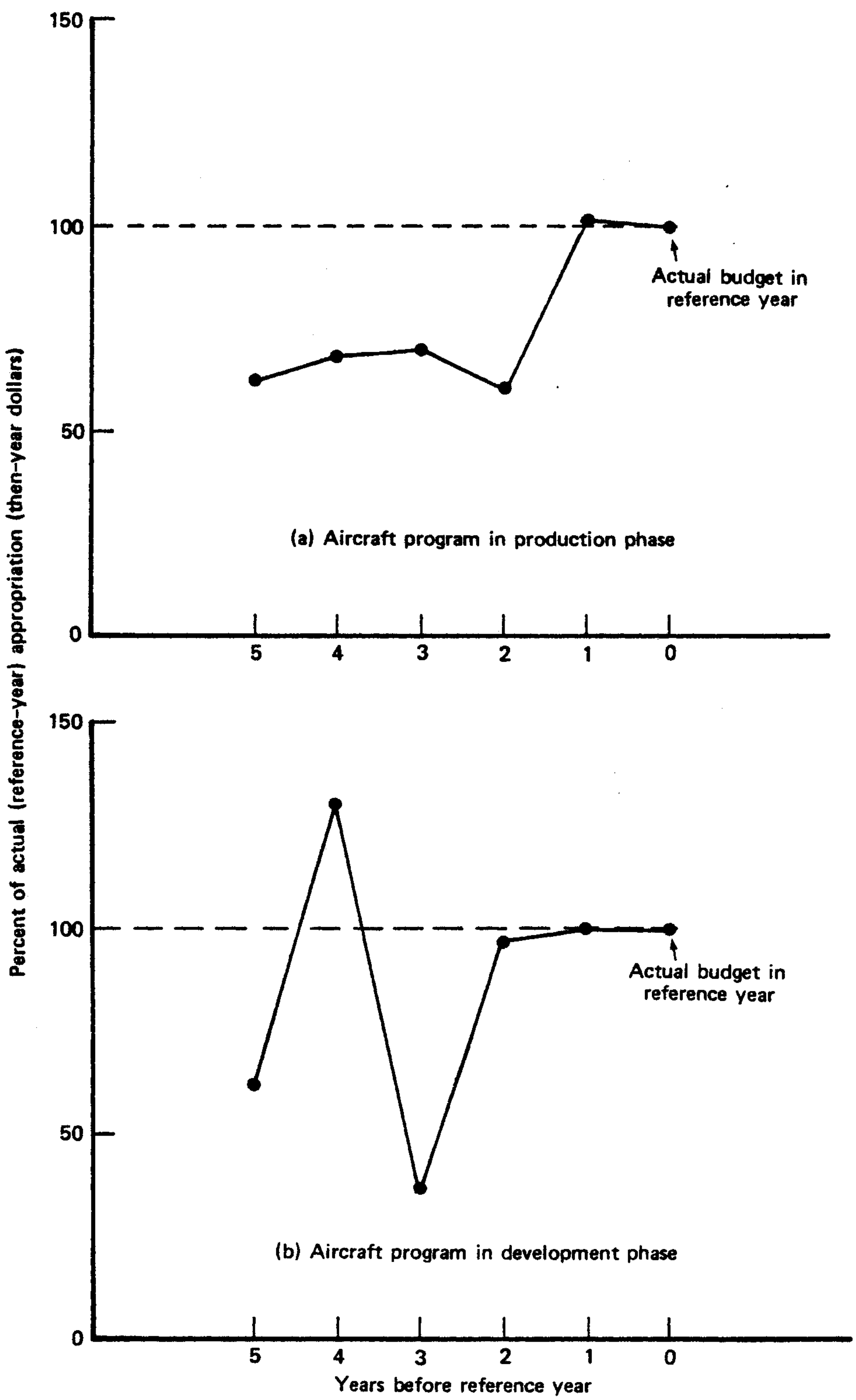


Fig. 21—Changes in budget projections over time, two illustrative aircraft programs

Clearly, if any substantial fraction of the cost growth due to schedule changes could be saved, it would be well worthwhile. As noted earlier, however, schedule changes are due to a number of different causes, and the available data do not permit a distinction between those due to events within the program and those imposed from outside. Our impression is that the major share of schedule changes are responses to budget constraints.

The question of the feasibility of achieving greater program stability is even more difficult to answer. The extent to which funding and schedule profiles can be maintained after a program gets under way clearly depends in part on the realism of the original projections. If the projected budget was inadequate for the task outlined, then subsequent adjustments will be required. In that case, the pressure from competing projects usually causes the adjustment to be in the form of a stretchout rather than a near term increase in funding. That stretchout in turn often causes an increase in total program cost, even though it does accommodate the budget constraint in the near term. The cure for this set of problems is therefore to be found, at least in part, in avoiding cost underestimates and matching the cost estimates by adequate funding in real terms—that is, funding increased as necessary to counter the effects of inflation. Obviously, this prescription may be difficult to achieve, and other approaches may be worthwhile, including greater use of multi-year funding.

Nowhere (to our knowledge) is there recognition of this set of problems in DoD-level policy, and OSD provides no policy guidance on the desirability or means of avoiding frequent budget and schedule changes. Such changes seem to be tacitly accepted as unavoidable facts of life. We note, however, that some of the Services at least acknowledge these problems in their policy documents, and the Army's statements have been particularly clear and specific:

> Within the RDT&E appropriation, the Army must fully fund its top priority projects so that development time is not lengthened for reasons of meager or marginal funding. This requires that lower priority demands on RDT&E funds must be regarded as potential trade-offs for full funding support of the Army's designated high priority system.[3]

The latest version of Army Regulation AR 1000-1 puts it somewhat differently:

> Program stability is one key to a successful program. All [Army] agencies associated with a program, but particularly the project manager, must resist attempts to change a program which is achieving established goals. Fluctuation in production quantities and changes in performance requirements reflect upon the Army's ability to manage major programs; such changes, when required, must be fully justified. . . . Once approved, major programs should be fully funded. If necessary, lesser programs will not be started or will be terminated to make this possible.[4]

We believe that, at the minimum, formal DoD acquisition policy should clearly acknowledge program instability as a serious problem, and should advise acquisi-

[3]Department of the Army, *Basic Policies for Systems Acquisition by the Department of the Army*, Army Regulation AR 1000-1, November 1974 (superseded by AR 1000-1 of April 1978).

[4]Department of the Army, *Basic Policies for Systems Acquisition*, Army Regulation AR 1000-1, April 1978, pp. 2-4 and 3-3.

tion management at all levels to reduce cost growth and delays in fielding times due to budget-caused stretchouts. The following language (or something along the same lines) is suggested for inclusion in DoD acquisition policy:

> The affordability of each major system shall be considered at each milestone to assure early identification of unaffordable systems and to facilitate an adequate and stable funding rate for the surviving programs. To accomplish this, acquisition and budget decisions will be coordinated.
>
> At each decision point, the cost objectives will be compared with the funding projected in the DoD Planning, Programming, and Budgeting System and inconsistencies will be highlighted for consideration by the DSARC. Milestone decisions shall be reflected in the Five Year Defense Program and in the next submission of the Program Objective Memorandum by the DoD Component. Consideration of affordability is particularly important at Milestone II, because this is the first decision point at which reasonably good cost and schedule estimates are available, and because the decision to enter full-scale development implies a major commitment of resources.
>
> After approval of an acqusition plan, and especially after initiation of full-scale development, any significant changes imposed on the plan, such as additions to the proposed system capability, or modifications in milestones or funding schedules, can cause major cost increases and schedule delays. To improve the efficiency of the acquisition process, such changes should be strictly limited, unless dictated by technical difficulties, unacceptable test results, or changes in the need for the system. In particular, every effort should be made to provide the program manager with a predictable level of funding for at least the current and the two succeeding fiscal years.

Further research is clearly required to establish the degree to which cost growth and schedule slippage are mutually reinforcing effects of funding instability. If it can be clearly demonstrated that such instability is one of the major causes, as we suspect, of both cost growth and schedule slippage, then instability may no longer be accepted as a fact of life, and appropriate means may be found, in cooperation with the Congress, for dealing with it.

There are some indications that funding instability has increased over time, with greater instability in the 1970s than in the 1960s or 1950s.[5] If this is so, the result may have been to nullify or reduce the improvements that would otherwise have followed the Packard innovations at the beginning of the 1970s. Further study to establish the time trends in schedule and budget instability is recommended, together with an effort to identify the causes of instability. For example, when is budget instability due directly to Congressional decisions relating to the particular program, and when is it due to actions taken at DoD or Service level to fit the demands of many programs into the overall acquisition budget?

---

[5]If budget-produced schedule slippages occur mainly in the production phase, such slippages may be more common in the 1970s than in the 1960s, even though the aggregate result-to-goal ratio for *all* scheduled events is somewhat smaller for the 1970s sample (see Sec. III, footnote 2).

DATA TRACKING AND LEARNING FROM EXPERIENCE

A major function of acquisition policy is to preserve the lessons learned from previous experience so that they can be applied to future programs. This is especially important in such agencies as the Department of Defense because defense programs are of long duration and the senior appointive officials typically spend a fairly short time in office (perhaps only two or three years). Seldom has a senior official sufficient tenure that he can draw on personal knowledge encompassing the full cycle of a program, from the statement of system requirements through development to production, operational use, and modification. Officials may have experience on many programs, but typically this experience extends over only a fraction of any one program. In these circumstances policymaking requires a good data-tracking system.

In the present study as in others, our examination of the form and content of the data available supports the observation that the present process for collecting, preserving, and retrieving program information is inadequate. It is true that, compared with a decade ago, more and better data are available: the Selected Acquisition Reports represent the most notable improvement. However, those reports are now configured to serve a specialized function: reporting to the Congress certain data on individual weapon systems. The SARs are not fully adequate to support the kind of policy-oriented analysis attempted in this study or to provide the means for OSD to monitor the effects of policy changes over time and across programs.

The cumulative effect of such data limitations is that much less than full benefit is derived from current program experience. We believe that a systematic attempt to improve acquisition policy should be supported by an equally systematic attempt to improve the quality and extent of program data, and that the design and implementation of an improved data collection system should be closely integrated with a continuing process of data analysis. The establishment of an "acquisition experience" or "program experience" activity may be required, because the kinds of data and analysis needed for learning from program experience extend beyond what is needed for the management of a particular program. Specifically, we recommend that in addition to data now provided by the SARs, an acquisition experience data base should include the following kinds of information:

- More information should be systematically recorded on the reasons for program decisions so that it would be possible to develop a meaningful set of historical cause and effect relationships. Currently available information focuses on *what* and *when*, but tends to ignore *why*. Even the ability to distinguish between internal and external factors in program decisions is rather tenuous. For example, if a schedule slip occurs it should be possible to learn the cause: Was it because the budget was changed, or because unexpected technical difficulties occurred, or because the perceived urgency of need changed, or what?
- Better information is needed on the dates of major milestones and decision points. Most program events are now fairly easy to track after the beginning of full scale development (DSARC II), but the record is quite spotty before that point and again late in the production phase. The whole of the

requirements process is difficult to track, although the MENS may help; and the contractor "source selection" process is something of a mystery, although this may be hard to avoid.

- The degree to which development really continues into or overlaps the production phase is difficult to determine, partly because of the extensive use of procurement (not development) funds for modification and retrofitting, usually without detailed program-related cost breakdowns and without a systematic statement of rationale. Although programs are now being structured so that development money is spent early in the program to obtain improved downstream operational reliability and maintainability, there is insufficient data feedback from the operational phase to enable one to judge whether this strategy is indeed proving to be cost effective.
- A record of the *initial* OSD-approved program goals in each program should be retained, together with a systematic documentation of any subsequent changes in the approved program. As noted above, the reasons for such changes should be recorded to the extent possible.
- The method of calculating cost variances due to changes in the planned buy size should be performed in the manner outlined in Appendix A. Cause-effect explanations for cost variances should be identified and recorded; a procedure is suggested in Appendix B of this report.

SUMMARY

No major acquisition program can be planned and managed with high efficiency in the face of frequent and unpredictable changes in program funding. Schedule slippage and cost growth are the closely related and mutually reinforcing effects of program funding instability. According to the SARs we examined, about 40 percent of program cost growth is attributable to schedule changes. Presumably a substantial share of these schedule changes occurred because of funding instability due to causes external to the programs. But the SAR information is not at present complete and detailed enough to enable us to distinguish confidently between internal, program-generated schedule changes and schedule changes responsive to externally generated alterations in program funding.

Externally generated funding instability appears to be a common experience even for major programs. At present, however, OSD policy provides little or no guidance as to the desirability or means of reducing program budget fluctuations and schedule changes. We therefore offer a draft policy statement for OSD consideration. For major programs that have passed Milestone II, the immediate objective would be to assure program managers of predictable funding for at least the current and the two succeeding fiscal years; the ultimate objective would be to increase acquisition efficiency in terms of lower costs and earlier fielding times.

Any systematic attempt to improve acquisition policy should be supported by an equally systematic attempt to improve the quality and extent of program data. An acquisition experience data base should be developed that would build on the SARs by adding additional information necessary to permit internally consistent comparisons among many programs and to reveal important cause-effect relationships.

Appendix A

BASIC METHODOLOGY FOR ASSESSING PROGRAM COST GROWTH

INTRODUCTION

Program cost data used throughout this study were drawn from Selected Acquisition Reports. The Office of the Assistant Secretary of Defense (Comptroller) (OASD(C)) also uses that source to develop measures of acquisition cost growth. However, some of the analytical methods used by OASD(C) differ from the methods we used, and this can lead to somewhat different results from what appear to be similar measures of cost growth. To avoid misinterpretation of our study results, in this appendix we explain our cost analysis methods and indicate how they differ from those used by OASD(C).

Program cost is the cost of the whole acquisition program, including the development and testing of the system, the production of system units (with their spares and peculiar support), and any directly related military construction. Program cost growth is the change in program cost over time. The more general terms "cost variance" and "cost change" are sometimes used in place of cost growth, because they are consistent with both increasing and decreasing costs. Here we understand cost growth to include both negative and positive changes. "Cost variance" is the term usually employed in the Selected Acquisition Reports.

We are interested in cost growth over the full lifetime of the acquisition program. Ideally, this involves a comparison between an initial cost estimate or cost projection[1] and the actual costs incurred in bringing the program to completion. In our study of 1970s programs, the initial or baseline program costs are the Development Estimates (DEs) prepared at the time of DSARC II; that is, at the program milestone between the validation phase and full-scale development. A program's DE is rarely changed, and for most programs it provides a fixed point from which to measure subsequent growth.[2] The costs used in the cost growth calculations are not, however, full term actuals, because no program in our 1970s sample has reached completion, although two have been cancelled.[3] Thus, the cost growth calculations presented here (and in most of the defense acquisition literature) are really comparisons between two estimates: an early estimate and an estimate made later in the program's evolution. For these later estimates we relied

[1]The term "cost-projection" is sometimes preferred as implying an estimate of a long time-stream of costs.

[2]For two programs—Harpoon and Condor—the DEs given in the recent SARs do not reflect the estimates used at the time of Milestone II. To be consistent with our study objective we adopted baseline cost estimates for these two programs derived from the Current Estimates (CEs) reported in the SARs at DSARC II. This is explained in Appendix C.

[3]The two cancelled programs are the B-1 bomber and the Condor missile. For these the costs are estimates as of the time these programs were cancelled. We understand that further cost growth was expected in these programs if they were not terminated.

on the Current Estimates (CEs) that are updated quarterly in the SARs. The CEs used in our cost growth calculations are those given in the March 1978 SARs.

To summarize: The program cost growth considered here is the difference between the CE and the DE, the CE being the more recent (and usually the larger) estimate. The period over which program cost growth is measured is the time between the date of the DE (approximately the date of DSARC II), and the March 1978 SAR. When the cost growth of several different programs is compared or aggregated, it is common to express cost growth not in dollar terms, but in terms of a percentage increase, or the ratio CE/DE, which we refer to here as the "cost-growth ratio."

ADJUSTING FOR CHANGES IN PRODUCTION QUANTITY: TWO ALTERNATIVE METHODS

As already explained in the text, we express both CE and DE in terms of constant FY 1979 dollars, to eliminate the effect of inflation on the program dollar totals. We also express program costs in terms of the original (DE) production quantity contemplated at Milestone II. Reference to some baseline production quantity is needed to negate the effect of any change in production quantity ("quantity change" or "quantity variance") that may occur. Such changes are common, and sometimes occur more than once in the course of a program's lifetime. Program cost is highly sensitive to the number of items produced, and without such a baseline it would be misleading to compare the CE/DE cost-growth ratios of several different programs if some programs held production quantities constant and others did not.

When the CE production quantity is different from the DE production quantity there is more than one way to adjust program cost to eliminate the cost effect of this change in quantity. One method is to use the *DE production quantity* as the baseline, as we have done. In this case, the CE, which is reported in the SAR in terms of the currently approved quantity, is "adjusted" or normalized on the basis of the DE quantity. Thus, if the production quantity has been reduced since DSARC II (a common occurrence), an addition to the CE is required to bring the program cost back up to what it would be if the originally programmed quantity were to be procured; if the production quantity has been increased, a reduction of the CE is required. This is accomplished simply by deleting the cost change attributed in the program's SAR to quantity variance.

Another method is to use the *currently approved (CE) quantity* as the baseline. When this is different from the quantity for which the DE was calculated, then the DE must be recalculated for the new quantity. For example, if the new quantity is less than the DE quantity, a reduction in the DE is necessary, equal to the quantity cost variance reported in the SAR. In this approach the denominator of the cost-growth ratio changes with each change in planned production. This is the method adopted by the Office of the Assistant Secretary of Defense (Comptroller) (OASD(C)).[4]

If quantity-induced cost changes were the only cost changes that occurred, it

[4]See the periodic report published by the Office of the Assistant Secretary of Defense (Comptroller), *SAR Program Acquisition Cost Summary.*

obviously would make no difference which of these two methods was followed. Whether we delete the variance from the CE or add it to the DE, the cost growth, after adjustment to either baseline quantity, would be zero (the cost-growth ratio would be unity). But quantity-induced cost variance is only one of the many types of cost variance encountered in acquisition programs and reported in the SARs. (For a description of the cost variance categories, see Section III of the text and Appendix B, below.) When other types of variance are involved, the baseline quantity has a direct bearing on the size of the computed cost-growth ratio. Moreover, when program cost variance includes both a change in quantity and a change in the cost per unit, the order in which the quantity variance is calculated (that is, whether before or after the cost-per-unit change is taken into account) can affect the share of total variance attributed to the change in quantity and hence to the size of the quantity adjustment. The result is that the cost-growth ratio normalized to exclude the effects of quantity changes can differ depending on the way the magnitude of quantity variance is estimated and on the way its effect on cost growth is eliminated. These considerations will be demonstrated below to indicate why the cost growth estimates calculated by OASD(C) for some programs differ from those shown in this study. Our approach was dictated, of course, by the basic ground rule of the study—to measure changes from the DSARC II benchmark.

Although the SARs designate many categories of cost variance, from a computational point of view these fall into four basic types of changes: (1) quantity, (2) recurring cost-per-unit, (3) cost-quantity curve slope, and (4) nonrecurring. These are illustrated in Fig. A.1, where total cost is measured vertically and quantity is shown on the horizontal axis. Because the logarithmic scale gives a good visual representation of percentage differences (the greater the vertical distance from the baseline the greater the proportional change) and also because cost-quantity curves are conventionally represented by straight lines in a log-log grid[5] we chose logarithmic scales for both axes in Figs. A.1 through A.4.

The DE and CE cost-quantity curves reveal their total costs at each indicated quantity. The quantity designated "Q_d" is a reference point representing a hypothetical baseline output of 40, programmed at the time of DSARC II. The total DE baseline cost, C_d, is measured at the point of intersection of Q_d and the baseline DE cost-quantity curve. The CE total cost shown on each graph, C_c, indicates the effect on cost growth of the specified amount and type of variance. These are measured at the DE quantity—except, of course, for the variance caused by a change in quantity.

