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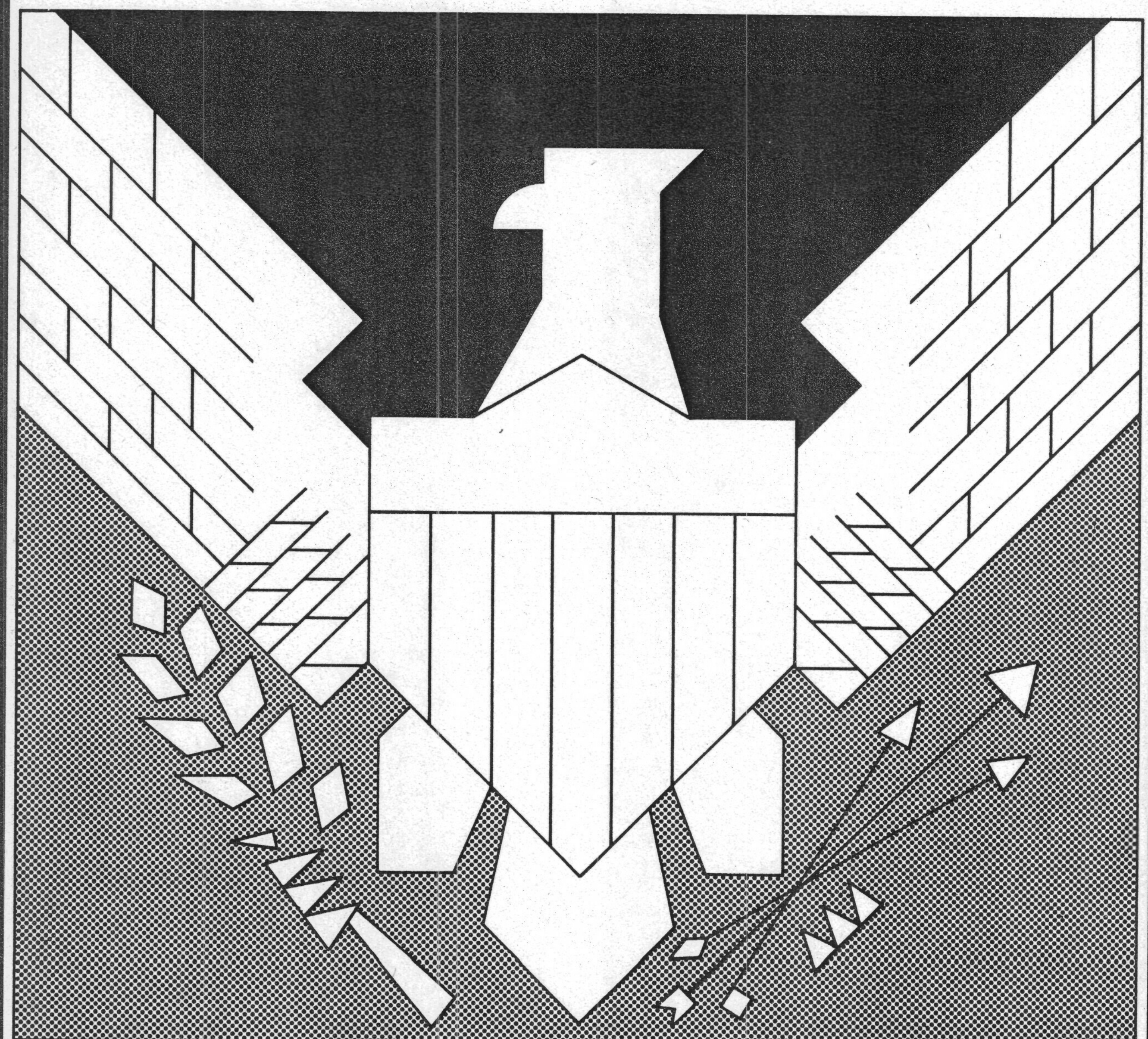
Concurrent Weapons Development and Production



CBO STUDY

CONCURRENT WEAPONS DEVELOPMENT AND PRODUCTION

The Congress of the United States
Congressional Budget Office

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PREFACE

Overlaps in the development and production of major weapons systems, called "concurrency," have been a topic of sustained debate in the weapons acquisition community and the Congress. Many ascribe the problems experienced by the B-1B bomber to concurrency in its development and production. Some have also concluded that the failure of the Army's Division Air Defense (DIVAD) gun system to perform successfully was the result, in part at least, of excessive concurrency. Others feel that, although concurrency involves risks, it can achieve significant savings and minimize the time required for acquisition. In reviewing Department of Defense budget requests, the Congress must consider the potential advantages and risks of using concurrency in acquiring major weapons systems.