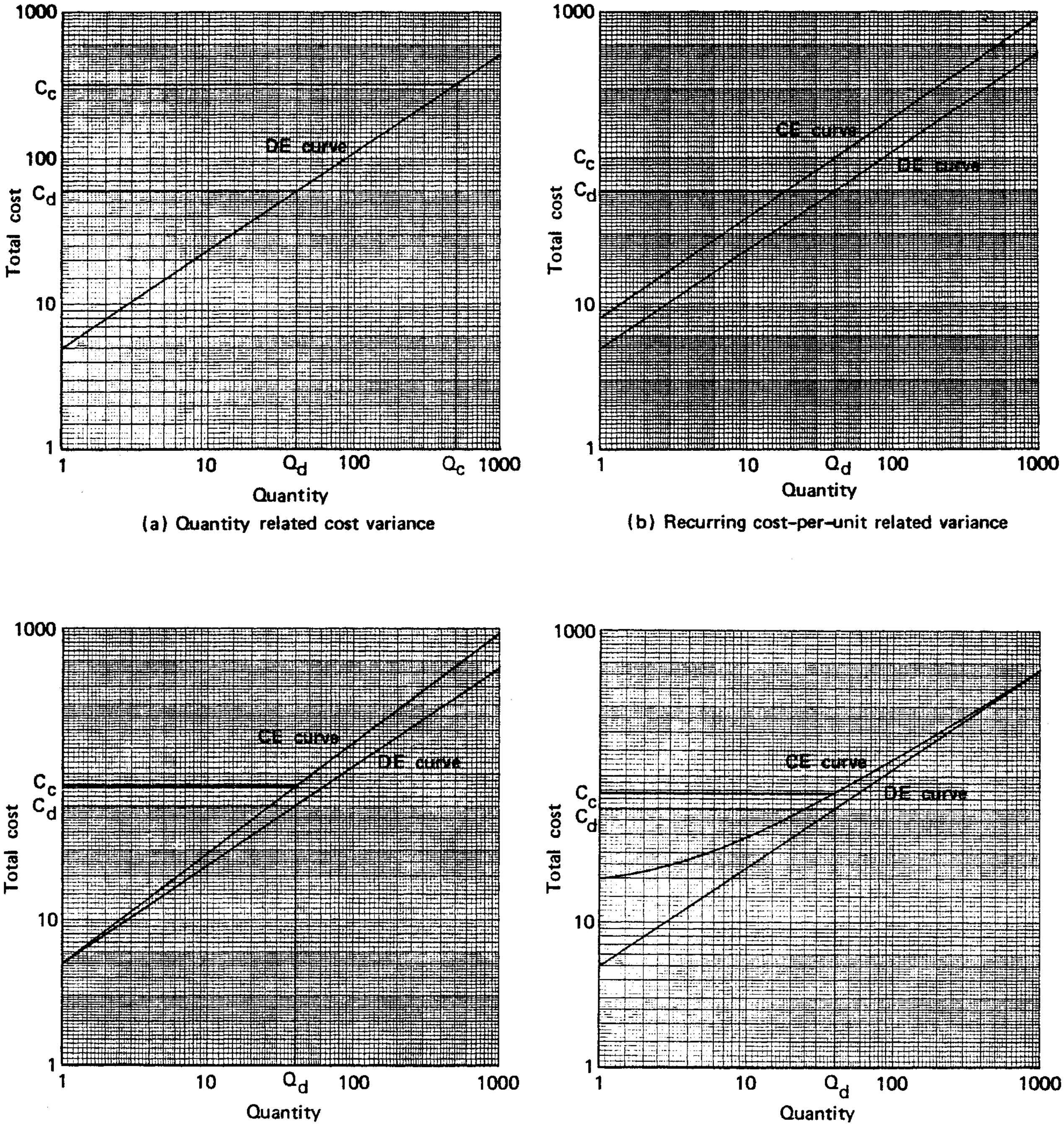
[5]A log-linear cumulative average cost-quantity curve implies that the average recurring cost per unit will decline at a constant rate with each doubling of the quantity, i.e., assuming a production cost-quantity curve with an 80 percent slope and a Unit 1 cost of 5 cost units (as in our examples), the average cost of Units 1 and 2 will be 4, Units 1 through 4 will average 3.2, etc. The equation for deriving a cumulative average recurring cost (c) is

$$c = U \cdot Q^{S}$$

where U = Recurring cost at Unit 1
Q = Quantity
S = Cost-quantity curve slope expression: log slope/log 2.

For convenience, the illustrations in Figs. A-1 through A-4 transform the average cost values into *total* costs at each indicated quantity, e.g., at Unit 1 the total cost is 5 cost units, at Unit 2 the total cost is 8, at Unit 4 the total is 12.8, etc. The equation for deriving total cost (C) is

$$C = U \cdot Q^{(S+1)}$$



(a) Quantity related cost variance

(b) Recurring cost-per-unit related variance

(c) Cost-quantity curve slope related variance

(d) Nonrecurring cost related variance

Fig. A.1—Four types of cost variance
(note use of log-log scale)

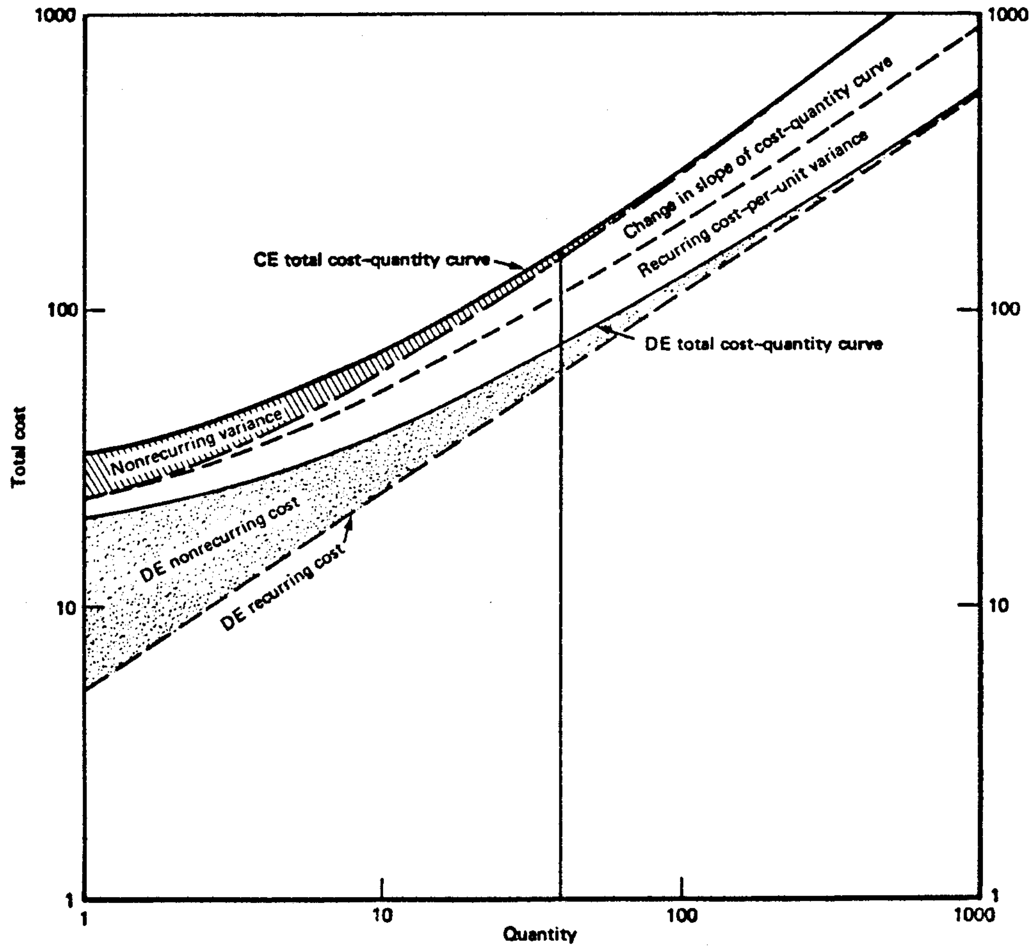


Fig. A.2—Components of cost growth
(note use of log-log grid)

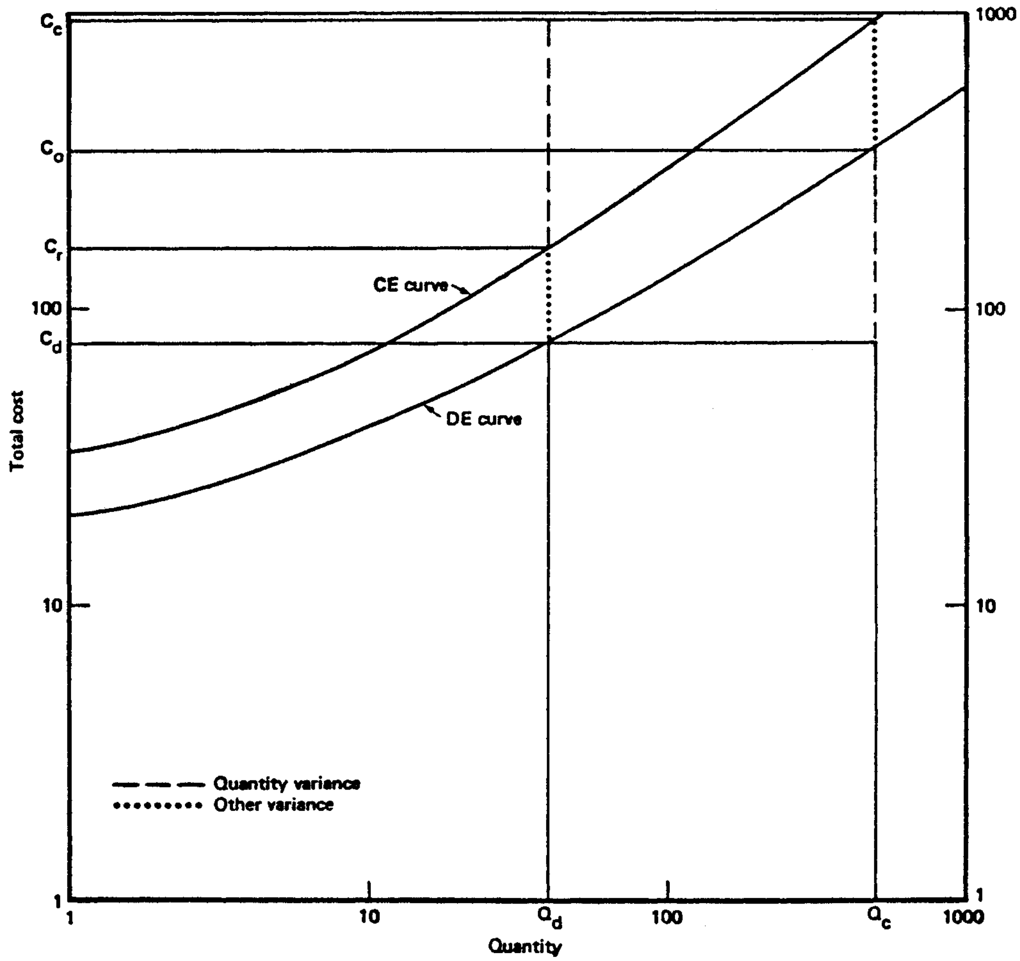


Fig. A.3—Cost growth in terms of DE or CE quantity
(note use of log-log grid)

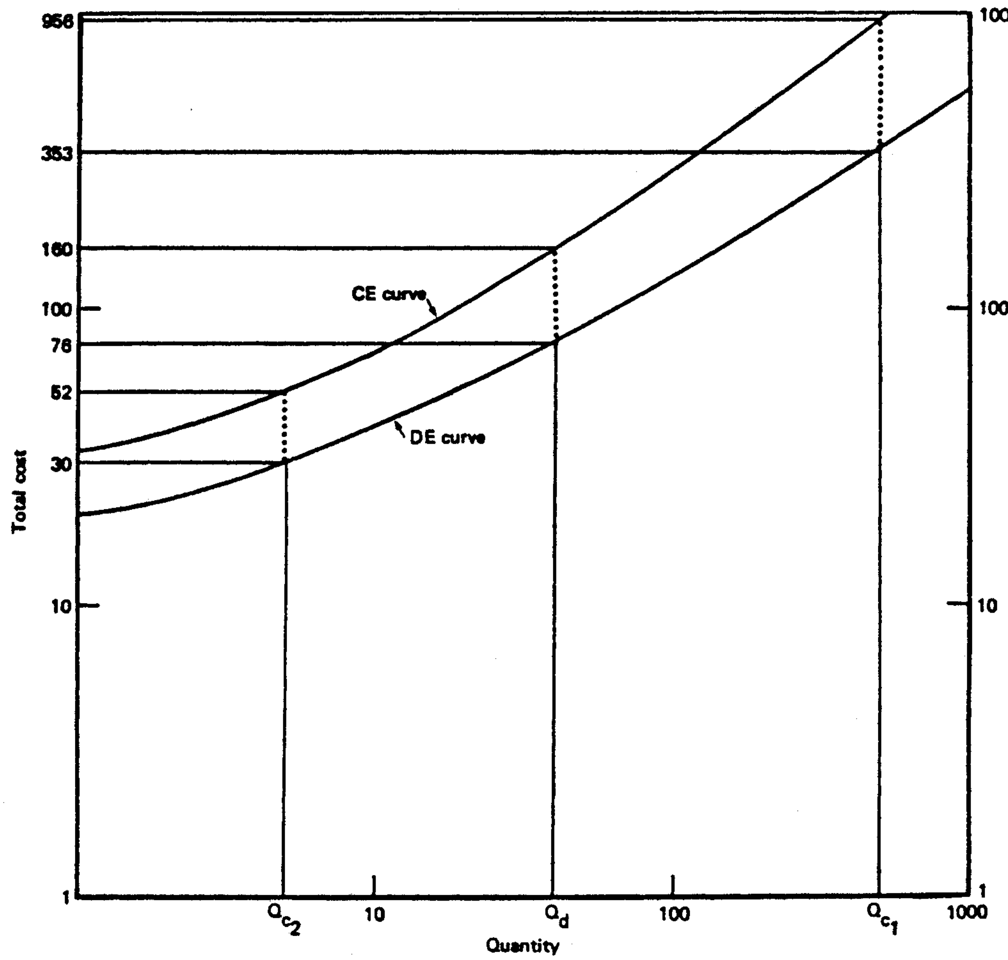


Fig. A.4—Effect of quantity on cost growth percentages (and ratios)
(note use of log-log grid)

Quantity-induced changes (Fig. A.1(a)) have already been discussed; they simply scale the program along the given cost-quantity curve to the new CE quantity, Q_c. Recurring cost-per-unit variance includes the kinds of engineering changes and corrections of estimating errors that shift the program to a new cost-quantity curve having the same slope as the DE curve but with a different initial recurring cost at Unit 1. An increase of 3 "cost units" at Unit 1 is illustrated in Fig. A.1(b). Figure A.1(c) illustrates variance that results from a change in the slope of the cost-quantity curve, in this case from 80 percent to 85 percent. This reflects a more pessimistic projection of the expected rate of cost reduction as production proceeds and results in the indicated increase in total costs. A slope change in the other direction would, of course, decrease total costs.

Nonrecurring cost variance, such as a change in development costs, is represented by a constant dollar increment (Fig. A.1(d)). In the example, the increment is 10 cost units. (The apparent decrease in the nonrecurring cost at higher levels of total cost results from the graph's logarithmic scale, which reflects the reduced *proportional* value of the fixed cost relative to the increased baseline; the absolute magnitude of the cost increment remains constant throughout.)

For simplicity we chose, in Fig. A.1, to illustrate the four types of variance, one at a time, as additions to a baseline DE curve that is represented as a straight line on the log-log grid. In effect, we limited the baseline to recurring costs which were assumed to exhibit the cost reduction characteristics of an 80 percent cost-quantity "learning" curve.

In Fig. A.2, the picture is more complete. Here we show the underlying structure of a complete DE baseline cost-quantity curve and a CE curve. The total DE cost-quantity curve includes both recurring and nonrecurring costs, and the total CE cost-quantity curve combines the DE baseline curve with additions of all four types of cost variance.[6] The cost and quantity numbers indicated in Fig. A.2 are hypothetical. In practice, it is not uncommon for an increase in one type of variance to be offset, at least partly, by a decrease in another. Fig. A.2 indicates how each component of the program cost responds to quantity changes.

Figure A.3 reproduces the total DE and CE cost-quantity curves from Fig. A.2. As noted earlier, the height of the DE cost-quantity curve at the baseline quantity, Q_d, establishes the total DE baseline cost, C_d. The CE total cost, C_c, results from the increase in quantity to Q_c plus a combination of the three types of variance shown in Fig. A.2 that cause the shift to the higher CE cost-quantity curve.

Figure A.3 illustrates our method and the method used by OASD(C) to eliminate the effect of such quantity changes from the cost growth assessment. As noted earlier, our method measures cost variance in terms of the DE cost projection established at DSARC II. Therefore, referring to Fig. A.3, we measure cost growth on the basis of the original quantity, Q_d. The cost variance due to the change in quantity is computed in terms of the known *current* unit cost, on the CE curve. Its share of the total cost growth is indicated in Fig. A.3 by the *dashed* vertical line ($C_c - C_r$) drawn at quantity Q_d. Following this approach, the program cost growth is converted to constant (DE) quantity terms by deleting the quantity cost variance

[6]Also, again to simplify the analysis, we assume a single cost-quantity curve for the equipment recurring costs of the example program. Actually, a complex program might have several curves, with different slopes, for its various major subsystems.

from the total cost growth. This leaves the remaining "adjusted" cost variance—indicated by the *dotted* vertical line ($C_r - C_d$) at quantity Q_d—in terms of the DE quantity, and this is the method we used in calculating cost growth.

The same figure illustrates the method used by OASD(C) in adjusting the DE to offset the effect of quantity change. In this latter method, cost growth is measured in terms of the currently programmed quantity. The quantity adjustment is made by adding to the DE cost a dollar amount equal to the quantity-induced cost variance. First the quantity cost variance is computed *in terms of the original DE cost-quantity curve.* Thus, referring to Fig. A.3, the share of the total cost growth attributed by OASD(C) to quantity cost variance is the amount ($C_o - C_d$), the dashed vertical line drawn at the new quantity, Q_c. Cost growth using the OASD(C) approach is then calculated on the basis of the adjusted DE cost at the new total quantity, i.e., the amount ($C_c - C_o$) shown in the figure as the dotted vertical line between the two cost-quantity curves at quantity Q_c.

The two dotted lines in Fig. A.3, representing cost growth adjusted for quantity change by the two methods, are clearly different in length. Thus, the DE and CE curves are not parallel, and, as the scale is logarithmic, it follows that the cost-growth *ratios* computed at these two different quantities are not the same.[7]

The example presented in Fig. A.4 demonstrates how the choice of baseline quantity can influence the value of the OASD(C) cost-growth ratio when it is adjusted to "offset" the quantity-induced cost variance. The DE and CE total cost curves are the same as before except that alternative CE quantities are included—

---

[7] The essence of the difference can be shown algebraically. The equation for total cost (C) assuming a log-linear cumulative total recurring cost-quantity curve is

$$C = U \cdot Q^{(S+1)}$$

where U = Recurring cost at Unit 1
Q = Quantity
S = Cost-quantity curve slope expression: log slope/log 2.

The nonrecurring costs, F, are then added in. If we subscript these to designate the DE, CE, and variance parameters—d, c, and v, respectively—the equation for the DE total cost (C_d) is

$$C_d = F_d + U_d \cdot Q_d^{(S_d+1)}$$

The equation for the CE (C_c) adds in the variance

$$C_c = (F_d + F_v) + (U_d + U_v) \cdot (Q_d + Q_v)^{[(S_d+S_v)+1]}$$

As c = d + v, the latter equation can be simplified, as follows

$$C_c = F_c + U_c \cdot Q_c^{(S_c+1)}$$

A comparison of the adjusted cost-growth *ratios* resulting from the two different methods and the cost and quantity numbers shown in Fig. A.3 will show that they are not equivalent. Our adjusted cost-growth ratio, R_r, is

$$R_r = \frac{F_c + U_c \cdot Q_d^{(S_c+1)}}{F_d + U_d \cdot Q_d^{(S_d+1)}}$$

whereas the OASD(C) ratio, R_o, is

$$R_o = \frac{F_c + U_c \cdot Q_c^{(S_c+1)}}{F_d + U_d \cdot Q_c^{(S_d+1)}}$$

The two ratios will differ if F_c is not equal to F_d, and S_c is not equal to S_d, because the numerator and denominator of the OASD(C) ratio will not vary proportionally as quantity Q_c increases or decreases from Q_d.

an increase over the DE baseline quantity to Q_{c1}, and a decrease to Q_{c2}. The DE baseline total cost at a quantity of 40 is 76 cost units. Including the quantity-induced cost variance, the Q_{c1} total cost at a quantity of 500 is 956 cost units. With a drastic cut in production leaving only 5 development articles, the total cost at Q_{c2} is 52 cost units.

If we apply the OASD(C) method for adjusting for the effect of a change in quantity, an increase from the DE quantity (Q_d) to the quantity Q_{c1} in Fig. A.4 would result in quantity-induced variance of 353 − 76 = 277 (measured on the basis of the original DE baseline cost-quantity curve). This amount added to the DE is 277 + 76 = 353 and the cost-growth ratio is 956/353 = 2.71. On the other hand, with the same nonrecurring cost variance and the same changes in curve slope and recurring cost-per-unit variance (that is, the same DE and CE cost-quantity curves), a decrease from the DE quantity to the quantity Q_{c2} in Fig. A.4 would result in quantity cost variance of 30 − 76 = −46 and an adjusted cost-growth ratio of 52/(76 − 46) = 52/30 = 1.73. Thus, when there are substantial changes in production quantity, the OASD(C) method of negating quantity cost variance can lead to large differences in the resulting adjusted cost-growth ratios. Or, to put it another way, the OASD(C) method of adjusting for quantity changes uses a floating baseline and this can lead to inconsistent cost-growth results.

These inconsistencies are avoided (at least in principle) in the method adopted in this study. In our approach, the DE quantity, Q_d, is a fixed baseline; the cost variance attributed to any change(s) in production quantity is subtracted from the total cost growth; and the result of this subtraction is the variance attributed to non-quantity-induced cost changes. In both the Q_{c1} and Q_{c2} examples in Fig. A.4 the result is the same: 160 − 76 = 84. The quantity-adjusted cost growth is thus independent of the sign and magnitude of the quantity change. When the cost-growth ratio is calculated for these two examples, the results are [956 − (956 − 160)]/76 = 160/76, and [52 − (52 − 160)]/76 = 160/76. In both cases the cost-growth ratio is 2.11. In practice, differences of this magnitude are rare. Except for programs that have been changed extensively, cost growth measured by either method is similar.

COST GROWTH TIME TRENDS

To estimate the average annual rate of cost growth for our 1970s cost analysis sample of 31 programs, we plotted their March 1978 growth ratios against the number of years past DSARC II for each of the programs. The results appear in Fig. 11 of the text.

Lacking statistical support for the expected flattened curve, or S-shaped curve with start-up lag[8] (see Figs. 9 and 10 of the text with the accompanying discussion of programs in the production phase), we opted for a linear curve showing a constant average annual growth rate as the best way to describe the data. The linear regression of the data points in Fig. 11 indicated that this set of programs

[8]For example, a modified exponential curve such as the Gompertz or "logistic" curves.

had an average annual cost growth rate of 5.6 percent.[9] It should be noted that we designated the Y-intercept of the regression line to show zero growth (a growth ratio of unity) at DSARC II. Also this procedure minimized the influence of programs that suffered unusually high growth rates soon after DSARC II. Experience suggests that programs with early high growth are likely to be restructured. Allowing the regression calculation to find its own Y-intercept might result in pulling up the origin of the trend line above unity, the true baseline at the time of DSARC II, thus decreasing the slope of the trend line (the more programs that had high *initial* growth rates, the lower the sample's marginal or incremental annual growth rate would appear to be).

OASD(C) obtained a somewhat lower aggregate cost growth rate for the programs current at this time, about 3.6 percent a year. A part of the difference between the two results derives from the differing methods used for adjusting for quantity-induced cost changes, as explained earlier.[10] But the primary reason for the different growth rates is the difference in the program samples. OASD(C) includes the 53 programs reported in Congressional SARs, minus the IFV, plus 5 additional programs that are covered in SARs not reported to the Congress. The sample we used excludes ships, programs that entered full-scale development before 1969 (and hence should be little influenced by the Packard policies), and programs with ambiguous data. When we used the complete OASD(C) sample but employed our computational method, the annual cost growth rate was 4.3 percent. The remaining difference between our 4.3 percent growth rate and OASD(C)'s 3.6 percent rate was almost completely accounted for by the different methods used for representing annual cost growth. Our percentage rate is simply a linear, average annual growth rate, whereas OASD(C) uses a compound growth rate.

---

[9]The regression was performed with the CURVES computer program. H. E. Boren, Jr., and G. W. Corwin, *CURVES: A Cost Analysis Curve-Fitting Program*, The Rand Corporation, R-1753/1-PR, September 1976.

[10]Actually, the different methods for dealing with quantity cost variance had only a small effect on the overall annual cost growth rates in this comparison. This is because the OASD(C) sample omitted the IFV and the other differences in cost-growth ratios were mixed, some higher than ours and some lower, and they tended to cancel each other out.

Appendix B

THE BASIC CAUSES OF COST GROWTH

INTRODUCTION

The categorization of reasons for cost variance currently provided in the SARs is a significant improvement over the past when critics saw only the bare fact of cost "overruns" with no explanation for such cost growth. However, as noted in the main text of this report, some of the major variance categories, particularly Schedule, do not identify the root causes of cost growth. This apparently is intentional. According to the draft SAR Cost Guidelines, "the variance categories are defined, generally, in terms of the cost effects of program changes rather than the causes of the change."[1] But OSD policymakers and Service personnel in high-level acquisition management positions require information regarding the fundamental causes of cost growth if they are to develop appropriate remedies. As an initial exploratory step in this important area, we describe the results of our attempt to isolate the more basic causes or "drivers" of the reported cost growth. Although we are unable to quantify their importance in dollar terms, we discuss the nature of the cost growth drivers we have identified, and where information permits we rank them as "large" or "small" according to our judgment of their effect on acquisition cost growth.

Because the SAR cost variance data provide useful points of reference, a brief description of each of the SAR categories is given below.

DEFINITIONS OF THE SAR COST VARIANCE CATEGORIES[2]

Cost variance, as reported in a SAR, measures the changes in program cost from the development estimate (DE) established at the time of DSARC II, to the date of the SAR. The SARs use eight categories to differentiate the causes of cost variance in terms of constant dollars.[3] A brief discussion of their contents appears below.

Quantity: This cost variance category shows the effect on program costs of changes in the number of units of the major equipment to be produced compared with the projection of total output made at the time of DSARC II. As explained in the text and in Appendix A, quantity cost variance is omitted from our analysis of cost growth. For consistency we measure cost growth for all of the programs in terms of their original production quantities planned at DSARC II.

Schedule: The cost effect of revisions in procurement delivery schedules or in

---

[1]Department of Defense Instruction 7000.3G, *Guide For The Preparation and Review of Selected Acquisition Report (SAR) Cost and Economic Information*, OASD (Comptroller), (Draft), p.19.

[2]Draft DoDI 7000.3G, pp. 13-19.

[3]A ninth category, Economic cost variance, accounts for the effects on program costs of inflation rates different from those originally predicted. As this category is not pertinent to cost variance in constant dollar terms, it is not discussed here.

the completion dates of tests and intermediate milestones of the major equipment items. It covers such things as terminating and perhaps later rehiring and retraining production workers, renegotiation expenses, changes in the size of bulk material orders, tooling changes, indivisibilities, and other scale effects.

Engineering: The cost effect of alterations in the physical or functional characteristics of the major equipment item.

Estimating: Correction of estimating errors in the baseline cost projection or refinements in the (physical) basis for the original major equipment estimate, contract renegotiation, availability of actual cost data, or change in the slope of the assumed learning curve.

Support: In each of the above descriptions we have stressed the point that the cost variance refers to the major equipment item. In the support area (e.g., support and training equipment, initial spares), cost variance, whatever its reason, is combined into a single support cost variance figure.

Cost Overrun/Underrun: These are cost changes attributed fully to the performance of the contractors. They are subjective appraisals of the contractors' ability to perform in a reasonable and efficient manner. In practice, the Cost Overrun/Underrun category seems to be used only when the cost change cannot reasonably be assigned to one of the other categories.

Unpredictable: This variance category might be expected to be a very popular one because almost all variance could be blamed on a failure to predict circumstances that led to the cost change. But in practice the use of this category is so circumscribed that it rarely has been used at all. Failure of the Congress to approve funding levels is so common that it is expressly excluded from the Unpredictable category. (It generally is reported as schedule slippage, the effect of the inadequate funds.) Higher than expected labor pay rate settlements and other "fact of life" occurrences also are not eligible for this category. Only acts of God, work stoppages, law changes, and unexpected circumstances that are random and without precedent seem to fulfill the requirements for this variance category.

Contract Performance Incentives: This category contains the net cost effect of contractor performance where the contract contains incentive provisions to reward better than predicted contractor achievement—such as delivery and value engineering goals—or to penalize underachievers.

These last two cost variance categories, Unpredictable and Contract Performance Incentives, tend to be less important in dollar terms than the others. In our tabulations we combined them into a single category, "Other."

BASIC CAUSES OF COST GROWTH

Apart from inflation and changes in quantity, the most important contributors to cost growth noted in the SARs are schedule slippage, engineering changes, estimating errors, and changes in the support area. In the following paragraphs we identify and describe the salient characteristics of more basic causes of acquisition program cost growth. An important finding of this investigation is that a substantial part of the cost growth in our sample of 1970s programs is not within the area of control and responsibility of program managers, and in some cases it is even beyond the scope of control measures available to top level acquisition managers in the Services and OSD.

Inadequate Funding Levels: The most frequent root cause for schedule slippage mentioned in the SARs (and in Congressional hearings) is inadequate annual funding. This reason was given in more than one-third of the 31 SAR programs we examined. An even larger proportion (one-half) of the programs at least three years past DSARC II blamed schedule slippage on inadequate funding. But funding shortfalls can, themselves, stem from many causes. For some programs, the underfunding is self-generated—increasing performance above that called for in the original program concept usually means higher costs. If the program's budget is increased to cover the rise in costs, the variance can be recorded in the engineering change category. But the additional dollars are not always immediately forthcoming. Similarly, the funding shortfall may be traced to an overly optimistic baseline cost estimate, or to unexpected technical difficulties. With a rise in unit cost and no compensatory increase in the program's annual funding, the most obvious solution to the funding squeeze is a cut in the production rate.

Frequently, funding cuts are made by the Congress because, in its view, there has been a failure to justify the program adequately. The Congress has been reluctant to fund programs until all of the outstanding issues are studied and resolved. It is understandable that Congress wants to avoid investing millions of dollars in a program only to see it subsequently canceled for reasons that might have been discovered with more extensive study and analysis.

Some of the reasons for funding cuts are clearly beyond the control of the individual program managers. For example, funds may be diverted from a less favored system to one of higher priority. During its early development, the Advanced Attack Helicopter benefited from a reprogramming of the Army's acquisition budget at the expense of programs considered less important. This shift in resources can occur even if the higher priority program suffered a cost overrun that contributed to the funding problem.

Although the above reasons for acquisition fund shortages may legitimately be attributed to Service or OSD management, acquisition programs also may suffer from fund limitations for broader reasons, such as POL price rises, DoD pay increases, other defense programs and contingencies, or even non-defense government needs. Schedule slippage due to these causes is not only beyond the control of individual program managers, it is beyond the scope of acquisition policy guidance and constraints. Identifying the amount of cost growth that stems from these exogenous causes, separate from the variance that is subject to DoD control, would enhance the usefulness of cost variance statistics for evaluating and improving acquisition management.

Another important cause of inadequate funding that is beyond the control of an individual program manager is the frequent downward bias in the forecasting of future inflation. This may lead to more programs being started, and programs being scheduled for a faster rate of accomplishment, than can be accommodated within the acquisition budget programmed for the outyears. The funding squeeze that eventually materializes is then often translated into a slippage of the original program schedules. This might have been avoided by a less optimistic projection of future inflation rates.

Unexpected Technical Difficulties: Engineering variance results from two basic causes. The first relates to the additional effort that is needed to meet the original requirements. Unforeseen technical difficulties are acknowledged in 11 of the acquisition programs in our study. Sixty percent of the programs at least three years beyond DSARC II mentioned unexpected development difficulties as a significant cause of cost growth.

Changed Performance: Unexpected technical difficulties are a minor problem compared with the second type of engineering variance—a change in the performance requirements of the major equipment. These latter engineering changes can consist of a major restructuring of the program (such as that experienced by Patriot and the IFV), new missions (F-16), added equipment (A-10, LAMPS III), greater reliability or maintainability than originally demanded, and a continual upgrading of tactical equipment (e.g., ECM) to match the increasingly hostile threat environment. These latter cost changes stemming from improved performance were factors in the cost growth of 12 of the 31 programs in our cost analysis study. These are not the same as cost increases required to achieve the original performance goals, and they deserve to be considered separately. In contrast, some programs accepted scaled-down performance in order to save dollars—for example Condor and Patriot.

Estimation Errors: Cost variance due to estimation errors was prominent in six of the acquisition programs in our 31-program sample and a minor problem in three; it was an important cause of cost growth in almost one-third of the programs at least three years beyond DSARC II.

Some of the estimation errors that turn up in the baseline estimates are due to mistakes in estimator judgment; for example, use of inappropriate analogs or estimating relationships. A large part of the cost growth of the CAPTOR program was attributed to use of an overly optimistic cost-quantity learning curve. Arithmetic errors were acknowledged in the SARs of some programs. Another frequently noted source of estimating cost growth is the initial omission of costly system elements such as training or depot equipment. The Navy's LAMPS III program is a notable example of cost growth due to the later addition of program elements that were excluded from the DE baseline.

Although the above estimating errors might have been avoided, cost estimating inaccuracies in many programs probably are inevitable. Some new acquisition programs simply have no previous counterparts to provide a firm basis on which to ground the required cost estimate at the time of DSARC II. It is common for military hardware to be at the frontiers of technology, with new physical stresses, new manufacturing processes, and new materials involved. Electronic subsystems form a conspicuous element in the military acquisition programs of the 1970s, and computers and their software are everywhere in evidence. These types of equipment and services are very difficult to cost with any degree of precision. The development of such advanced military systems involves many imponderables, which explains the prevalence of cost plus contracts in that area. Clearly, it is unrealistic to expect the same degree of accuracy in the Development Estimate for a high-technology system as one might expect for a system of current design.

For some systems, the use of established technology and off-the-shelf components may make the cost projection reasonably straightforward—some Army vehicles for example. Some portion of most program costs probably can be estimated with a high degree of confidence, but "educated guesses" must, of necessity, form the basis of many baseline cost projections for advanced systems.[4]

Unpredictable: Two Air Force programs blamed a part of their cost growth on circumstances that could not be predicted at the time of their DSARC II approvals. The F-15's engine cost rose as a result of the Navy's decision to use a different engine for the F-14 program. The original A-10 program funding did not allow for a fly-off against the A-7 nor the transfer into the program of engine component improvement charges.

Table 11 of the text is repeated here, for convenience, as Table B.1. It presents a first-cut identification of the principal underlying causes of acquisition program cost variance for the 31-program sample. Our sources did not permit further breakdowns of the Inadequate Funding category into the more basic causes discussed above, but the information to provide the needed breakdowns and to quantify their importance presumably is available in the program offices.

The argument against allocating cost variance to these root causes—that such allocations would necessarily be somewhat subjective—is not entirely convincing. In the absence of this information derived from those at program management level (who are best able to provide it), high level budget decisions are necessarily even more subjective. Although it would be naive to accept this information without some validation process, subjective assessments from program managers are likely to be better than none at all. Some of this information does reach higher levels during individual program reviews, but it is not systematically recorded and hence it is not available as a basis for *policy* improvements.

SUMMARY

To sum up, the fundamental causes of cost growth in the 1970s (after adjustments for quantity change and inflation) were inadequate funding, unexpected technical difficulties, changes in equipment performance, and estimating errors. By no means all of the root causes for cost growth reflect unfavorably on the management of the acquisition system—some cost increases finance fully justified cost-effective improvements while others are completely beyond the scope of program manager or OSD responsibility. It is important to be able to distinguish these from the causes of cost growth that are more amenable to managerial overview and OSD policy guidance. To this end, we suggest the systematic collection of cost growth data using the kinds of breakdowns discussed in this appendix. We believe that this more detailed approach is required to provide the information needed to properly evaluate and control cost growth.

---

[4]An interesting method for indicating the confidence level of a cost estimate is given in ASD Regulation 173-1 (Draft), Attachment 4, Headquarters Aeronautical Systems Division (AFSC), March 1979. It involves a statement of the technique used to make the estimate—detailed, parametric, factor, or analog—and the kind of data base used.

Table B.1

PRELIMINARY ATTEMPT TO IDENTIFY THE UNDERLYING CAUSES OF PROGRAM COST VARIANCE

Program	Inadequate Funding	Unexpected Technical Difficulties	Changed Performance	Estimating Errors	Unpredictable
ARMY					
Patriot	s	s	r	s	
Hellfire	s		s		
UH-60					
YAH-64	s				
IFV		L	L	L	
XM-1		L			
Roland				L	
Copperhead (CLGP)					
DIVAD Gun					
M-198 Howitzer		s		L	
NAVY					
F-18					
LAMPS III		s	L	s	
Aegis	s		s		
CAPTOR	s		L	L	
Harpoon	s		L		
Sidewinder (AIM-9L)		L	L	L	
Tomahawk					
5-in. Guided Projectile					
8-in. Guided Projectile					
SURTASS			L	L	
TACTAS	s				
Condor	s	s	r	r	
AIR FORCE					
A-10	L		s		s
B-1	s	s	s		
F-15	s	s	s		s
F-16		s	s		
E-3A (AWACS)	L	s			
PLSS					
DSCS III					
ALCM					
GLCM					

Key: L = cause of large increase.
s = cause of small increase.
r = cause of small reduction.

Appendix C

PROGRAM DESCRIPTIONS AND COST GROWTH SUMMARIES

INTRODUCTION

This appendix contains brief program descriptions and financial summaries of 26 of the 31 acquisition programs examined in the cost analysis portion of this study. Excluded are the Navy's Tomahawk missile and 5-inch and 8-inch guided projectiles, and the Air Force's air-launched and ground-launched cruise missiles (ALCM and GLCM). As of March 1978, the costs of these new systems had not changed from their baseline Development Estimates. Included in each of the 26 program descriptions is a tabular summary of acquisition cost data based on the program's Selected Acquisition Report (SAR), and a discussion of the causes of program cost growth. These program descriptions are organized by Service and presented in the following order:

ARMY	*NAVY*	*AIR FORCE*
Patriot	F-18	A-10
Hellfire	LAMPS III	B-1
UH-60 (UTTAS)	Aegis	F-15
YAH-64 (AAH)	CAPTOR	F-16
IFV	Harpoon	AWACS (E-3A)
XM-1 Tank	AIM-9L	PLSS
Roland	TACTAS	DSCS III
CLGP	SURTASS	
DIVAD Gun	Condor	
M-198 Howitzer		

The cost summary for each program compares the baseline Development Estimate and the March 1978 Current Estimate. Any cost variance between these figures is allocated among the following categories.[1]

COST VARIANCE CATEGORIES
Quantity[2]
Schedule
Engineering
Support
Estimating
Over/Underrun

[1]The SAR variance categories are defined in Appendix B.
[2]It should be remembered that cost variance due to quantity changes was explicitly excluded from our analyses. For consistency, we measured cost growth in terms of the original DE quantity established at DSARC II.

Other Changes[3]
Program changes
Economic (general economic conditions)[4]

Separate cost breakdowns are given for Development, Procurement, and Military Construction as well as for the overall program totals. Costs are shown in program *base year constant dollars, then year (inflated) dollars,* and *1979 constant dollars.*[5]

The source of the cost variance allocations was the variance analysis section of the SARs. There the cost of program changes is shown in base year constant dollars together with an estimate of the associated escalation (inflation) that will be encountered when the changes are funded in future budgets. Besides the escalation associated directly with program changes there is a separate figure for Economic variance. This category corrects for additional, unanticipated escalation not covered by DoD's projections of future inflation rates. Adding the above escalation to the base year dollar estimates yields program cost variance in then year dollar terms. The transformation of base year dollars into 1979 dollars was made on the basis of the DoD price level indexes for R&D, procurement, and military construction approved in June 1978.