This study, performed at the request of the House Committee on Armed Services, analyzes the effectiveness of concurrency in selected major weapons programs during the 1970s. The study also traces the recent history of the use of concurrency and outlines relevant legislation, policies, and regulations. Finally, it evaluates the potential benefits and costs of improving Congressional review of concurrent programs. In keeping with the mandate of the Congressional Budget Office to provide objective analysis, the study does not recommend any particular course of action.

G. Wayne Glass of CBO's National Security Division prepared the study with the extensive assistance of William Kostak and under the general supervision of Robert F. Hale and John D. Mayer, Jr. The author acknowledges the helpful assistance provided by Philip Webre and R. William Thomas of the Congressional Budget Office and Dr. Gerald R. McNichols of Management Consulting and Research, Inc. (The assistance of external participants implies no responsibility for the final product, which rests solely with CBO.) Francis S. Pierce edited the report, and Rebecca Kees and Kathryn Quattrone prepared it for publication.

James L. Blum
Acting Director

August 1988

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SUMMARY

Some analyses of weapons programs in the Department of Defense (DoD) have suggested that the practice of allowing development and production to overlap--that is, to proceed concurrently--is a principal contributor to program problems. These views have been reinforced by difficulties with recent major weapons projects that featured concurrency, including the B-1B aircraft and the Division Air Defense (DIVAD) gun system. Other analyses, however, have argued that concurrency is a useful, if not essential, means to meet urgent defense requirements by accelerating the weapons acquisition process.

Concurrency is fairly common in weapons acquisition programs. Out of a sample of 31 major programs surveyed in this study, 13 could be classified as highly concurrent.

To assist the Congress in reconciling the conflicting claims about concurrency, the study reviews the success of selected weapons programs that featured concurrency, and summarizes the history of its use by DoD. The study also proposes several actions the Congress could take to improve its oversight of weapons systems in which development and production are proceeding concurrently.

ADVANTAGES AND DISADVANTAGES OF CONCURRENCY

Concurrency can provide important advantages over the sequential development and production of a weapons system. Perhaps most important, it can shorten the time required to field a weapons system, perhaps enabling U.S. forces to meet a new enemy threat sooner or to establish a technological advantage important to national security. Accelerating the acquisition process can also reduce the risk that the useful lives of some weapons will be shortened by obsolescence.

Concurrency can also achieve cost savings and management efficiencies. Reducing the time required to develop and produce a weapon can mean lower overhead costs. In addition, the tighter schedule of a concurrent program may mean more continuity and stability in the labor force, improving management efficiency. For example, close collaboration between design and production personnel can facilitate adjustments or improvements in a weapons system.

Concurrency can also prevent program changes that might compromise cost and schedule objectives. For example, to meet tighter schedules, an accelerated program must avoid design changes that would add substantially to costs. Also, by compressing development and production, a concurrent program can reduce the number of management reviews and minimize opportunities for budget adjustments.

On the other hand, there are significant risks in the concurrent development and production of weapons systems. As was the case with the B-1B aircraft and the DIVAD gun, after production has begun problems may be uncovered that require major redesign and production changes, significantly increasing costs and delaying deployment. Weapons already deployed may need to be modified, further adding to costs. Finally, the program's performance and schedule objectives may not be met, placing in jeopardy one of the key goals of concurrency.

ANALYSIS OF THE EFFECTS OF CONCURRENCY

To what extent has concurrency succeeded or failed? Lack of information makes it difficult to separate the effects of concurrency from the many other factors that influence the success or failure of weapons programs. Nevertheless, it is possible to correlate concurrency with two measures often associated with the success or failure of weapons programs: cost growth and schedule delays.