The cost figures that appear in the body of this report are in terms of 1979 constant dollars. The use of this 1979 dollar cost base places the acquisition costs of the various programs in our study in a consistent—and familiar—cost framework. It makes the size of cost changes easier to comprehend, and the common cost base facilitates comparisons between acquisition programs having different starting dates and spendout rates.

Besides the three kinds of dollar cost figures described above (base year, current year, then year), the tables also show cost variance in terms of percentage changes from the baseline Development Estimate to the March 1978 Current Estimate.[6]

---

[3]The Other Changes category combines the variance attributed in the SARs to Contract Performance Incentives and Unpredictable.

[4]These changes in economic conditions are reflected in a revised price level index, which affects the cost projections expressed in then year dollars.

[5]Program costs in base year constant dollars are shown in terms of the average level of prices that prevailed when the Development Estimate was approved. Cost growth expressed in constant dollars excludes inflation and often is referred to as "real" cost growth. Program costs in then year dollars are the sum of annual funding increments that are expected to be required over the course of the program; they therefore include inflation for the spendout years at the inflation rates projected for those years. The third cost base, 1979 constant dollars, is a simple conversion from the base year dollar format that places all programs on a common cost base.

[6]These tables were produced by means of a JOSS computer program designed for this study. An associated computer program facilitates the entry and revision of the basic cost variance data from the SARs. JOSS is the trademark and service mark of The Rand Corporation for its computer program and services using that program.

ARMY PROGRAMS

PATRIOT

"Patriot" is the present designation of the Army's long-range air defense missile program that, prior to the restructuring of the program, was known as "SAM-D." An overall reduction of 19 percent was shown in the March 1978 projected cost compared with its FY 1972 Development Estimate; however, this was achieved largely by a reduction in quantity to about three-quarters of the original number. Cost growth measured in terms of the quantity assumed in the Development Estimate reveals an *increase* of 6 percent for the total program. This figure was the net result of some increases and some decreases, the largest single item being a reduction of 13 percent due to engineering changes, e.g., the deletion of the nuclear warhead, conversion of the airborne guidance to modular/digital design, and the deletion of adaption kits. Schedule slippages resulted in an increase of 6 percent, mostly in the development phase. Some of the delays resulted from unforeseen difficulties that were encountered; for example, in the radar software. In FY 1976, development funds were reduced, the program was redirected, and a 1-year slippage resulted. The Estimating category accounted for an additional increase in program costs of 10 percent. Some of this increase was due to "refined estimates" but a part of the estimating problem was attributed to the unexpected program reorientation and the reduction, followed shortly thereafter by the reinstatement, of FY 1978 budget funds. There also was an add-on to the program costs in the form of NATO studies that were not in the original estimate. The Support category showed an increase of about 3 percent. Part of this increase was due to a transfer of range support costs from TECOM to the program management office. There also were some increases in initial spares and training devices, and there were some equipment changes as well. Deletion of a CONUS fire unit (platoon) was noted.

Patriot

PROGRAM ACQUISITION COST
(Costs in $ millions)

	Base Yr (FY 72) $		Cur Yr (FY 79) $		Then Year $	
	Cost	% of DE	Cost	% of DE	Cost	% of DE
DEVELOPMENT						
DEV ESTIMATE	1078.4	100.0	1722.9	100.0	1200.0	100.0
VARIANCE:						
Quantity	-59.2	-5.5	-94.6	-5.5	-77.7	-6.5
Schedule	231.3	21.4	369.5	21.4	322.2	26.9
Engineering	22.1	2.0	35.3	2.0	46.7	3.9
Support	15.0	1.4	24.0	1.4	21.9	1.8
Estimating	92.9	8.6	148.4	8.6	154.6	12.9
Over/underrun	24.5	2.3	39.1	2.3	27.6	2.3
(Pgm changes)	(326.6)	(30.3)	(521.8)	(30.3)	(495.3)	(41.3)
Economic					99.8	8.3
TOT VARIANCE	326.6	30.3	521.8	30.3	595.1	49.6
CUR ESTIMATE	1405.0	130.3	2244.7	130.3	1795.1	149.6
PROCUREMENT						
DEV ESTIMATE	3121.2	100.0	5131.2	100.0	3969.8	100.0
VARIANCE:						
Quantity	-941.9	-30.2	-1548.5	-30.2	-974.6	-24.6
Schedule	6.3	.2	10.4	.2	134.3	3.4
Engineering	-573.2	-18.4	-942.3	-18.4	-901.9	-22.7
Support	94.7	3.0	155.7	3.0	175.7	4.4
Estimating	341.7	10.9	561.7	10.9	716.6	18.1
(Pgm changes)	(-1072.4)	(-34.4)	(-1763.0)	(-34.4)	(-849.9)	(-21.4)
Economic					1304.2	32.9
TOT VARIANCE	-1072.4	-34.4	-1763.0	-34.4	454.3	11.4
CUR ESTIMATE	2048.8	65.6	3368.2	65.6	4424.1	111.4
MIL CONST						
DEV ESTIMATE	40.0	100.0	68.4	100.0	70.7	100.0
VARIANCE:						
Quantity	-30.1	-75.3	-51.5	-75.3	-30.1	-42.6
Schedule	.0	.0	.0	.0	2.7	3.8
Estimating	-2.0	-5.0	-3.4	-5.0	-3.8	-5.4
(Pgm changes)	(-32.1)	(-80.3)	(-54.9)	(-80.3)	(-31.2)	(-44.1)
Economic					-26.7	-37.8
TOT VARIANCE	-32.1	-80.3	-54.9	-80.3	-57.9	-81.9
CUR ESTIMATE	7.9	19.8	13.5	19.8	12.8	18.1
TOT PROGRAM						
DEV ESTIMATE	4239.6	100.0	6922.4	100.0	5240.5	100.0
VARIANCE:						
Quantity	-1031.2	-24.3	-1694.5	-24.5	-1082.4	-20.7
Schedule	237.6	5.6	379.9	5.5	459.2	8.8
Engineering	-551.1	-13.0	-907.0	-13.1	-855.2	-16.3
Support	109.7	2.6	179.6	2.6	197.6	3.8
Estimating	432.6	10.2	706.7	10.2	867.4	16.6
Over/underrun	24.5	.6	39.1	.6	27.6	.5
(Pgm changes)	(-777.9)	(-18.3)	(-1296.1)	(-18.7)	(-385.8)	(-7.4)
Economic					1377.3	26.3
TOT VARIANCE	-777.9	-18.3	-1296.1	-18.7	991.5	18.9
CUR ESTIMATE	3461.7	81.7	5626.3	81.3	6232.0	118.9

Hellfire

Hellfire is a standoff, laser-guided missile. It replaced TOW as the AH-64's primary weapon system. The Hellfire missile program had a cost growth of 2 percent since its DSARC II approval in FY 1976. A budget reduction in FY 1978 caused some schedule slippage which required a reprofiling of procurement funds. This added 1 percent to the cost and Engineering changes caused the other 1 percent growth. This latter increase was due to the addition of a competitive low-cost target seeker program.

Hellfire

PROGRAM ACQUISITION COST
(Costs in $ millions)

	Base Yr (FY 75) $		Cur Yr (FY 79) $		Then Year $	
	Cost	% of DE	Cost	% of DE	Cost	% of DE
DEVELOPMENT						
DEV ESTIMATE	210.3	100.0	268.9	100.0	266.2	100.0
VARIANCE:						
Schedule	6.0	2.9	7.7	2.9	8.5	3.2
Engineering	5.3	2.5	6.8	2.5	7.0	2.6
Support	-1.8	-.9	-2.3	-.9	-2.5	-.9
Estimating	.9	.4	1.2	.4	1.6	.6
(Pgm changes)	(10.4)	(4.9)	(13.3)	(4.9)	(14.6)	(5.5)
Economic					3.0	1.1
TOT VARIANCE	10.4	4.9	13.3	4.9	17.6	6.6
CUR ESTIMATE	220.7	104.9	282.2	104.9	283.8	106.6
PROCUREMENT						
DEV ESTIMATE	297.9	100.0	386.0	100.0	468.9	100.0
VARIANCE:						
Schedule	.0	.0	.0	.0	8.2	1.7
Support	-1.5	-.5	-1.9	-.5	-2.9	-.6
Estimating	-.1	.0	-.1	.0	-.5	-.1
(Pgm changes)	(-1.6)	(-.5)	(-2.1)	(-.5)	(4.8)	(1.0)
Economic					47.3	10.1
TOT VARIANCE	-1.6	-.5	-2.1	-.5	52.1	11.1
CUR ESTIMATE	296.3	99.5	383.9	99.5	521.0	111.1
MIL CONST						
DEV ESTIMATE	.0	.0	.0	.0	.0	.0
VARIANCE:						
TOT VARIANCE	.0	.0	.0	.0	.0	.0
CUR ESTIMATE	.0	.0	.0	.0	.0	.0
TOT PROGRAM						
DEV ESTIMATE	508.2	100.0	654.9	100.0	735.1	100.0
VARIANCE:						
Schedule	6.0	1.2	7.7	1.2	16.7	2.3
Engineering	5.3	1.0	6.8	1.0	7.0	1.0
Support	-3.3	-.6	-4.2	-.6	-5.4	-.7
Estimating	.8	.2	1.0	.2	1.1	.1
(Pgm changes)	(8.8)	(1.7)	(11.2)	(1.7)	(19.4)	(2.6)
Economic					50.3	6.8
TOT VARIANCE	8.8	1.7	11.2	1.7	69.7	9.5
CUR ESTIMATE	517.0	101.7	666.1	101.7	804.8	109.5

UH-60 (UTTAS)

The UH-60 is the Army's new utility transport helicopter. The March 1978 estimate for the UH-60 program indicated an expected 14 percent saving compared with the FY 1971 Development Estimate. A 1 percent reduction resulted from a cut in the number of development helicopters from 16 to 10. If we omit the quantity effect, the cost savings amounted to 13 percent. There was an increase in the authorized production rate, which is expected to allow the program to be completed 1 year earlier. This speed-up was expected to result in a Schedule saving of 3 percent in constant dollars. A refined independent cost estimate was used to justify a reduction of 2 percent in Estimating. The largest change was in the support category which recorded a saving of 7 percent.

UH-60

Program Acquisition Cost
(Costs in $ millions)

	Base Yr (FY 71) $		Cur Yr (FY 79) $		Then Year $	
	Cost	% of DE	Cost	% of DE	Cost	% of DE
DEVELOPMENT						
DEV ESTIMATE	357.3	100.0	597.2	100.0	409.9	100.0
VARIANCE:						
Quantity	-20.2	-5.7	-33.8	-5.7	-22.0	-5.4
Schedule	.3	.1	.5	.1	1.0	.2
Engineering	-.2	-.1	-.3	-.1	-.2	.0
Support	6.2	1.7	10.4	1.7	8.2	2.0
Estimating	5.1	1.4	8.5	1.4	3.6	.9
Over/underrun	9.3	2.6	15.5	2.6	13.2	3.2
Other changes	1.2	.3	2.0	.3	1.8	.4
(Pgm changes)	(1.7)	(.5)	(2.8)	(.5)	(5.6)	(1.4)
Economic					52.3	12.8
TOT VARIANCE	1.7	.5	2.8	.5	57.9	14.1
CUR ESTIMATE	359.0	100.5	600.0	100.5	467.8	114.1
PROCUREMENT						
DEV ESTIMATE	1584.4	100.0	2703.8	100.0	1897.4	100.0
VARIANCE:						
Schedule	-66.8	-4.2	-114.0	-4.2	-194.6	-10.3
Engineering	-24.9	-1.6	-42.5	-1.6	-24.9	-1.3
Support	-135.8	-8.6	-231.7	-8.6	-135.8	-7.2
Estimating	-41.9	-2.6	-71.5	-2.6	204.7	10.8
(Pgm changes)	(-269.4)	(-17.0)	(-459.7)	(-17.0)	(-150.6)	(-7.9)
Economic					1400.1	73.8
TOT VARIANCE	-269.4	-17.0	-459.7	-17.0	1249.5	65.9
CUR ESTIMATE	1315.0	83.0	2244.1	83.0	3146.9	165.9
MIL CONST						
DEV ESTIMATE	.0	.0	.0	.0	.0	.0
VARIANCE:						
TOT VARIANCE	.0	.0	.0	.0	.0	.0
CUR ESTIMATE	.0	.0	.0	.0	.0	.0
TOT PROGRAM						
DEV ESTIMATE	1941.7	100.0	3301.0	100.0	2307.3	100.0
VARIANCE:						
Quantity	-20.2	-1.0	-33.8	-1.0	-22.0	-1.0
Schedule	-66.5	-3.4	-113.5	-3.4	-193.6	-8.4
Engineering	-25.1	-1.3	-42.8	-1.3	-25.1	-1.1
Support	-129.6	-6.7	-221.4	-6.7	-127.6	-5.5
Estimating	-36.8	-1.9	-63.0	-1.9	208.3	9.0
Over/underrun	9.3	.5	15.5	.5	13.2	.6
Other changes	1.2	.1	2.0	.1	1.8	.1
(Pgm changes)	(-267.7)	(-13.8)	(-456.9)	(-13.8)	(-145.0)	(-6.3)
Economic					1452.4	62.9
TOT VARIANCE	-267.7	-13.8	-456.9	-13.8	1307.4	56.7
CUR ESTIMATE	1674.0	86.2	2844.1	86.2	3614.7	156.7

YAH-64 (AAH)

The Army's advanced attack helicopter program showed a 1 percent net cost increase in March 1978 compared with its December 1976 Development Estimate. This was due primarily to a Schedule cost increase of 1.4 percent which occurred when OSD in 1977 reduced AAH funding by $212 million and Congress subsequently restored $175 million. This resulted in some schedule slippage plus the additional expenses incurred in the renegotiation process that ensued.

YAH-64

Program Acquisition Cost
(Costs in $ millions)

	Base Yr (FY 72) $		Cur Yr (FY 79) $		Then Year $	
	Cost	% of DE	Cost	% of DE	Cost	% of DE
DEVELOPMENT						
DEV ESTIMATE	609.4	100.0	973.6	100.0	935.7	100.0
VARIANCE:						
Schedule	27.6	4.5	44.1	4.5	45.5	4.9
(Pgm changes)	(27.6)	(4.5)	(44.1)	(4.5)	(45.5)	(4.9)
Economic					5.0	.5
TOT VARIANCE	27.6	4.5	44.1	4.5	50.5	5.4
CUR ESTIMATE	637.0	104.5	1017.7	104.5	986.2	105.4
PROCUREMENT						
DEV ESTIMATE	1266.3	100.0	2081.8	100.0	2822.4	100.0
VARIANCE:						
Schedule	-.3	.0	-.5	.0	58.0	2.1
Support	-9.6	-.8	-15.8	-.8	-30.2	-1.1
(Pgm changes)	(-9.9)	(-.8)	(-16.3)	(-.8)	(27.8)	(1.0)
Economic					302.9	10.7
TOT VARIANCE	-9.9	-.8	-16.3	-.8	330.7	11.7
CUR ESTIMATE	1256.4	99.2	2065.5	99.2	3153.1	111.7
MIL CONST						
DEV ESTIMATE	.0	.0	.0	.0	.0	.0
VARIANCE:						
TOT VARIANCE	.0	.0	.0	.0	.0	.0
CUR ESTIMATE	.0	.0	.0	.0	.0	.0
TOT PROGRAM						
DEV ESTIMATE	1875.7	100.0	3055.4	100.0	3758.1	100.0
VARIANCE:						
Schedule	27.3	1.5	43.6	1.4	103.5	2.8
Support	-9.6	-.5	-15.8	-.5	-30.2	-.8
(Pgm changes)	(17.7)	(.9)	(27.8)	(.9)	(73.3)	(2.0)
Economic					307.9	8.2
TOT VARIANCE	17.7	.9	27.8	.9	381.2	10.1
CUR ESTIMATE	1893.4	100.9	3083.2	100.9	4139.3	110.1

IFV

The Infantry Fighting Vehicle (IFV) is a new version of the armored personnel carrier that was under development for many years as MICV (Mechanized Infantry Combat Vehicle). The IFV SAR includes the costs of its MICV predecessor. According to its March 1978 SAR, the overall cost of this program fell by 41 percent (net) compared with the FY 1972 Development Estimate. This dramatic reduction, however, resulted from the deletion of all of the 1205 procurement vehicles until its requirements could be reassessed. This cut in quantity reduced costs by an amount equal to 122 percent of the baseline estimate because its unit price had grown significantly since its inception.

Recomputing cost growth in terms of the baseline quantity indicated that the IFV total program cost had increased 81 percent before the cut in quantity. A 52 percent increase in cost resulted from engineering changes—changes in primary armament, development of the TBAT II weapon station, scrapping the MICV design and starting over, and various enhancements in the IFV design over that of the original MICV design. These changes resulted in schedule slippage which added about 6 percent to the program cost. The Estimating category showed a 15 percent rise due to underestimates: the cost of redesign and retesting that, of course, were not in the original estimate; a transmission backup dual program development; and the cost of rebuilding the test vehicles. There was a net increase in the Support category for weapons trainers, the TECOM cost that was transferred to the program management office and added testing and spares for the new version of the vehicle. According to the SAR, these support increases added 5 percent to the initial cost.

IFV (MICV)

Program Acquisition Cost
(Costs in $ millions)

	Base Yr (FY 72) $		Cur Yr (FY 79) $		Then Year $	
	Cost	% of DE	Cost	% of DE	Cost	% of DE
DEVELOPMENT						
DEV ESTIMATE	34.3	100.0	54.8	100.0	37.1	100.0
VARIANCE:						
Quantity	10.4	30.3	16.6	30.3	16.8	45.3
Schedule	7.2	21.0	11.5	21.0	10.5	28.3
Engineering	28.2	82.2	45.1	82.2	46.2	124.5
Support	13.5	39.4	21.6	39.4	22.5	60.6
Estimating	25.2	73.5	40.3	73.5	34.6	93.3
Over/underrun	7.0	20.4	11.2	20.4	11.2	30.2
Other changes	-.8	-2.3	-1.3	-2.3	-.9	-2.4
(Pgm changes)	(90.7)	(264.4)	(144.9)	(264.4)	(140.9)	(379.8)
Economic					2.5	6.7
TOT VARIANCE	90.7	264.4	144.9	264.4	143.4	386.5
CUR ESTIMATE	125.0	364.4	199.7	364.4	180.5	486.5
PROCUREMENT						
DEV ESTIMATE	173.1	100.0	284.6	100.0	208.3	100.0
VARIANCE:						
Quantity	-261.1	-150.8	-429.2	-150.8	-507.5	-243.6
Schedule	4.6	2.7	7.6	2.7	58.4	28.0
Engineering	79.5	45.9	130.7	45.9	264.9	127.2
Support	-2.7	-1.6	-4.4	-1.6	-1.7	-.8
Estimating	7.0	4.0	11.5	4.0	13.2	6.3
(Pgm changes)	(-172.7)	(-99.8)	(-283.9)	(-99.8)	(-172.7)	(-82.9)
Economic					-35.2	-16.9
TOT VARIANCE	-172.7	-99.8	-283.9	-99.8	-207.9	-99.8
CUR ESTIMATE	.4	.2	.7	.2	.4	.2
MIL CONST						
DEV ESTIMATE	.0	.0	.0	.0	0	.0
VARIANCE:						
TOT VARIANCE	.0	.0	.0	.0	.0	.0
CUR ESTIMATE	.0	.0	.0	.0	.0	.0
TOT PROGRAM						
DEV ESTIMATE	207.4	100.0	339.4	100.0	245.4	100.0
VARIANCE:						
Quantity	-250.7	-120.9	-412.6	-121.6	-490.7	-200.0
Schedule	11.8	5.7	19.1	5.6	68.9	28.1
Engineering	107.7	51.9	175.7	51.8	311.1	126.8
Support	10.8	5.2	17.1	5.0	20.8	8.5
Estimating	32.2	15.5	51.8	15.3	47.8	19.5
Over/underrun	7.0	3.4	11.2	3.3	11.2	4.6
Other changes	-.8	-.4	-1.3	-.4	-.9	-.4
(Pgm changes)	(-82.0)	(-39.5)	(-139.0)	(-41.0)	(-31.8)	(-13.0)
Economic					-32.7	-13.3
TOT VARIANCE	-82.0	-39.5	-139.0	-41.0	-64.5	-26.3
CUR ESTIMATE	125.4	60.5	200.4	59.0	180.9	73.7

XM-1 Tank

The Army's new main battle tank received approval for full-scale development early in FY 1977. By March 1978 the program had experienced a 73 percent cost growth, primarily due to increased buy quantities. When this quantity effect is removed, the overall cost growth for this program falls to 7 percent. A 4 percent growth in the baseline estimate caused by stretchouts was recorded in the Schedule category. The SAR indicated that the reasons for the stretchouts were unanticipated increases in engineering support, data documentation, system/project management, and logistics support. The Estimating category indicated a 2 percent growth in program cost due to unexpectedly large outlays for system and project management.

Other increases in the Estimating category were due to the decision to have two plants produce the tanks at a rate of 60 a month rather than have a single plant produce 30 a month. There also was mention of "no licensing savings" and increased contractor support. A footnote stated that the "facilitization" costs included only the initial production facilities and not the total production base support. Also, the cost for evaluating the use of a West German 120mm smooth-bore gun on the XM-1 tank was excluded from the cost growth shown in this SAR. It was stated that these costs would be included in the future. A 1 percent increase was shown in the Support category, for increased training equipment and peculiar support equipment. These were partially offset by decreases in initial spares and common support equipment. It should be noted that this engineering development was preceded by a competitive advanced development program between General Motors and Chrysler from which the latter corporation emerged the winner.

XM-1

PROGRAM ACQUISITION COST
(Costs in $ millions)

	Base Yr (FY 72) $		Cur Yr (FY 79) $		Then Year $	
	Cost	% of DE	Cost	% of DE	Cost	% of DE
DEVELOPMENT						
DEV ESTIMATE	422.6	100.0	675.2	100.0	584.6	100.0
VARIANCE:						
Estimating	-3.0	-.7	-4.8	-.7	-3.2	-.5
(Pgm changes)	(-3.0)	(-.7)	(-4.8)	(-.7)	(-3.2)	(-.5)
Economic					.2	.0
TOT VARIANCE	-3.0	-.7	-4.8	-.7	-3.0	-.5
CUR ESTIMATE	419.6	99.3	670.4	99.3	581.6	99.5
PROCUREMENT						
DEV ESTIMATE	1970.2	100.0	3239.0	100.0	4194.8	100.0
VARIANCE:						
Quantity	1578.3	80.1	2594.7	80.1	4784.0	114.0
Schedule	96.5	4.9	158.6	4.9	326.1	7.8
Support	13.2	.7	21.7	.7	53.3	1.3
Estimating	58.8	3.0	96.7	3.0	139.7	3.3
(Pgm changes)	(1746.8)	(88.7)	(2871.7)	(88.7)	(5303.1)	(126.4)
Economic					356.2	8.5
TOT VARIANCE	1746.8	88.7	2871.7	88.7	5659.3	134.9
CUR ESTIMATE	3717.0	188.7	6110.7	188.7	9854.1	234.9
MIL CONST						
DEV ESTIMATE	.0	.0	.0	.0	.0	.0
VARIANCE:						
TOT VARIANCE	.0	.0	.0	.0	.0	.0
CUR ESTIMATE	.0	.0	.0	.0	.0	.0
TOT PROGRAM						
DEV ESTIMATE	2392.8	100.0	3914.1	100.0	4779.4	100.0
VARIANCE:						
Quantity	1578.3	66.0	2594.7	66.3	4784.0	100.1
Schedule	96.5	4.0	158.6	4.1	326.1	6.8
Support	13.2	.6	21.7	.6	53.3	1.1
Estimating	55.8	2.3	91.9	2.3	136.5	2.9
(Pgm changes)	(1743.8)	(72.9)	(2866.9)	(73.2)	(5299.9)	(110.9)
Economic					356.4	7.5
TOT VARIANCE	1743.8	72.9	2866.9	73.2	5656.3	118.3
CUR ESTIMATE	4136.6	172.9	6781.0	173.2	10435.7	218.3

Roland

Roland is not a new U.S. development; it is a European-designed air defense missile which is to be built under license in the United States by Hughes, with Boeing as the major subcontractor. There will be a moderate amount of new development—primarily a higher-powered radar to penetrate ECM—but the pre-production effort for the most part is "technological transfer, fabrication, and test." Though the Roland program was little more than a year old in March 1978, its quantity-adjusted costs had already grown by 54 percent, almost all of it in the Estimating category. Apparently, the early estimates were overly optimistic, perhaps reflecting some hesitation on the part of the European manufacturers to release complete information prior to program approval. The growth in the Estimating category was shown to be 45 percent. This was attributed to an underestimate not only of the missile cost but also of the fire unit cost and to increases stemming from the need for U.S. source qualification for parts that will be manufactured in Europe. This duplication is dictated by the U.S. policy that forbids any weapon destined for the U.S. armed forces to be solely dependent on foreign suppliers. A 2 percent cost increase, shown in the Engineering category was due to the change in the system carrier from the GOER to the M-109 vehicle. An overrun of 7 percent was blamed on the contractor for growth in the cost of the technical transfer, fabrication, and test contract. The Support category recorded a −1 percent change due to a reduction in initial spares.

Program Acquisition Cost
(Costs in $ millions)

	Base Yr (FY 75) $		Cur Yr (FY 79) $		Then Year $	
	Cost	% of DE	Cost	% of DE	Cost	% of DE
DEVELOPMENT						
DEV ESTIMATE	160.2	100.0	204.8	100.0	177.3	100.0
VARIANCE:						
Estimating	8.6	5.4	11.0	5.4	11.2	6.3
Over/underrun	60.8	38.0	77.7	38.0	84.9	47.9
(Pgm changes)	(69.4)	(43.3)	(88.7)	(43.3)	(96.1)	(54.2)
Economic					3.0	1.7
TOT VARIANCE	69.4	43.3	88.7	43.3	99.1	55.9
CUR ESTIMATE	229.6	143.3	293.6	143.3	276.4	155.9
PROCUREMENT						
DEV ESTIMATE	677.8	100.0	878.2	100.0	942.2	100.0
VARIANCE:						
Quantity	19.2	2.8	24.9	2.8	32.1	3.4
Schedule	.0	.0	.0	.0	78.6	8.3
Engineering	19.3	2.8	25.0	2.8	28.0	3.0
Support	-7.6	-1.1	-9.8	-1.1	-12.3	-1.3
Estimating	366.7	54.1	475.1	54.1	498.6	52.9
(Pgm changes)	(397.6)	(58.7)	(515.2)	(58.7)	(625.0)	(66.3)
Economic					85.5	9.1
TOT VARIANCE	397.6	58.7	515.2	58.7	710.5	75.4
CUR ESTIMATE	1075.4	158.7	1393.4	158.7	1652.7	175.4
MIL CONST						
DEV ESTIMATE	.0	.0	.0	.0	.0	.0
VARIANCE:						
TOT VARIANCE	.0	.0	.0	.0	.0	.0
CUR ESTIMATE	.0	.0	.0	.0	.0	.0
TOT PROGRAM						
DEV ESTIMATE	838.0	100.0	1083.1	100.0	1119.5	100.0
VARIANCE:						
Quantity	19.2	2.3	24.9	2.3	32.1	2.9
Schedule	.0	.0	.0	.0	78.6	7.0
Engineering	19.3	2.3	25.0	2.3	28.0	2.5
Support	-7.6	-.9	-9.8	-.9	-12.3	-1.1
Estimating	375.3	44.8	486.1	44.9	509.8	45.5
Over/underrun	60.8	7.3	77.7	7.2	84.9	7.6
(Pgm changes)	(467.0)	(55.7)	(603.9)	(55.8)	(721.1)	(64.4)
Economic					88.5	7.9
TOT VARIANCE	467.0	55.7	603.9	55.8	809.6	72.3
CUR ESTIMATE	1305.0	155.7	1687.0	155.8	1929.1	172.3

Cannon Launched Guided Projectile (CLGP) "Copperhead"

The March 1978 Current Estimate for the Army's cannon-launched guided-projectile program showed a net decrease of 8 percent since full-scale development began in July 1975. The cost decrease stemmed from an 11 percent decline in cost due to a reduction in quantity. In terms of the buy program as initially proposed, there had been a 4 percent increase in the program cost. This was the net result of a 2 percent decrease in Schedule costs, 1 percent increases each in Engineering and Support, and a 4 percent increase in the Estimating category. The latter increase was attributed to underestimates of the tooling requirements. The Support increase was caused by reprogramming of tests for the basic program requirement. The 1 percent increase in Engineering costs was due to technical problems and alternative, backup designs for the fuze and other components. A small part of the Schedule reduction was in the procurement account—elimination of the "educational buy" and a schedule adjustment—but the bulk of it was in the development account. It was attributed to Congressional reductions in the funding for FY 1976, a budget shortfall in FY 1978 to 1980, and an FY 1978 funding delay. Although the amount involved is not great, it is interesting to note that in other SARs, instances of schedule stretchout due to reduced annual funding customarily were translated into cost *increases*.

CLGP (Copperhead)

Program Acquisition Cost
(Costs in $ millions)

	Base Yr (FY 75) $		Cur Yr (FY 79) $		Then Year $	
	Cost	% of DE	Cost	% of DE	Cost	% of DE
DEVELOPMENT						
DEV ESTIMATE	104.9	100.0	134.1	100.0	118.2	100.0
VARIANCE:						
Schedule	-7.2	-6.9	-9.2	-6.9	-7.6	-6.4
Engineering	6.7	6.4	8.6	6.4	9.5	8.0
Support	8.0	7.6	10.2	7.6	10.0	8.5
Estimating	2.9	2.8	3.7	2.8	4.0	3.4
Other changes	1.4	1.3	1.8	1.3	1.9	1.6
(Pgm changes)	(11.8)	(11.2)	(15.1)	(11.2)	(17.8)	(15.1)
Economic					1.9	1.6
TOT VARIANCE	11.8	11.2	15.1	11.2	19.7	16.7
CUR ESTIMATE	116.7	111.2	149.2	111.2	137.9	116.7
PROCUREMENT						
DEV ESTIMATE	738.0	100.0	956.3	100.0	1122.5	100.0
VARIANCE:						
Quantity	-94.9	-12.9	-123.0	-12.9	-126.1	-11.2
Schedule	-9.3	-1.3	-12.1	-1.3	-13.4	-1.2
Estimating	28.9	3.9	37.4	3.9	41.7	3.7
(Pgm changes)	(-75.3)	(-10.2)	(-97.6)	(-10.2)	(-97.8)	(-8.7)
Economic					59.2	5.3
TOT VARIANCE	-75.3	-10.2	-97.6	-10.2	-38.6	-3.4
CUR ESTIMATE	662.7	89.8	858.7	89.8	1083.9	96.6
MIL CONST						
DEV ESTIMATE	.0	.0	.0	.0	.0	.0
VARIANCE:						
TOT VARIANCE	.0	.0	.0	.0	.0	.0
CUR ESTIMATE	.0	.0	.0	.0	.0	.0
TOT PROGRAM						
DEV ESTIMATE	842.9	100.0	1090.4	100.0	1240.7	100.0
VARIANCE:						
Quantity	-94.9	-11.3	-123.0	-11.3	-126.1	-10.2
Schedule	-16.5	-2.0	-21.3	-1.9	-21.0	-1.7
Engineering	6.7	.8	8.6	.8	9.5	.8
Support	8.0	.9	10.2	.9	10.0	.8
Estimating	31.8	3.8	41.2	3.8	45.7	3.7
Other changes	1.4	.2	1.8	.2	1.9	.2
(Pgm changes)	(-63.5)	(-7.5)	(-82.5)	(-7.6)	(-80.0)	(-6.4)
Economic					61.1	4.9
TOT VARIANCE	-63.5	-7.5	-82.5	-7.6	-18.9	-1.5
CUR ESTIMATE	779.4	92.5	1007.9	92.4	1221.8	98.5

DIVAD Gun

The Division Air Defense (DIVAD) Gun program received its DSARC II go-ahead in October 1977. Its March 1978 SAR showed total cost growth of 4 percent, most of it due to a quantity increase. According to the SAR, there was no increase in the equipment account; the increase was attributable to ammunition alone. Excluding this "Quantity" increase, the cost growth was only 1 percent—all of it in the Estimating category. This program was less than a year old at the time of our data collection, however, and more growth may be expected. In fact, the SAR mentioned that these costs assumed a benign environment; requirements for an ECM environment are to be submitted at a later date.

The chassis for this self-propelled gun is an obsolescent M-48 tank which is government-furnished equipment. The ammunition is currently of European manufacture and the program costs included European Technology Transfer. The costs of producing the DIVAD Gun ammunition reflected total U.S. production of the ammunition.

It is interesting to point out that this development contract is of the firm fixed price "best effort" variety which features a 29-month "hands off" competitive development. The initial production contract for approximately 200 fire units will go to the winner of the competitive shoot. There then will be competitive follow-on production of the remaining 418 units.

DIVAD Gun

Program Acquisition Cost
(Costs in $ millions)

	Base Yr (FY 78) $		Cur Yr (FY 79) $		Then Year $	
	Cost	% of DE	Cost	% of DE	Cost	% of DE
DEVELOPMENT						
DEV ESTIMATE	162.9	100.0	173.0	100.0	184.7	100.0
VARIANCE:						
TOT VARIANCE	.0	.0	.0	.0	.0	.0
CUR ESTIMATE	162.9	100.0	173.0	100.0	184.7	100.0
PROCUREMENT						
DEV ESTIMATE	2043.4	100.0	2167.7	100.0	3001.1	100.0
VARIANCE:						
Quantity	59.5	2.9	63.1	2.9	64.1	2.1
Estimating	31.6	1.5	33.5	1.5	34.0	1.1
(Pgm changes)	(91.1)	(4.5)	(96.6)	(4.5)	(98.1)	(3.3)
TOT VARIANCE	91.1	4.5	96.6	4.5	98.1	3.3
CUR ESTIMATE	2134.5	104.5	2264.3	104.5	3099.2	103.3
MIL CONST						
DEV ESTIMATE	.0	.0	.0	.0	.0	.0
VARIANCE:						
TOT VARIANCE	.0	.0	.0	.0	.0	.0
CUR ESTIMATE	.0	.0	.0	.0	.0	.0
TOT PROGRAM						
DEV ESTIMATE	2206.3	100.0	2340.7	100.0	3185.8	100.0
VARIANCE:						
Quantity	59.5	2.7	63.1	2.7	64.1	2.0
Estimating	31.6	1.4	33.5	1.4	34.0	1.1
(Pgm changes)	(91.1)	(4.1)	(96.6)	(4.1)	(98.1)	(3.1)
TOT VARIANCE	91.1	4.1	96.6	4.1	98.1	3.1
CUR ESTIMATE	2297.4	104.1	2437.3	104.1	3283.9	103.1

M-198 Howitzer

Although the engineering development for the Army's M-198 Howitzer began in FY 1971, the first SAR was not published until January 1976, six months before the scheduled DSARC III. The March 1978 Current Estimate was 13 percent above its Development Estimate; however, this understated its actual cost growth because the Current Estimate included a 22 percent reduction in cost due to a temporary decrease in the programmed quantity—until requirement studies were completed. Thus, in terms of the original quantity, the howitzer program had a cost increase of 35 percent. The bulk of it was recorded in the Estimating category.

The initial production of 49 howitzers features a competition between the Rock Island Arsenal and private industry for integration and final assembly and manufacture of the recoil mechanisms. The Marine Corps intends to procure the M-198 Howitzer also, but the SAR included only the Army costs of the contract.

M-198 Howitzer

Program Acquisition Cost
(Costs in $ millions)

	Base Yr (FY 72) $		Cur Yr (FY 79) $		Then Year $	
	Cost	% of DE	Cost	% of DE	Cost	% of DE
DEVELOPMENT						
DEV ESTIMATE	30.9	100.0	49.4	100.0	32.6	100.0
VARIANCE:						
Schedule	1.4	4.5	2.2	4.5	1.6	4.9
Engineering	1.4	4.5	2.2	4.5	1.8	5.5
Support	4.5	14.6	7.2	14.6	7.2	22.1
Estimating	6.0	19.4	9.6	19.4	6.6	20.2
(Pgm changes)	(13.3)	(43.0)	(21.2)	(43.0)	(17.2)	(52.8)
Economic					.3	.9
TOT VARIANCE	13.3	43.0	21.2	43.0	17.5	53.7
CUR ESTIMATE	44.2	143.0	70.6	143.0	50.1	153.7
PROCUREMENT						
DEV ESTIMATE	80.2	100.0	131.8	100.0	89.3	100.0
VARIANCE:						
Quantity	-24.2	-30.2	-39.8	-30.2	-41.6	-46.6
Schedule	1.4	1.7	2.3	1.7	9.2	10.3
Support	-1.8	-2.2	-3.0	-2.2	-1.6	-1.8
Estimating	26.3	32.8	43.2	32.8	44.3	49.6
(Pgm changes)	(1.7)	(2.1)	(2.8)	(2.1)	(10.3)	(11.5)
Economic					53.3	59.7
TOT VARIANCE	1.7	2.1	2.8	2.1	63.6	71.2
CUR ESTIMATE	81.9	102.1	134.6	102.1	152.9	171.2
MIL CONST						
DEV ESTIMATE	.0	.0	.0	.0	.0	.0
VARIANCE:						
TOT VARIANCE	.0	.0	.0	.0	.0	.0
CUR ESTIMATE	.0	.0	.0	.0	.0	.0
TOT PROGRAM						
DEV ESTIMATE	111.1	100.0	181.2	100.0	121.9	100.0
VARIANCE:						
Quantity	-24.2	-21.8	-39.8	-22.0	-41.6	-34.1
Schedule	2.8	2.5	4.5	2.5	10.8	8.9
Engineering	1.4	1.3	2.2	1.2	1.8	1.5
Support	2.7	2.4	4.2	2.3	5.6	4.6
Estimating	32.3	29.1	52.8	29.1	50.9	41.8
(Pgm changes)	(15.0)	(13.5)	(24.0)	(13.3)	(27.5)	(22.6)
Economic					53.6	44.0
TOT VARIANCE	15.0	13.5	24.0	13.3	81.1	66.5
CUR ESTIMATE	126.1	113.5	205.3	113.3	203.0	166.5

NAVY PROGRAMS

F-18

A derivative of Northrop's YF-17 prototype entry in the lightweight fighter competition of the mid-70s, the Navy's F-18 is a twin-engined, highly maneuverable fighter aircraft which will be armed with AIM-9L Sidewinder and AIM-7F Sparrow missiles and an M-61 20mm gun. Full-scale development was authorized in December 1975.

The F-18 program had experienced cost growth of 3 percent by March 1978, with a program stretchout accounting for two-thirds of the increase. The rest was attributed to the Estimating category and a small (−.5 percent) reduction in Support.