This study examined concurrency, cost growth, and schedule data for 14 major weapons systems that were developed during the 1970s and have been subsequently produced and deployed. The systems include a variety of types of weapons from each of the military services, and all of them have been reviewed by the Defense Systems

Acquisition Review Council (DSARC).[1] The analysis showed that no strong relationship exists between concurrency and schedule delay (see Summary Table). A statistical regression analysis found that only a couple of percentage points of the variation in schedule delays are explained by concurrency. A modestly stronger relationship exists between concurrency and cost growth: approximately 14 percent of the variance in cost growth is explained by concurrency.

Despite these ambivalent statistical findings for the 14 programs as a group, it is clear that some highly concurrent programs have experienced significant cost growth. For example, unit cost for the Patriot missile, a highly concurrent program, is 256 percent of what was originally planned. The Copperhead artillery shell, another highly concurrent program, did not achieve its initial operational capability (IOC) until 41 months after the date in the original plan--a period equal to about 84 percent of the time originally planned from the beginning of full-scale development to IOC.

HISTORY OF CONCURRENCY

Concurrent development and production of weapons systems has been emphasized during wartime or periods of national emergency, when a consensus readily supported the acceleration of high-priority weapons systems. Examples include the depth charges developed for use against German submarines in World War I, the atom bomb developed during World War II, the missile programs initiated during the "Sputnik" era of the late 1950s, and the "smart" weapons used in Vietnam. Until the 1960s, however, concurrency was seldom used in acquiring weapons during peacetime.

Department of Defense policies governing concurrency have fluctuated since then. In the 1960s, under Secretary of Defense Robert McNamara, DoD encouraged the use of concurrency through the "Total Package Procurement" approach to buying weapons. But prob-

1. The Defense Systems Acquisition Review Council is a senior-level advisory board to the Secretary of Defense that recommends actions concerning the acquisition of major weapons systems. The DSARC was recently restructured and is now called the Defense Acquisition Board (DAB).

SUMMARY TABLE. CONCURRENCY, COST GROWTH, AND SCHEDULE CHANGE FOR 14 MAJOR PROGRAMS

	Concurrency (Percentage of IOT&E testing to complete after production) a/	Cost Growth (Current/ baseline unit cost in percent) b/	Schedule Change (Change in IOC as percentage of program length) c/
	Group I (High concurrency)		
Harpoon Missile	100	228	69
Patriot Missile	83	256	24
CH-47 Helicopter	67	141	22
Copperhead Shell	67	527	84
Average	79.3	288.0	49.0
	Group II (Medium concurrency)		
Bradley Fighting Vehicle	55	389	120
I2R Maverick Missile	50	249	100
UH-60 Helicopter	50	232	1
M1 Tank	39	176	6
Phalanx Gun System	33	118	126
Average	45.4	232.8	70.6
	Group III (Low concurrency)		
Hellfire Missile	32	172	47
Stinger Missile	25	300	69
SH-60 LAMPS Helicopter	19	174	0
CH-53 Helicopter	0	133	139
F/A-18 Aircraft	0	185	38
Average	15.2	192.8	58.6

SOURCE: Congressional Budget Office based on Department of Defense program data and budget and schedule information.

NOTE: Concurrency was defined as the percentage of initial operational testing and evaluation (IOT&E) planned for completion after initial production was authorized. Zero concurrency means that all testing was to be completed before production began, while a concurrency value of 100 percent means that all testing was to take place after the beginning of production. The study defined high concurrency as 66 percent or above, medium concurrency as 33 percent to 66 percent and low concurrency as below 33 percent.

a. IOT&E = Initial Operational Testing and Evaluation.

b. Calculated using current dollars.

c. IOC = Initial Operational Capability.

lems encountered by the C-5 aircraft and other concurrent programs in the 1960s led to a change of policy. In 1969, DoD adopted a "fly before buy" approach that emphasized successful testing of prototype systems before production began. In 1977, however, when studies showed that development and production of weapons were taking longer than ever before, the Defense Science Board--a high-level advisory board to the Secretary of Defense--recommended a return to the concurrent acquisition practices of the past. More recently, the current has seemed to be moving in the other direction: the President's Blue Ribbon Commission on Defense Management recommended in 1987 that development and testing of prototypes be completed before production begins.