F-18

PROGRAM ACQUISITION COST
(Costs in $ millions)

	Base Yr (FY 75) $		Cur Yr (FY 79) $		Then Year $	
	Cost	% of DE	Cost	% of DE	Cost	% of DE
DEVELOPMENT						
DEV ESTIMATE	1437.7	100.0	1838.1	100.0	1834.4	100.0
VARIANCE:						
Schedule	8.6	.6	11.0	.6	13.0	.7
Engineering	15.2	1.1	19.4	1.1	22.5	1.2
Estimating	96.1	6.7	122.9	6.7	146.3	8.0
(Pgm changes)	(119.9)	(8.3)	(153.3)	(8.3)	(181.8)	(9.9)
Economic					10.2	.6
TOT VARIANCE	119.9	8.3	153.3	8.3	192.0	10.5
CUR ESTIMATE	1557.6	108.3	1991.4	108.3	2026.4	110.5
PROCUREMENT						
DEV ESTIMATE	6560.9	100.0	8501.2	100.0	11012.6	100.0
VARIANCE:						
Schedule	160.1	2.4	207.4	2.4	296.7	2.7
Engineering	-7.0	-.1	-9.1	-.1	-11.0	-.1
Support	-38.8	-.6	-50.3	-.6	-78.7	-.7
Estimating	-8.3	-.1	-10.8	-.1	-13.8	-.1
(Pgm changes)	(106.0)	(1.6)	(137.3)	(1.6)	(193.2)	(1.8)
Economic					1034.2	9.4
TOT VARIANCE	106.0	1.6	137.3	1.6	1227.4	11.1
CUR ESTIMATE	6666.9	101.6	8638.5	101.6	12240.0	111.1
MIL CONST						
DEV ESTIMATE	18.0	100.0	21.4	100.0	28.3	100.0
VARIANCE:						
Schedule	.0	.0	.0	.0	1.6	5.7
Estimating	.8	4.4	1.0	4.4	1.0	3.5
(Pgm changes)	(.8)	(4.4)	(1.0)	(4.4)	(2.6)	(9.2)
Economic					2.6	9.2
TOT VARIANCE	.8	4.4	1.0	4.4	5.2	18.4
CUR ESTIMATE	18.8	104.4	22.4	104.4	33.5	118.4
TOT PROGRAM						
DEV ESTIMATE	8016.6	100.0	10360.8	100.0	12875.3	100.0
VARIANCE:						
Schedule	168.7	2.1	218.4	2.1	311.3	2.4
Engineering	8.2	.1	10.4	.1	11.5	.1
Support	-38.8	-.5	-50.3	-.5	-78.7	-.6
Estimating	88.6	1.1	113.1	1.1	133.5	1.0
(Pgm changes)	(226.7)	(2.8)	(291.6)	(2.8)	(377.6)	(2.9)
Economic					1047.0	8.1
TOT VARIANCE	226.7	2.8	291.6	2.8	1424.6	11.1
CUR ESTIMATE	8243.3	102.8	10652.4	102.8	14299.9	111.1

LAMPS III

The Navy's Light Airborne Multi-Purpose System III (LAMPS III) uses helicopters deployed on cruisers, destroyers, and frigates to extend the surveillance range and attack capabilities of these surface ships. LAMPS helicopters armed with Mk 46 torpedoes are to be launched in response to ASW detections made by sensors of the ships and aircraft in the task force. In an antiship role, LAMPS helicopters provide initial detection, surveillance and targeting data information to the combat ships in the force. The LAMPS III program costs include the helicopters and also the ship systems and installation charges for existing ships. For new ships, the LAMPS equipment will be produced and installed as a part of the ship construction costs without charge to this program.

The LAMPS III program experienced 30 percent overall cost growth from the time of its Development Estimate in FY 1974 to March 1978. During the period, however, the number of ship equipment sets had been cut in half,[7] from 116 to 58, resulting in a 12 percent reduction in the LAMPS III program costs in the Quantity category. Following our methodology we added the 12 percent back in to establish cost growth based on the original quantity, thereby arriving at an adjusted cost rise of 42 percent. A small part of this growth was due to a schedule slip. The major increases were in Engineering and Support, which increased program costs by 16 percent and 15 percent, respectively. Underestimates contributed another 10 percent to program growth.

About one-half of the Engineering increase was attributed to aircraft specification changes. Another half was due to procurement and installation of ship system support equipment, which were omitted from the original estimate.

Some of the increases in the Support category were attributed to the addition of trainer facilities and added reliability and maintainability requirements, computer software, and testing criteria. The largest items in the Support category, however, were "aircraft procurement" and "ship system procurement and installation."

---

[7]The number of production helicopters, 204, remained unchanged.

LAMPS III

Program Acquisition Cost
(Costs in $ millions)

	Base Yr (FY 76) $		Cur Yr (FY 79) $		Then Year $	
	Cost	% of DE	Cost	% of DE	Cost	% of DE
DEVELOPMENT						
DEV ESTIMATE	394.7	100.0	473.7	100.0	442.8	100.0
VARIANCE:						
Quantity	-4.9	-1.2	-5.9	-1.2	-4.9	-1.1
Schedule	12.1	3.1	14.5	3.1	23.0	5.2
Engineering	89.7	22.7	107.7	22.7	122.0	27.6
Support	53.6	13.6	64.3	13.6	72.8	16.4
Estimating	34.5	8.7	41.4	8.7	46.9	10.6
(Pgm changes)	(185.0)	(46.9)	(222.0)	(46.9)	(259.8)	(58.7)
Economic					19.2	4.3
TOT VARIANCE	185.0	46.9	222.0	46.9	279.0	63.0
CUR ESTIMATE	579.7	146.9	695.8	146.9	721.8	163.0
PROCUREMENT						
DEV ESTIMATE	1443.6	100.0	1739.0	100.0	2095.7	100.0
VARIANCE:						
Quantity	-208.7	-14.5	-251.4	-14.5	-205.3	-9.8
Schedule	13.4	.9	16.1	.9	175.5	8.4
Engineering	200.2	13.9	241.2	13.9	358.4	17.1
Support	217.0	15.0	261.4	15.0	370.0	17.7
Estimating	142.5	9.9	171.7	9.9	240.1	11.5
(Pgm changes)	(364.4)	(25.2)	(439.0)	(25.2)	(938.7)	(44.8)
Economic					136.0	6.5
TOT VARIANCE	364.4	25.2	439.0	25.2	1074.7	51.3
CUR ESTIMATE	1808.0	125.2	2177.9	125.2	3170.4	151.3
MIL CONST						
DEV ESTIMATE	.0	.0	.0	.0	.0	.0
VARIANCE:						
Schedule	.0	.0	.0	.0	1.7	.0
Support	9.0	.0	10.5	.0	13.4	.0
(Pgm changes)	(9.0)	(.0)	(10.5)	(.0)	(15.1)	(.0)
Economic					.3	.0
TOT VARIANCE	9.0	.0	10.5	.0	15.4	.0
CUR ESTIMATE	9.0	.0	10.5	.0	15.4	.0
TOT PROGRAM						
DEV ESTIMATE	1838.3	100.0	2212.7	100.0	2538.5	100.0
VARIANCE:						
Quantity	-213.6	-11.6	-257.3	-11.6	-210.2	-8.3
Schedule	25.5	1.4	30.7	1.4	200.2	7.9
Engineering	289.9	15.8	348.8	15.8	480.4	18.9
Support	279.6	15.2	336.3	15.2	456.2	18.0
Estimating	177.0	9.6	213.1	9.6	287.0	11.3
(Pgm changes)	(558.4)	(30.4)	(671.5)	(30.3)	(1213.6)	(47.8)
Economic					155.5	6.1
TOT VARIANCE	558.4	30.4	671.5	30.3	1369.1	53.9
CUR ESTIMATE	2396.7	130.4	2884.3	130.3	3907.6	153.9

Aegis

Aegis is an ECM-resistant fire control/tracking system to be installed on combat ships to counter high density missile attacks against the fleet. It features long range automatic detection and track of multiple targets. The program costs are limited to R&D; procurement will be included in the ship construction costs. Overall, cost growth amounted to 24 percent since its FY 1970 engineering development go-ahead. The SM-2 Standard Missile is the primary weapon to be used with the Aegis system. The Standard Missile is a separate development.

The largest cost growth occurred in the Engineering category (12 percent). The original program was revised and reoriented with an increase in scope. Funds are included to "initiate" an effort to provide a vertical launch capability. There are also some funds for the transition from development to manufacturing and for in-service support and maintenance of the system.

The Schedule category accounted for an 8 percent cost rise due to stretchouts of the schedule. It was stated in the SAR that "total funding constraints on the Navy" caused Aegis funds to be cut in FYs 1971, 1973, and 1974. Congress specifically cut Aegis funds in FY 1975 and a similar cut in the budget for the Standard Missile had an adverse effect on the timing of Aegis tests.

There was a 3 percent cost increase, in the Support category, to incorporate availability and operational improvements into the operational system configuration following completion of full-scale development. The additional support funds also are intended to continue the engineering support of the transition from development to manufacturing and to initiate government control and maintenance of pertinent tactical computer programs.

Aegis

Program Acquisition Cost
(Costs in $ millions)

	Base Yr (FY 70) $		Cur Yr (FY 79) $		Then Year $	
	Cost	% of DE	Cost	% of DE	Cost	% of DE
DEVELOPMENT						
DEV ESTIMATE	394.2	100.0	693.3	100.0	427.6	100.0
VARIANCE:						
Schedule	32.7	8.3	57.5	8.3	52.9	12.4
Engineering	48.9	12.4	86.0	12.4	71.7	16.8
Support	13.3	3.4	23.4	3.4	19.2	4.5
(Pgm changes)	(94.9)	(24.1)	(166.9)	(24.1)	(143.8)	(33.6)
Economic					23.9	5.6
TOT VARIANCE	94.9	24.1	166.9	24.1	167.7	39.2
CUR ESTIMATE	489.1	124.1	860.3	124.1	595.3	139.2
PROCUREMENT						
DEV ESTIMATE	.0	.0	.0	.0	.0	.0
VARIANCE:						
TOT VARIANCE	.0	.0	.0	.0	.0	.0
CUR ESTIMATE	.0	.0	.0	.0	.0	.0
MIL CONST						
DEV ESTIMATE	.0	.0	.0	.0	.0	.0
VARIANCE:						
TOT VARIANCE	.0	.0	.0	.0	.0	.0
CUR ESTIMATE	.0	.0	.0	.0	.0	.0
TOT PROGRAM						
DEV ESTIMATE	394.2	100.0	693.3	100.0	427.6	100.0
VARIANCE:						
Schedule	32.7	8.3	57.5	8.3	52.9	12.4
Engineering	48.9	12.4	86.0	12.4	71.7	16.8
Support	13.3	3.4	23.4	3.4	19.2	4.5
(Pgm changes)	(94.9)	(24.1)	(166.9)	(24.1)	(143.8)	(33.6)
Economic					23.9	5.6
TOT VARIANCE	94.9	24.1	166.9	24.1	167.7	39.2
CUR ESTIMATE	489.1	124.1	860.3	124.1	595.3	139.2

CAPTOR[8]

The CAPTOR weapon system consists of a detection and control unit linked to a deep-water mine capable of launching a specially modified Mk 46 torpedo. Although the DSARC II for this system was held in FY 1971, the first SAR was not published until December 1975, at DSARC III. By March 1978, the total cost growth in the CAPTOR program amounted to 110 percent, if we include the 2 percent reduction in cost due to a 4 percent reduction in the weapon buy. In terms of the original quantity, CAPTOR had experienced a 112 percent net cost growth.

Estimating problems accounted for a 41 percent growth in CAPTOR costs. This was attributed to general underestimation of the program and, more specifically, to the choice of a 90 percent cost-quantity curve. Most of this error was corrected by the simple expedient of employing a 95 percent curve. The Engineering category, which had experienced 36 percent growth, had a significant jump in FY 1977 as more tests and added reliability and quality assurance provisions were incorporated into the program. The Support category showed a 24 percent increase due to additional tests and the cost of qualifying a second source. Also, additional training dummy mines and the cost of 7 storage magazines were added to the cost of this program. Cost growth of 12 percent, recorded in the Schedule category, was caused by a lower production rate than originally planned and a gap between development and production of 20 months, compared with the originally planned 12-month gap.

[8]enCAPsulated TORpedo.

CAPTOR

Program Acquisition Cost
(Costs in $ millions)

	Base Yr (FY 71) $		Cur Yr (FY 79) $		Then Year $	
	Cost	% of DE	Cost	% of DE	Cost	% of DE
DEVELOPMENT						
DEV ESTIMATE	85.5	100.0	142.9	100.0	85.5	100.0
VARIANCE:						
Quantity	-2.4	-2.8	-4.0	-2.8	-2.4	-2.8
Schedule	2.9	3.4	4.8	3.4	2.9	3.4
Engineering	.2	.2	.3	.2	.3	.4
Estimating	-.1	-.1	-.2	-.1	-.1	-.1
(Pgm changes)	(.6)	(.7)	(1.0)	(.7)	(.7)	(.8)
Economic					13.9	16.3
TOT VARIANCE	.6	.7	1.0	.7	14.6	17.1
CUR ESTIMATE	86.1	100.7	143.9	100.7	100.1	117.1
PROCUREMENT						
DEV ESTIMATE	215.8	100.0	368.3	100.0	241.4	100.0
VARIANCE:						
Quantity	-4.0	-1.9	-6.8	-1.9	2.2	.9
Schedule	34.4	15.9	58.7	15.9	103.0	42.7
Engineering	107.2	49.7	182.9	49.7	218.1	90.3
Support	65.5	30.4	111.8	30.4	147.7	61.2
Estimating	124.2	57.6	212.0	57.6	242.1	100.3
Over/underrun	.1	.0	.2	.0	.1	.0
(Pgm changes)	(327.4)	(151.7)	(558.7)	(151.7)	(713.2)	(295.4)
Economic					182.2	75.5
TOT VARIANCE	327.4	151.7	558.7	151.7	895.4	370.9
CUR ESTIMATE	543.2	251.7	927.0	251.7	1136.8	470.9
MIL CONST						
DEV ESTIMATE	2.3	100.0	4.2	100.0	2.3	100.0
VARIANCE:						
Support	5.3	230.4	9.6	230.4	10.4	452.2
Estimating	-.3	-13.0	-.5	-13.0	-.5	-21.7
(Pgm changes)	(5.0)	(217.4)	(9.1)	(217.4)	(9.9)	(430.4)
Economic					1.3	56.5
TOT VARIANCE	5.0	217.4	9.1	217.4	11.2	487.0
CUR ESTIMATE	7.3	317.4	13.3	317.4	13.5	587.0
TOT PROGRAM						
DEV ESTIMATE	303.6	100.0	515.4	100.0	329.2	100.0
VARIANCE:						
Quantity	-6.4	-2.1	-10.8	-2.1	-.2	-.1
Schedule	37.3	12.3	63.6	12.3	105.9	32.2
Engineering	107.4	35.4	183.3	35.6	218.4	66.3
Support	70.8	23.3	121.4	23.6	158.1	48.0
Estimating	123.8	40.8	211.2	41.0	241.5	73.4
Over/underrun	.1	.0	.2	.0	.1	.0
(Pgm changes)	(333.0)	(109.7)	(568.8)	(110.4)	(723.8)	(219.9)
Economic					197.4	60.0
TOT VARIANCE	333.0	109.7	568.8	110.4	921.2	279.8
CUR ESTIMATE	636.6	209.7	1084.2	210.4	1250.4	379.8

Harpoon

The Navy's Harpoon missile is designed for attacking ships at sea. Launched from surface ships, submarines, or P-3C aircraft, the Harpoon acquires and homes on its target by means of its on-board active radar.

The cost variance shown in the current Harpoon SARs is measured against a Development Estimate derived in 1975 when the Harpoon program was radically restructured in the interval between DSARC II and DSARC III. As one of the ground rules of the present study is to use the baseline estimate at DSARC II, we based our cost growth calculations on the program CE that was projected in the March 1973 SAR, just prior to DSARC II. In the following year the missile buy was reduced to less than half the original quantity and in FY 1975, in time for DSARC III, the present Development Estimate was established as the SAR baseline.

Our DSARC II cost base is slightly higher than the official cost baseline. As a result, our overall program cost growth figure is 2 percent instead of the 9 percent that would be calculated using the DE shown in the current SAR. On the other hand, when we delete the cost saving attributed to the cut in quantity, our adjusted estimate of cost growth is 24 percent, compared with 19 percent using the official SAR cost base.

The net 21 percent drop in costs we show under Quantity primarily reflects a drastic reduction in the missile buy. However, it also includes a partially offsetting cost increase in FY 1975 due to an increase in quantity. This was not an increase in the number of missiles but an increase in the number of capsules and cannisters, and an increase in the "exercise section."

The 2 percent cost growth, shown in the Schedule category, was attributed to budget constraints. According to the SAR, 20 missiles were deleted from the FY 1977 procurement quantity of 245 to offset the cost of reliability improvements incorporated into the FY 1977 contract. Congress subsequently cut 81 missiles from FY 1978 procurement. Capsule procurement also was delayed because of budget constraints. The delayed IOC for the P-3C aircraft, a proposed launching platform for the Harpoon, was blamed on the deletion of modification funds. This program will be delayed until 9 new production aircraft configured with the Harpoon aircraft command and launcher system (HACLS) roll off the assembly line.

The Support category displayed an increase of 1 percent, and Estimating errors added 3 percent to the program cost. The major increase was recorded in the Engineering category (17 percent). This increase was attributed to an improved radar seeker to counter ECM, greater complexity in the missile components, adding the "encapsulated Harpoon," and the addition of a cannister/launcher system for the naval patrol vessels included in the program.

Harpoon

(DE at DSARC II) Escalation omitted
Program Acquisition Cost
(Costs in $ millions)

	Base Yr (FY 70) $		Cur Yr (FY 79) $	
	Cost	% of DE	Cost	% of DE
DEVELOPMENT				
DEV ESTIMATE	216.5	100.0	380.8	100.0
VARIANCE:				
Quantity	-4.0	-1.8	-7.0	-1.8
Engineering	77.6	35.8	136.5	35.8
Support	-2.0	-.9	-3.5	-.9
Other changes	13.6	6.3	23.9	6.3
(Pgm changes)	(85.2)	(39.4)	(149.9)	(39.4)
TOT VARIANCE	85.2	39.4	149.9	39.4
CUR ESTIMATE	301.7	139.4	530.7	139.4
PROCUREMENT				
DEV ESTIMATE	629.2	100.0	1122.6	100.0
VARIANCE:				
Quantity	-175.3	-27.9	-312.8	-27.9
Schedule	18.9	3.0	33.7	3.0
Engineering	70.0	11.1	124.9	11.1
Support	14.1	2.2	25.2	2.2
Estimating	22.1	3.5	39.4	3.5
Other changes	-13.6	-2.2	-24.3	-2.2
(Pgm changes)	(-63.8)	(-10.1)	(-113.8)	(-10.1)
TOT VARIANCE	-63.8	-10.1	-113.8	-10.1
CUR ESTIMATE	565.4	89.9	1008.7	89.9
MIL CONST				
DEV ESTIMATE	.0	.0	.0	.0
VARIANCE:				
TOT VARIANCE	.0	.0	.0	.0
CUR ESTIMATE	.0	.0	.0	.0
TOT PROGRAM				
DEV ESTIMATE	845.7	100.0	1503.3	100.0
VARIANCE:				
Quantity	-179.3	-21.2	-319.8	-21.3
Schedule	18.9	2.2	33.7	2.2
Engineering	147.6	17.5	261.4	17.4
Support	12.1	1.4	21.6	1.4
Estimating	22.1	2.6	39.4	2.6
Other changes	.0	.0	-.3	.0
(Pgm changes)	(21.4)	(2.5)	(36.0)	(2.4)
TOT VARIANCE	21.4	2.5	36.0	2.4
CUR ESTIMATE	867.1	102.5	1539.4	102.4

AIM-9L (Sidewinder)

This follow-on development to the Navy's basic Sidewinder missile was initiated in FY 1971. Our analysis includes the combined Air Force and Navy shares of this program. Despite abnormally high cost growth, the improved Sidewinder appears to be a successful program judging from the fact that the buy quantities increased by 60 percent. This resulted in cost growth of 55 percent. Adjusting the estimate to the original quantity, however, still leaves a total cost growth of 98 percent over the Development Estimate. The major contributor to this cost rise was the Estimating category, amounting to 53 percent of the baseline cost. The explanation given for the cost estimating error was simply "refined production pricing estimates." There also was a note in the SAR indicating that some development money from this program would be used to begin research on the AIM-9M missile which, it is hoped, will be able to distinguish targets from "hot" backgrounds. An increase of 13 percent, shown in the Engineering category, was for improving the performance to counter an expanded threat, i.e., by means of a more complex fuze design. The SAR also mentioned a component engineering product improvement program to reduce life cycle costs. The 15 percent increase shown in the Schedule category attached no blame to budget constraints. Instead the SAR mentioned technical difficulties, slippage needed to comply with the fly-before-buy concept, the use of two contractors instead of one, and added vendor qualification which slipped the production start from FY 1973 to FY 1976. The stretchout and the requirement for new test equipment was the stated cause of a 16 percent increase recorded in the Support category.

AIM-9L (Sidewinder)

Program Acquisition Cost[a]
(Costs in $ millions)

	Base Yr (FY 71) $		Cur Yr (FY 79) $		Then Year $	
	Cost	% of DE	Cost	% of DE	Cost	% of DE
DEVELOPMENT						
DEV ESTIMATE	13.4	100.0	22.4	100.0	13.8	100.0
VARIANCE:						
Quantity	8.6	64.2	14.4	64.2	9.3	67.4
Schedule	12.5	93.3	20.9	93.3	14.5	105.1
Engineering	19.5	145.5	32.6	145.5	27.5	199.3
Support	5.1	38.1	8.5	38.1	6.3	45.7
Estimating	5.4	40.3	9.0	40.3	9.1	65.9
Other changes	.4	3.0	.7	3.0	.5	3.6
(Pgm changes)	(51.5)	(384.3)	(86.1)	(384.3)	(67.2)	(487.0)
Economic					1.5	10.9
TOT VARIANCE	51.5	384.3	86.1	384.3	68.7	497.8
CUR ESTIMATE	64.9	484.3	108.5	484.3	82.5	597.8
PROCUREMENT						
DEV ESTIMATE	188.8	100.0	322.2	100.0	219.6	100.0
VARIANCE:						
Quantity	102.1	54.1	174.2	54.1	196.9	89.7
Schedule	18.8	10.0	32.1	10.0	37.5	17.1
Engineering	8.0	4.2	13.7	4.2	14.1	6.4
Support	27.4	14.5	46.8	14.5	56.2	25.6
Estimating	102.4	54.2	174.7	54.2	170.4	77.6
Other changes	-1.7	-.9	-2.9	-.9	-2.0	-.9
(Pgm changes)	(257.0)	(136.1)	(438.6)	(136.1)	(473.1)	(215.4)
Economic					76.2	34.7
TOT VARIANCE	257.0	136.1	438.6	136.1	549.3	250.1
CUR ESTIMATE	445.8	236.1	760.8	236.1	768.9	350.1
MIL CONST						
DEV ESTIMATE	.0	.0	.0	.0	.0	.0
VARIANCE:						
TOT VARIANCE	.0	.0	.0	.0	.0	.0
CUR ESTIMATE	.0	.0	.0	.0	.0	.0
TOT PROGRAM						
DEV ESTIMATE	202.2	100.0	344.6	100.0	233.4	100.0
VARIANCE:						
Quantity	110.7	54.7	188.6	54.7	206.2	88.3
Schedule	31.3	15.5	53.0	15.4	52.0	22.3
Engineering	27.5	13.6	46.2	13.4	41.6	17.8
Support	32.5	16.1	55.3	16.0	62.5	26.8
Estimating	107.8	53.3	183.8	53.3	179.5	76.9
Other changes	-1.3	-.6	-2.2	-.6	-1.5	-.6
(Pgm changes)	(308.5)	(152.6)	(524.7)	(152.3)	(540.3)	(231.5)
Economic					77.7	33.3
TOT VARIANCE	308.5	152.6	524.7	152.3	618.0	264.8
CUR ESTIMATE	510.7	252.6	869.2	252.3	851.4	364.8

[a] Navy and Air Force combined total

Tactical Towed Array Sonar (TACTAS) System

TACTAS, utilizing the AN/SQR-19 Sonar, will provide long range, passive detection, classification, and tracking capability to surface combat ships. Components include a large sonar array, shipboard electronics, and array handling equipment.

TACTAS passed its DSARC II review in August 1976. The Current Estimate in the March 1978 SAR indicated a saving of 30 percent under its Development Estimate, but this was accomplished by a 40 percent reduction in the number of ship sets.[9] In terms of the original quantity, TACTAS experienced cost growth of 5 percent, most of it because of schedule slippage. According to the SAR, funding deficiencies in fiscal 1977 and 1978 led to cost growth of 4 percent and slippage in development of 8 months. A Support increase (1 percent) reflected delivery delays, inadequate documentation, workarounds, and rescheduling.

The engineering development contract with GE was terminated in May 1978, without cancellation of the TACTAS program. The reason given for this action was to restructure the TACTAS program to reduce what was described as excessive technical risk.

[9]These are to be procured later with shipbuilding funds.

TACTAS

Program Acquisition Cost
(Costs in $ millions)

	Base Yr (FY 76) $ Cost	Base Yr (FY 76) $ % of DE	Cur Yr (FY 79) $ Cost	Cur Yr (FY 79) $ % of DE	Then Year $ Cost	Then Year $ % of DE
DEVELOPMENT						
DEV ESTIMATE	58.0	100.0	69.6	100.0	62.4	100.0
VARIANCE:						
Schedule	19.4	33.4	23.3	33.4	23.9	38.3
Support	3.1	5.3	3.7	5.3	3.8	6.1
Estimating	5.7	9.8	6.8	9.8	7.3	11.7
(Pgm changes)	(28.2)	(48.6)	(33.8)	(48.6)	(35.0)	(56.1)
Economic					4.1	6.6
TOT VARIANCE	28.2	48.6	33.8	48.6	39.1	62.7
CUR ESTIMATE	86.2	148.6	103.5	148.6	101.5	162.7
PROCUREMENT						
DEV ESTIMATE	368.6	100.0	444.0	100.0	538.7	100.0
VARIANCE:						
Quantity	-150.2	-40.7	-180.9	-40.7	-206.9	-38.4
Estimating	-6.8	-1.8	-8.2	-1.8	-9.7	-1.8
(Pgm changes)	(-157.0)	(-42.6)	(-189.1)	(-42.6)	(-216.6)	(-40.2)
Economic					36.9	6.8
TOT VARIANCE	-157.0	-42.6	-189.1	-42.6	-179.7	-33.4
CUR ESTIMATE	211.6	57.4	254.9	57.4	359.0	66.6
MIL CONST						
DEV ESTIMATE	.0	.0	.0	.0	.0	.0
VARIANCE:						
TOT VARIANCE	.0	.0	.0	.0	.0	.0
CUR ESTIMATE	.0	.0	.0	.0	.0	.0
TOT PROGRAM						
DEV ESTIMATE	426.6	100.0	513.6	100.0	601.1	100.0
VARIANCE:						
Quantity	-150.2	-35.2	-180.9	-35.2	-206.9	-34.4
Schedule	19.4	4.5	23.3	4.5	23.9	4.0
Support	3.1	.7	3.7	.7	3.8	.6
Estimating	-1.1	-.3	-1.3	-.3	-2.4	-.4
(Pgm changes)	(-128.8)	(-30.2)	(-155.3)	(-30.2)	(-181.6)	(-30.2)
Economic					41.0	6.8
TOT VARIANCE	-128.8	-30.2	-155.3	-30.2	-140.6	-23.4
CUR ESTIMATE	297.8	69.8	358.4	69.8	460.5	76.6

SURTASS

The Surveillance Towed Array Sensor System (SURTASS) is designed for mobile, long range passive surveillance in ocean areas of interest beyond the reach of the Navy's stationary surveillance arrays. It consists of three segments: The sonar segment (hydrophone array, handling equipment, and electronics), the communication/navigation segment (to determine array position and to relay acoustic data to shore stations), and the platform segment (a civilian-manned ship, T-AGOS). Development began in September 1975.

The SURTASS program cost rose 52 percent in less than 3 years. Estimating errors caused cost growth of 28 percent. Originally conceived as a ship of commercial standard design (a supply tug used in the petroleum industry) the T-AGOS has since been enhanced with greater endurance and the propulsion system has been quieted. Crew space was made more hospitable and private.

The above platform changes, plus increases in the communications equipment cost for a lightweight super high frequency (SHF) shipboard satellite terminal raised Engineering estimates by 18 percent.

Support costs rose 3 percent for increased spares and for increases in outfitting and post-delivery. An overrun by Hughes in the sonar segment accounted for an increase of 4 percent.

A 1-year slip in the program translated into a slight saving in constant dollar terms.

SURTASS

Program Acquisition Cost
(Costs in $ millions)

	Base Yr (FY 75) $		Cur Yr (FY 79) $		Then Year $	
	Cost	% of DE	Cost	% of DE	Cost	% of DE
DEVELOPMENT						
DEV ESTIMATE	59.4	100.0	75.9	100.0	64.0	100.0
VARIANCE:						
Schedule	3.2	5.4	4.1	5.4	4.2	6.6
Engineering	3.2	5.4	4.1	5.4	3.7	5.8
Support	.2	.3	.3	.3	.2	.3
Estimating	8.1	13.6	10.4	13.6	10.0	15.6
Over/underrun	7.2	12.1	9.2	12.1	8.8	13.8
(Pgm changes)	(21.9)	(36.9)	(28.0)	(36.9)	(26.9)	(42.0)
Economic					1.6	2.5
TOT VARIANCE	21.9	36.9	28.0	36.9	28.5	44.5
CUR ESTIMATE	81.3	136.9	103.9	136.9	92.5	144.5
PROCUREMENT						
DEV ESTIMATE	146.5	100.0	189.8	100.0	195.3	100.0
VARIANCE:						
Schedule	-3.9	-2.7	-5.1	-2.7	28.1	14.4
Engineering	33.6	22.9	43.5	22.9	51.2	26.2
Support	5.1	3.5	6.6	3.5	9.2	4.7
Estimating	49.7	33.9	64.4	33.9	74.9	38.4
(Pgm changes)	(84.5)	(57.7)	(109.5)	(57.7)	(163.4)	(83.7)
Economic					38.0	19.5
TOT VARIANCE	84.5	57.7	109.5	57.7	201.4	103.1
CUR ESTIMATE	231.0	157.7	299.3	157.7	396.7	203.1
MIL CONST						
DEV ESTIMATE	.0	.0	.0	.0	.0	.0
VARIANCE:						
TOT VARIANCE	.0	.0	.0	.0	.0	.0
CUR ESTIMATE	.0	.0	.0	.0	.0	.0
TOT PROGRAM						
DEV ESTIMATE	205.9	100.0	265.8	100.0	259.3	100.0
VARIANCE:						
Schedule	-.7	-.3	-1.0	-.4	32.3	12.5
Engineering	36.8	17.9	47.6	17.9	54.9	21.2
Support	5.3	2.6	6.9	2.6	9.4	3.6
Estimating	57.8	28.1	74.8	28.1	84.9	32.7
Over/underrun	7.2	3.5	9.2	3.5	8.8	3.4
(Pgm changes)	(106.4)	(51.7)	(137.5)	(51.7)	(190.3)	(73.4)
Economic					39.6	15.3
TOT VARIANCE	106.4	51.7	137.5	51.7	229.9	88.7
CUR ESTIMATE	312.3	151.7	403.3	151.7	489.2	188.7

Condor

The Condor program was undertaken in the mid-1960s to develop a long range standoff missile for attacking well-defined, high-value point targets. It was intended to be launched from A-6E aircraft, the missile's electro-optical TV guidance keeping a man in the loop to ensure precise guidance control. The Condor, however, had a checkered history: the IOC was slipped 8 years, performance reductions were accepted to keep costs down, and desired capabilities (such as the dual mode seeker) were eliminated. Reliability problems plagued the program and finally, in September 1976, Congress brought it to a close.

Although Condor's DSARC II took place in November of 1973, the DE in the Condor SAR is the same as the planning estimate made in 1966 and reaffirmed in 1970. Costs by FY 1977 had risen 26 percent above this estimate, but it should be noted that most of the increases preceded the DSARC II decision to go ahead with full-scale development in FY 1974. Using the Current Estimate cost projection made just prior to DSARC II as the baseline, to be consistent with the other programs in the sample, the Condor program actually ended at 22 percent below the estimate. This, however, is misleading. After we take out the effect of the cuts in missile quantity, the net saving amounts to 10 percent. It also is probable that a large share of the 5 percent saving in the Support area was made possible by the missile quantity reduction, and adjustment for this would reduce the apparent saving still further. A 5 percent saving was due to reductions in required performance, shown in Engineering. The 12 percent increase in the Schedule category plus the 1 percent overrun attributed to the contractor was offset by a 13 percent reduction in Estimating. A large part of the schedule slippage was attributed to insufficient funding in FY 1975 but, of course, the funding level may have been a reflection of a growing lack of confidence in the program.

Condor

(DE AT DSARC II) ESCALATION OMITTED
PROGRAM ACQUISITION COST
(Costs in $ millions)

	Base Yr (FY 70) $		Cur Yr (FY 79) $	
	Cost	% of DE	Cost	% of DE
DEVELOPMENT				
DEV ESTIMATE	238.7	100.0	419.8	100.0
VARIANCE:				
Quantity	-.6	-.3	-1.1	-.3
Schedule	14.9	6.2	26.2	6.2
Engineering	-22.7	-9.5	-39.9	-9.5
Estimating	-14.1	-5.9	-24.8	-5.9
(Pgm changes)	(-22.5)	(-9.4)	(-39.6)	(-9.4)
TOT VARIANCE	-22.5	-9.4	-39.6	-9.4
CUR ESTIMATE	216.2	90.6	380.3	90.6
PROCUREMENT				
DEV ESTIMATE	114.7	100.0	204.6	100.0
VARIANCE:				
Quantity	-43.4	-37.8	-77.4	-37.8
Schedule	28.1	24.5	50.1	24.5
Engineering	6.0	5.2	10.7	5.2
Support	-17.2	-15.0	-30.7	-15.0
Estimating	-32.4	-28.2	-57.8	-28.2
Over/underrun	2.7	2.4	4.8	2.4
(Pgm changes)	(-56.2)	(-49.0)	(-100.3)	(-49.0)
TOT VARIANCE	-56.2	-49.0	-100.3	-49.0
CUR ESTIMATE	58.5	51.0	104.4	51.0
MIL CONST				
DEV ESTIMATE	.0	.0	.0	.0
VARIANCE:				
TOT VARIANCE	.0	.0	.0	.0
CUR ESTIMATE	.0	.0	.0	.0
TOT PROGRAM				
DEV ESTIMATE	353.4	100.0	624.5	100.0
VARIANCE:				
Quantity	-44.0	-12.5	-78.5	-12.6
Schedule	43.0	12.2	76.3	12.2
Engineering	-16.7	-4.7	-29.2	-4.7
Support	-17.2	-4.9	-30.7	-4.9
Estimating	-46.5	-13.2	-82.6	-13.2
Over/underrun	2.7	.8	4.8	.8
(Pgm changes)	(-78.7)	(-22.3)	(-139.8)	(-22.4)
TOT VARIANCE	-78.7	-22.3	-139.8	-22.4
CUR ESTIMATE	274.7	77.7	484.6	77.6

New Programs

Three major Navy acquisition programs were included in our study which were too new in March 1978 to have yet experienced any cost changes. The programs and their DSARC II go-ahead dates follow.

Tomahawk	FY 1977
5-inch Guided Projectile	FY 1978
8-inch Guided Projectile	FY 1978

AIR FORCE PROGRAMS
A-10

The A-10 close air support aircraft was preceded by a competitive prototype hardware phase. In spite of this and its much-publicized design-to-cost goal, A-10 cost growth had by March 1978 reached 27 percent above the baseline estimate made in FY 1973, most of it occurring after DSARC III. Engineering cost variance for tactical aircraft customarily registers increases as avionics are upgraded over the acquisition program (and beyond) to offset the continual improvements in enemy anti-air capability, but the A-10's increase in that area (8 percent) is particularly noteworthy because its avionics were consciously held to an austere level in the original design. A two-seat version was deleted to keep costs in this program from registering an even higher increase.

Support cost variance recorded only a minor gain of 2 percent. However, some needed items (simulators) were deleted from the acquisition program, to be bought after the completion of the A-10 acquisition program. The primary cause for the A-10's cost growth—even in constant dollars—was schedule slippage, which increased program costs by 17 percent. The OSD decision in FY 1977 to hold production to a rate of 14 per month, rather than the planned rate of 20 per month, led to 15 additional months of production and this was blamed for over 90 percent of the rise in this category. Cost growth attributable to a change in the government's bargaining position (i.e., in this case from two competitors originally to sole source in the renegotiations) is supposed to be recorded as Estimating cost variance. Since this is difficult to identify, however, it is not unlikely that the unusually large Schedule cost variance was partly a reflection of the changed bargaining atmosphere.

A-10

Program Acquisition Cost
(Costs in $ millions)

	Base Yr (FY 70) $		Cur Yr (FY 79) $		Then Year $	
	Cost	% of DE	Cost	% of DE	Cost	% of DE
DEVELOPMENT						
DEV ESTIMATE	281.9	100.0	495.8	100.0	336.7	100.0
VARIANCE:						
Quantity	-14.4	-5.1	-25.3	-5.1	-18.9	-5.6
Schedule	10.6	3.8	18.6	3.8	15.1	4.5
Engineering	35.5	12.6	62.4	12.6	64.4	19.1
Support	11.5	4.1	20.2	4.1	17.8	5.3
Estimating	-14.8	-5.3	-26.0	-5.3	-16.1	-4.8
Other changes	22.8	8.1	40.1	8.1	28.8	8.6
(Pgm changes)	(51.2)	(18.2)	(90.1)	(18.2)	(91.1)	(27.1)
Economic					19.2	5.7
TOT VARIANCE	51.2	18.2	90.1	18.2	110.3	32.8
CUR ESTIMATE	333.1	118.2	585.9	118.2	447.0	132.8
PROCUREMENT						
DEV ESTIMATE	1486.5	100.0	2652.1	100.0	2153.0	100.0
VARIANCE:						
Quantity	14.4	1.0	25.7	1.0	18.9	.9
Schedule	290.4	19.5	518.1	19.5	820.8	38.1
Engineering	108.4	7.3	193.4	7.3	225.8	10.5
Support	17.2	1.2	30.7	1.2	23.6	1.1
Estimating	-7.5	-.5	-13.4	-.5	108.1	5.0
(Pgm changes)	(422.9)	(28.4)	(754.5)	(28.4)	(1197.2)	(55.6)
Economic					868.9	40.4
TOT VARIANCE	422.9	28.4	754.5	28.4	2066.1	96.0
CUR ESTIMATE	1909.4	128.4	3406.5	128.4	4219.1	196.0
MIL CONST						
DEV ESTIMATE	.0	.0	.0	.0	.0	.0
VARIANCE:						
TOT VARIANCE	.0	.0	.0	.0	.0	.0
CUR ESTIMATE	.0	.0	.0	.0	.0	.0
TOT PROGRAM						
DEV ESTIMATE	1768.4	100.0	3147.9	100.0	2489.7	100.0
VARIANCE:						
Quantity	.0	.0	.4	.0	.0	.0
Schedule	301.0	17.0	536.7	17.1	835.9	33.6
Engineering	143.9	8.1	255.8	8.1	290.2	11.7
Support	28.7	1.6	50.9	1.6	41.4	1.7
Estimating	-22.3	-1.3	-39.4	-1.3	92.0	3.7
Other changes	22.8	1.3	40.1	1.3	28.8	1.2
(Pgm changes)	(474.1)	(26.8)	(844.5)	(26.8)	(1288.3)	(51.7)
Economic					888.1	35.7
TOT VARIANCE	474.1	26.8	844.5	26.8	2176.4	87.4
CUR ESTIMATE	2242.5	126.8	3992.4	126.8	4666.1	187.4

B-1

The B-1 program to replace the aging B-52 as the manned bomber portion of our strategic retaliatory triad of forces was approved for development in FY 1970. It was cancelled in June 1977 apparently on the basis of its high cost. Although in terms of the original quantity its cost projection had risen only 18 percent in 7 years, this amounted to $3 billion in 1979 dollars. A 7 percent increase was due to a funding-induced stretchout in the programmed production schedule and an 11 percent gain was recorded in the Engineering category reflecting "design evolution." Minor, offsetting, cost increases and decreases were recorded in the Support and Estimating categories.