These ebbs and flows of policy are reflected in today's regulations and legislation, which do not prohibit concurrency and in some cases encourage it. On the one hand, DoD's basic acquisition regulations favor concurrency by emphasizing the need to reduce the time it takes to acquire weapons. On the other hand, the Congress has placed legal constraints on acquisition policy that seem to limit concurrency. For example, the 1987 Defense Authorization Act states that "a major defense acquisition program may not proceed beyond low-rate initial production until IOT&E [Initial Operational Testing and Evaluation] of the program is completed."

IMPROVING CONGRESSIONAL OVERSIGHT OF CONCURRENT PROGRAMS

Given the ambivalent statistical evidence concerning the effects of concurrency on costs and schedules, and the fact that current laws and regulations limit its use, the Congress may wish to take no further action regarding concurrent programs as a group. On the other hand, in view of recent problems with certain programs, the Congress may wish to have more information on high-priority programs that are employing concurrency.

Measures of Concurrency

DoD does not have a standard definition of concurrency, or provide criteria by which concurrency could be determined. Such a measure would enable the Congress to identify concurrent programs and would encourage DoD to focus management attention on them. It would not be difficult for DoD to develop a measure of concurrency and report the results for each major program as part of an existing report such as the Congressional Data Sheets or the Selected Acquisition Reports.

Nonconcurrent Benchmarks

For selected programs, DoD might also be asked to prepare an alternative plan that would minimize concurrency. Comparing the two plans should clarify the advantages of concurrency during Congressional debate. Updated to include the experience acquired as the weapon was developed and tested, this nonconcurrent benchmark would also permit future analysts to assess more carefully the advantages and disadvantages of concurrency. Since such a nonconcurrent benchmark would require substantial effort, it should probably be required only for highly concurrent, high-priority projects.

Operational Testing

The Congress may also wish to address critical elements of the operational testing plan for concurrent programs in order to ensure that test plans and funding are adequate. For example, through hearings or staff analyses, the Congress could determine whether sufficient test assets, testing facilities, targets, and threat simulations have been planned and budgeted. Adequate testing is important for all weapons programs, but it is particularly important for concurrent programs in which compressed schedules often allow little time to deal with problems that are revealed late in the program.

Risk Assessment

The DoD does not routinely conduct and report comprehensive risk assessments for major weapons programs, either for internal management or for the use of the Congress. A program may fail to achieve its planned goals for a number of reasons, including cost overruns, schedule delays, or poor performance. An assessment of such risk may be particularly important in programs involving concurrency. The Congress might request DoD to provide a comprehensive risk analysis addressing key areas where problems could develop, such as the nature of the enemy threat, the availability of adequate means of testing, the kind of technology involved, and the methods of manufacture.

Preparing risk analyses would mean adding to DoD's reporting workload. This disadvantage would have to be weighed against the potential benefit of more informed decision making.

CHAPTER I

INTRODUCTION

In fiscal year 1988, the Congress appropriated about $121.3 billion for the acquisition of weapons and their support systems. Weapons acquisition consists of a series of phases beginning with the establishment of a military need and proceeding to the development of a system concept; then to the design, fabrication, and testing of a system; and finally, to production and deployment. The basic goal of the weapons acquisition process is to produce weapons systems that meet military requirements at the lowest possible cost and in a timely manner. This is not easy to achieve, however, because of the expense of high technology and the many uncertainties associated with the acquisition process.