B-1

Program Acquisition Cost
(Costs in $ millions)

	Base Yr (FY 70) $		Cur Yr (FY 79) $		Then Year $	
	Cost	% of DE	Cost	% of DE	Cost	% of DE
DEVELOPMENT						
DEV ESTIMATE	2431.0	100.0	4275.8	100.0	2685.0	100.0
VARIANCE:						
Quantity	-19.7	-.8	-34.6	-.8	-78.1	-2.9
Schedule	231.1	9.5	406.5	9.5	366.3	13.6
Engineering	152.7	6.3	268.6	6.3	197.0	7.3
Support	-16.6	-.7	-29.2	-.7	-118.5	-4.4
Estimating	-124.9	-5.1	-219.7	-5.1	451.7	16.8
Other changes	83.5	3.4	146.9	3.4	143.4	5.3
(Pgm changes)	(306.1)	(12.6)	(538.4)	(12.6)	(961.8)	(35.8)
Economic					329.6	12.3
TOT VARIANCE	306.1	12.6	538.4	12.6	1291.4	48.1
CUR ESTIMATE	2737.1	112.6	4814.2	112.6	3976.4	148.1
PROCUREMENT						
DEV ESTIMATE	7422.8	100.0	13243.0	100.0	8533.8	100.0
VARIANCE:						
Quantity	-8535.6	-115.0	-15228.3	-115.0	-11046.9	-129.4
Schedule	420.6	5.7	750.4	5.7	2366.1	27.7
Engineering	964.7	13.0	1721.1	13.0	1242.5	14.6
Support	-227.3	-3.1	-405.5	-3.1	-449.6	-5.3
Estimating	321.7	4.3	573.9	4.3	1096.3	12.8
(Pgm changes)	(-7055.9)	(-95.1)	(-12588.4)	(-95.1)	(-6791.6)	(-79.6)
Economic					-1044.2	-12.2
TOT VARIANCE	-7055.9	-95.1	-12588.4	-95.1	-7835.8	-91.8
CUR ESTIMATE	366.9	4.9	654.6	4.9	698.0	8.2
MIL CONST						
DEV ESTIMATE	.0	.0	.0	.0	.0	.0
VARIANCE:						
TOT VARIANCE	.0	.0	.0	.0	.0	.0
CUR ESTIMATE	.0	.0	.0	.0	.0	.0
TOT PROGRAM						
DEV ESTIMATE	9853.8	100.0	17518.8	100.0	11218.8	100.0
VARIANCE:						
Quantity	-8555.3	-86.8	-15262.9	-87.1	-11125.0	-99.2
Schedule	651.7	6.6	1156.9	6.6	2732.4	24.4
Engineering	1117.4	11.3	1989.7	11.4	1439.5	12.8
Support	-243.9	-2.5	-434.7	-2.5	-568.1	-5.1
Estimating	196.8	2.0	354.3	2.0	1548.0	13.8
Other changes	83.5	.8	146.9	.8	143.4	1.3
(Pgm changes)	(-6749.8)	(-68.5)	(-12050.0)	(-68.8)	(-5829.8)	(-52.0)
Economic					-714.6	-6.4
TOT VARIANCE	-6749.8	-68.5	-12050.0	-68.8	-6544.4	-58.3
CUR ESTIMATE	3104.0	31.5	5468.8	31.2	4674.4	41.7

F-15

The F-15 air superiority fighter entered full-scale development in FY 1970 and passed its DSARC III review 3 years later. The March 1978 SAR indicated that the F-15 was about halfway through the production phase. Cost growth totaled 24 percent overall and, as in the A-10 case, most of it had occurred after DSARC III. Production rate changes (Schedule) caused an increase in the DE cost of 11 percent, and performance enhancement above the baseline program (Engineering) accounted for another 4 percent.[10] The rest of the increase (9 percent) was recorded as "Unpredictable" because of the Navy's cancellation of its plan to purchase the Pratt & Whitney F100 engine. This presumably left the Air Force with a larger overhead burden than was expected originally, and the bulk of the expensive early production engines.

[10]The engine self-diagnosis system may result in support cost economies downstream that will recover the additional acquisition cost of this feature. Some part of the Engineering increase may reflect additional hours needed to redesign and test the P&W F100 engines to overcome their tendency to stall during certain maneuvers.

F-15

Program Acquisition Cost
(Costs in $ millions)

	Base Yr (FY 70) $ Cost	Base Yr (FY 70) $ % of DE	Cur Yr (FY 79) $ Cost	Cur Yr (FY 79) $ % of DE	Then Year $ Cost	Then Year $ % of DE
DEVELOPMENT						
DEV ESTIMATE	1654.9	100.0	2910.8	100.0	1778.6	100.0
VARIANCE:						
Engineering	110.5	6.7	194.4	6.7	148.7	8.4
Support	-52.9	-3.2	-93.0	-3.2	-56.4	-3.2
Estimating	18.5	1.1	32.5	1.1	23.7	1.3
Over/underrun	-.1	.0	-.2	.0	-.1	.0
Other changes	174.0	10.5	306.0	10.5	208.7	11.7
(Pgm changes)	(250.0)	(15.1)	(439.7)	(15.1)	(324.6)	(18.3)
Economic					.8	.0
TOT VARIANCE	250.0	15.1	439.7	15.1	325.4	18.3
CUR ESTIMATE	1904.9	115.1	3350.5	115.1	2104.0	118.3
PROCUREMENT						
DEV ESTIMATE	4333.2	100.0	7730.8	100.0	5576.6	100.0
VARIANCE:						
Schedule	673.3	15.5	1201.2	15.5	1247.6	22.4
Engineering	145.4	3.4	259.4	3.4	336.9	6.0
Support	-.9	.0	-1.6	.0	-5.4	-.1
Estimating	-63.6	-1.5	-113.5	-1.5	187.2	3.4
Over/underrun	66.2	1.5	118.1	1.5	79.5	1.4
Other changes	382.4	8.8	682.2	8.8	486.2	8.7
(Pgm changes)	(1202.8)	(27.8)	(2145.9)	(27.8)	(2332.0)	(41.8)
Economic					3168.2	56.8
TOT VARIANCE	1202.8	27.8	2145.9	27.8	5500.2	98.6
CUR ESTIMATE	5536.0	127.8	9876.7	127.8	11076.8	198.6
MIL CONST						
DEV ESTIMATE	.0	.0	.0	.0	.0	.0
VARIANCE:						
TOT VARIANCE	.0	.0	.0	.0	.0	.0
CUR ESTIMATE	.0	.0	.0	.0	.0	.0
TOT PROGRAM						
DEV ESTIMATE	5988.1	100.0	10641.6	100.0	7355.2	100.0
VARIANCE:						
Schedule	673.3	11.2	1201.2	11.3	1247.6	17.0
Engineering	255.9	4.3	453.8	4.3	485.6	6.6
Support	-53.8	-.9	-94.7	-.9	-61.8	-.8
Estimating	-45.1	-.8	-80.9	-.8	210.9	2.9
Over/underrun	66.1	1.1	117.9	1.1	79.4	1.1
Other changes	556.4	9.3	988.3	9.3	694.9	9.4
(Pgm changes)	(1452.8)	(24.3)	(2585.6)	(24.3)	(2656.6)	(36.1)
Economic					3169.0	43.1
TOT VARIANCE	1452.8	24.3	2585.6	24.3	5825.6	79.2
CUR ESTIMATE	7440.9	124.3	13227.2	124.3	13180.8	179.2

F-16

The F-16 is a lightweight, single-engine fighter being co-produced by a consortium of U.S. and other NATO-country[11] manufacturers. The costs shown here are for the USAF buy program. Originally set at 650 production aircraft, the total programmed quantity for USAF was increased to 1388 in FY 1977.

Including this more than doubling of the buy quantity, the cost projection rose by 94 percent over the Development Estimate. This increase drops to 27 percent when the Quantity variance is subtracted. Data given in the F-16's January 1978 SAR revealed that the aircraft quantity increase generated a corresponding increase in support equipment amounting to another 13 percent of cost growth. Although this also is a quantity-induced increase and it seems logical that this amount also should be subtracted from the cost growth, in the present analysis we corrected only for the amount of cost change recorded in the SAR Quantity variance category. The rest of the Support cost increase was caused by additions to the program—an automated test facility, new support equipment for added weaponry, and additional data requirements—and better definitization of this support equipment. Some savings were recorded as a result of cutting simulators and some of the spares from the acquisition program.

The Engineering category accounted for a cost rise of 6 percent. It stemmed from engine improvements (including a dual element pump and a digital electronic engine control), and other new tasks such as AIM-9L capability, nuclear stores, etc.

Estimating showed a minor reduction of −1 percent, but the recent cancellation of Iran's F-16 order will negate some cost avoidance that is included in that figure. Because of the co-production element, variations in both foreign currency exchange rates and inflation rates, and other factors not present in all-U.S. production programs, the F-16 program presents a real challenge in cost estimating—and tracking.

[11]Belgium, Denmark, The Netherlands, and Norway.

F-16

Program Acquisition Cost
(Costs in $ millions)

	Base Yr (FY 75) $		Cur Yr (FY 79) $		Then Year $	
	Cost	% of DE	Cost	% of DE	Cost	% of DE
DEVELOPMENT						
DEV ESTIMATE	578.6	100.0	739.8	100.0	659.1	100.0
VARIANCE:						
Engineering	77.1	13.3	98.6	13.3	107.9	16.4
Support	92.5	16.0	118.3	16.0	133.9	20.3
Estimating	-9.7	-1.7	-12.4	-1.7	7.8	1.2
Other changes	5.5	1.0	7.0	1.0	7.4	1.1
(Pgm changes)	(165.4)	(28.6)	(211.5)	(28.6)	(257.0)	(39.0)
Economic					42.2	6.4
TOT VARIANCE	165.4	28.6	211.5	28.6	299.2	45.4
CUR ESTIMATE	744.0	128.6	951.2	128.6	958.3	145.4
PROCUREMENT						
DEV ESTIMATE	3798.2	100.0	4921.5	100.0	5395.4	100.0
VARIANCE:						
Quantity	2946.7	77.6	3818.1	77.6	5364.7	99.4
Engineering	191.7	5.0	248.4	5.0	322.9	6.0
Support	862.9	22.7	1118.1	22.7	1381.6	25.6
Estimating	-51.7	-1.4	-67.0	-1.4	80.6	1.5
Other changes	6.7	.2	8.7	.2	10.3	.2
(Pgm changes)	(3956.3)	(104.2)	(5126.3)	(104.2)	(7160.1)	(132.7)
Economic					1523.0	28.2
TOT VARIANCE	3956.3	104.2	5126.3	104.2	8683.1	160.9
CUR ESTIMATE	7754.5	204.2	10047.8	204.2	14078.5	260.9
MIL CONST						
DEV ESTIMATE	.0	.0	.0	.0	.0	.0
VARIANCE:						
TOT VARIANCE	.0	.0	.0	.0	.0	.0
CUR ESTIMATE	.0	.0	.0	.0	.0	.0
TOT PROGRAM						
DEV ESTIMATE	4376.8	100.0	5661.2	100.0	6054.5	100.0
VARIANCE:						
Quantity	2946.7	67.3	3818.1	67.4	5364.7	88.6
Engineering	268.8	6.1	347.0	6.1	430.8	7.1
Support	955.4	21.8	1236.4	21.8	1515.5	25.0
Estimating	-61.4	-1.4	-79.4	-1.4	88.4	1.5
Other changes	12.2	.3	15.7	.3	17.7	.3
(Pgm changes)	(4121.7)	(94.2)	(5337.8)	(94.3)	(7417.1)	(122.5)
Economic					1565.2	25.9
TOT VARIANCE	4121.7	94.2	5337.8	94.3	8982.3	148.4
CUR ESTIMATE	8498.5	194.2	10999.0	194.3	15036.8	248.4

E-3A (AWACS)[12]

The AWACS program combines a proven aircraft, the Boeing 707, with sophisticated command, control, and surveillance systems for monitoring the tactical threat and controlling our response.

According to the March 1978 SAR, the cost of AWACS rose by 18 percent since its FY 1973 go-ahead, but this included the offset effect of reduced procurement—34 rather than 42 aircraft. In terms of the original buy quantity, cost growth was 21 percent, again using the SAR figures.

Other Schedule stretchouts added 28 percent to the projected costs, and Engineering enhancements added another 1 percent. Partial offsets included the transfer of JTIDS[13] from this acquisition program to its own separate program, which saved 7 percent (shown in Estimating), and deferment of training and peculiar support equipment plus an initial spares adjustment which together saved another 1 percent.

---

[12]Airborne Warning and Control System.
[13]Joint Tactical Information Distribution System.

E-3A (AWACS)

Program Acquisition Cost
(Costs in $ millions)

	Base Yr (FY 70) $ Cost	% of DE	Cur Yr (FY 79) $ Cost	% of DE	Then Year $ Cost	% of DE
DEVELOPMENT						
DEV ESTIMATE	761.0	100.0	1338.5	100.0	876.5	100.0
VARIANCE:						
Schedule	70.1	9.2	123.3	9.2	158.1	18.0
Engineering	27.2	3.6	47.8	3.6	32.3	3.7
Support	-31.0	-4.1	-54.5	-4.1	-31.5	-3.6
Estimating	28.1	3.7	49.4	3.7	90.1	10.3
Over/underrun	-2.2	-.3	-3.9	-.3	-2.5	-.3
Other changes	326.6	42.9	574.4	42.9	387.8	44.2
(Pgm changes)	(418.8)	(55.0)	(736.6)	(55.0)	(634.3)	(72.4)
Economic					61.0	7.0
TOT VARIANCE	418.8	55.0	736.6	55.0	695.3	79.3
CUR ESTIMATE	1179.8	155.0	2075.1	155.0	1571.8	179.3
PROCUREMENT						
DEV ESTIMATE	1389.9	100.0	2479.7	100.0	1785.1	100.0
VARIANCE:						
Quantity	-62.5	-4.5	-111.5	-4.5	50.4	2.8
Schedule	525.3	37.8	937.2	37.8	1020.1	57.1
Engineering	-1.0	-.1	-1.8	-.1	-3.3	-.2
Support	11.5	.8	20.5	.8	37.1	2.1
Estimating	-171.7	-12.4	-306.3	-12.4	-183.5	-10.3
Other changes	-331.8	-23.9	-592.0	-23.9	-395.1	-22.1
(Pgm changes)	(-30.2)	(-2.2)	(-53.9)	(-2.2)	(525.7)	(29.4)
Economic					273.4	15.3
TOT VARIANCE	-30.2	-2.2	-53.9	-2.2	799.1	44.8
CUR ESTIMATE	1359.7	97.8	2425.8	97.8	2584.2	144.8
MIL CONST						
DEV ESTIMATE	.0	.0	.0	.0	.0	.0
VARIANCE:						
TOT VARIANCE	.0	.0	.0	.0	.0	.0
CUR ESTIMATE	.0	.0	.0	.0	.0	.0
TOT PROGRAM						
DEV ESTIMATE	2150.9	100.0	3818.2	100.0	2661.6	100.0
VARIANCE:						
Quantity	-62.5	-2.9	-111.5	-2.9	50.4	1.9
Schedule	595.4	27.7	1060.5	27.8	1178.2	44.3
Engineering	26.2	1.2	46.1	1.2	29.0	1.1
Support	-19.5	-.9	-34.0	-.9	5.6	.2
Estimating	-143.6	-6.7	-256.9	-6.7	-93.4	-3.5
Over/underrun	-2.2	-.1	-3.9	-.1	-2.5	-.1
Other changes	-5.2	-.2	-17.5	-.5	-7.3	-.3
(Pgm changes)	(388.6)	(18.1)	(682.7)	(17.9)	(1160.0)	(43.6)
Economic					334.4	12.6
TOT VARIANCE	388.6	18.1	682.7	17.9	1494.4	56.1
CUR ESTIMATE	2539.5	118.1	4501.0	117.9	4156.0	156.1

Precision Location Strike System (PLSS)

The mission of PLSS is to provide tactical forces with an all-weather standoff system for precise target location and destruction in a dense ECM environment.

With a DSARC go-ahead in September of 1977, PLSS was scarcely into its full-scale development program by the time of its first SAR in March 1978. A minor increase in Support costs due to additional tests was offset by a −1 percent reduction in the Estimating category reflecting work completion despite higher-than-expected inflation, i.e., the work was done at less cost in terms of constant dollars.

PLSS

Program Acquisition Cost
(Costs in $ millions)

	Base Yr (FY 77) $		Cur Yr (FY 79) $		Then Year $	
	Cost	% of DE	Cost	% of DE	Cost	% of DE
DEVELOPMENT						
DEV ESTIMATE	195.4	100.0	222.1	100.0	223.2	100.0
VARIANCE:						
Support	2.5	1.3	2.8	1.3	3.4	1.5
Estimating	-5.1	-2.6	-5.8	-2.6	-5.1	-2.3
(Pgm changes)	(-2.6)	(-1.3)	(-3.0)	(-1.3)	(-1.7)	(-.8)
Economic					5.1	2.3
TOT VARIANCE	-2.6	-1.3	-3.0	-1.3	3.4	1.5
CUR ESTIMATE	192.8	98.7	219.1	98.7	226.6	101.5
PROCUREMENT						
DEV ESTIMATE	482.8	100.0	547.3	100.0	731.3	100.0
VARIANCE:						
TOT VARIANCE	.0	.0	.0	.0	.0	.0
CUR ESTIMATE	482.8	100.0	547.3	100.0	731.3	100.0
MIL CONST						
DEV ESTIMATE	.0	.0	.0	.0	.0	.0
VARIANCE:						
TOT VARIANCE	.0	.0	.0	.0	.0	.0
CUR ESTIMATE	.0	.0	.0	.0	.0	.0
TOT PROGRAM						
DEV ESTIMATE	678.2	100.0	769.4	100.0	954.5	100.0
VARIANCE:						
Support	2.5	.4	2.8	.4	3.4	.4
Estimating	-5.1	-.8	-5.8	-.8	-5.1	-.5
(Pgm changes)	(-2.6)	(-.4)	(-3.0)	(-.4)	(-1.7)	(-.2)
Economic					5.1	.5
TOT VARIANCE	-2.6	-.4	-3.0	-.4	3.4	.4
CUR ESTIMATE	675.6	99.6	766.4	99.6	957.9	100.4

Defense Satellite Communications System (DSCS) Phase III (Space Segment)[14]

DSCS III will provide global super high frequency (SHF) satellite communications for secure voice and high data rate transmissions in the presence of electronic countermeasures.

By March 1978, DSCS III had experienced an apparent cost saving of −22 percent since its DSARC II approval in FY 1977. The quantity remained the same and no economies were realized; in fact, there had been delays in deliveries and some design problems. The saving resulted from a reduction in program scope.

[14]The Army is responsible for the ground terminal segment, the Navy has the shipboard terminal segment, and the Air Force has the space segment.

DSCS III

Program Acquisition Cost
(Costs in $ millions)

	Base Yr (FY 77) $		Cur Yr (FY 79) $		Then Year $	
	Cost	% of DE	Cost	% of DE	Cost	% of DE
DEVELOPMENT						
DEV ESTIMATE	134.3	100.0	152.6	100.0	151.8	100.0
VARIANCE:						
Estimating	2.8	2.1	3.2	2.1	2.2	1.4
(Pgm changes)	(2.8)	(2.1)	(3.2)	(2.1)	(2.2)	(1.4)
Economic					-.3	-.2
TOT VARIANCE	2.8	2.1	3.2	2.1	1.9	1.3
CUR ESTIMATE	137.1	102.1	155.8	102.1	153.7	101.3
PROCUREMENT						
DEV ESTIMATE	496.8	100.0	563.2	100.0	741.8	100.0
VARIANCE:						
Estimating	-139.0	-28.0	-157.6	-28.0	-219.5	-29.6
(Pgm changes)	(-139.0)	(-28.0)	(-157.6)	(-28.0)	(-219.5)	(-29.6)
Economic					7.7	1.0
TOT VARIANCE	-139.0	-28.0	-157.6	-28.0	-211.8	-28.6
CUR ESTIMATE	357.8	72.0	405.6	72.0	530.0	71.4
MIL CONST						
DEV ESTIMATE	.0	.0	.0	.0	.0	.0
VARIANCE:						
TOT VARIANCE	.0	.0	.0	.0	.0	.0
CUR ESTIMATE	.0	.0	.0	.0	.0	.0
TOT PROGRAM						
DEV ESTIMATE	631.1	100.0	715.8	100.0	893.6	100.0
VARIANCE:						
Estimating	-136.2	-21.6	-154.4	-21.6	-217.3	-24.3
(Pgm changes)	(-136.2)	(-21.6)	(-154.4)	(-21.6)	(-217.3)	(-24.3)
Economic					7.4	.8
TOT VARIANCE	-136.2	-21.6	-154.4	-21.6	-209.9	-23.5
CUR ESTIMATE	494.9	78.4	561.4	78.4	683.7	76.5

New Programs

Two major Air Force programs included in the list were too new in March of 1978 to have yet experienced any cost changes. The programs and their DSARC II approval dates follow:

Air Launched Cruise Missile (ALCM) .... FY 1977
Ground Launched Cruise Missile (GLCM) .... FY 1977