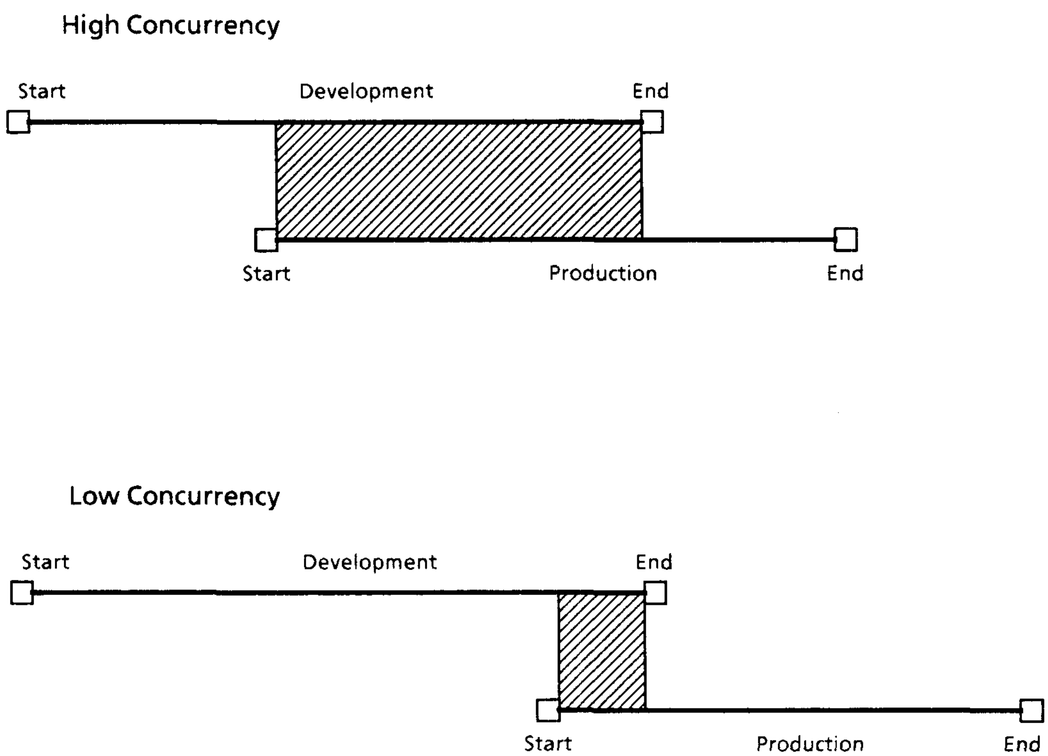
One way of reducing acquisition time and cost is through concurrent development and production. In simplified terms, weapons programs can be thought of as progressing through a development stage, which includes perfecting ideas and perhaps building a prototype of the system, and a production stage that provides operational weapons for use in the field. Concurrent programs feature significant overlap of development and production (see Figure 1).[1] The degree of concurrency may be measured by the overlap between the testing of weapons, which indicates readiness to enter into production, and the production phase. Chapter II of this study develops a more precise definition and measure of concurrency.

1. This definition--the overlap between development and production--is consistent with the definition used by the Defense Science Board in its study of the weapons system acquisition process. See Defense Science Board 1977 Summer Study, *Report of the Acquisition Cycle Task Force* (March 1978), p. 47.

SOME EXAMPLES OF CONCURRENCY

Recent experience with highly concurrent programs has caused concern in the Congress. The B-1B bomber, intended to close quickly what was perceived as a "window" of U.S. strategic vulnerability, was authorized to enter production about three years before its developmental testing would be completed. Several years after production began, serious problems were discovered with the bomber, particu-

Figure 1.
Simplified Diagram of Concurrency in a Weapons Program



SOURCE: Congressional Budget Office.

larly with its defensive avionics--a system designed to jam or confuse Soviet radars. It is possible that some of those problems were caused, or at least exacerbated, by concurrency in the program.

Another highly concurrent program was the Army's Division Air Defense (DIVAD) gun, which was designed to destroy enemy helicopters and fixed-wing aircraft before they could attack U.S. and allied ground forces. Again, production began well before completion of testing. But that testing raised questions about DIVAD's effectiveness, especially at long ranges. After purchasing 146 DIVAD guns, the program was terminated in August 1985. The Army recently selected another weapon to meet its air defense needs.

Concurrency is not rare in the acquisition process. Virtually all major weapons programs that have begun full-scale development in recent years have exhibited at least some concurrency. Indeed, of 31 major weapons programs surveyed, 13 were found to be highly concurrent.[2]

Concurrency has sometimes worked well. For example, the Pershing I missile program applied concurrency successfully during the 1960s. Despite the fact that production of the missile was approved over two years before field testing began, the Pershing I met the most critical milestone, performance, and deployment goals without significant cost increases or schedule delays.[3] Other major programs, including the Polaris submarine, the Minuteman missile, and the F-5E aircraft, have also been cited as successful examples of concurrent programs.[4] In these cases, concurrency has meant that a useful weapons system has been deployed more quickly than if a more sequential approach to acquisition had been used.

2. An operational definition of concurrency is developed in Chapter II. "Major weapons systems" here means systems reviewed by the Defense Acquisition Board, a high-level review group in DoD.

3. See the Blue Ribbon Defense Panel, *Report to the President and the Secretary of Defense on the Department of Defense* (July 1970), Appendix F, pp. F-5 through F-8.

4. The Defense Science Board, *Report of the Acquisition Cycle Task Force* (March 1978), pp. 49-50.

ADVANTAGES OF CONCURRENCY

Indeed the key objective of concurrency is to speed up a weapons program. Speeding delivery can improve military capability in a number of ways. It can meet an immediate threat as in the case of the Pershing II missile program. (Pershing II is a U.S. intermediate-range missile that was placed in Europe in the early 1980s to counter Soviet missiles already in place.) Speed may also be needed to replace inadequate weapons, as was intended with the DIVAD gun. Finally, concurrency may offer a way of capitalizing on technological advances, such as the new stealth technology designed to help aircraft and other weapons evade enemy radar.

Speed achieved through concurrency may have other advantages besides increasing military capability. Program managers may invoke it to make up for past delays. Less nobly, concurrency may be used to insure that those managing a program are around to witness its delivery to operating forces. Contractors may support concurrency to hasten the moment when the government commits production money to a program. Also, accelerating a weapons system may promote greater program stability by encouraging an early commitment to designs and by discouraging design changes in order to meet cost and schedule goals. It can also minimize opportunities for arbitrary budgetary adjustments that can disrupt program plans and activities and ultimately add to the total cost of a program.

Concurrency may also lead to cost savings through greater efficiency. Duplicative tasks can be consolidated or eliminated. Development testing, for example, can be conducted concurrently with operational testing to save time and money. Also, program staff can be used more efficiently: design engineers, for example, might collaborate with production personnel in creating an efficient production plan. If the same contractor is performing both development and production, shortening the program may reduce the contractor's overhead. Finally, a shorter program may avoid some costs associated with inflation, though these would not be savings in real (inflation-adjusted) terms.

POSSIBLE DISADVANTAGES OF CONCURRENCY

While concurrency may speed up programs, this very fact may lead to complications. If problems are discovered during development and testing that require major design changes, it may be necessary to stop production while the changes are incorporated into weapons already produced. Such disruptions mean delay, and may even result in the program taking longer than would have been the case without concurrency. Even if the problems discovered during development and testing are minor, solutions to these problems may have to be incorporated into weapons already produced--a process that is often expensive and time consuming.

CHAPTER II

THE EFFECTS OF CONCURRENCY

Does concurrency meet its objectives of speeding up programs or holding down costs? Concurrent programs have often not met their cost and schedule goals. But would they have performed better with less concurrency? Analysis of recent programs suggests no strong relationship between concurrency and schedule slippage, and only a moderate relationship between concurrency and cost growth. Nevertheless, some highly concurrent programs have experienced major cost growth and schedule delays. These ambivalent findings are reflected in the history of the use of concurrency and in current policies.

ANALYSIS OF RECENT PROGRAMS

When the Department of Defense proposes a concurrent program to the Congress, it does not submit an alternative plan that avoids concurrency. In the absence of such a benchmark for judging the success or failure of a concurrent program, analysts must rely on more general measures. One such measure is the amount of growth in cost above planned levels. Presumably, substantial growth in costs is a sign of program problems, some of which could have been caused or exacerbated by concurrency. Another measure is the degree of delay in a program beyond its planned schedule. Schedule delays may be especially important in assessing the success of concurrency, since one of its key goals is to speed program completion.

Definitions of Variables

Three major variables used in the analysis are "concurrency," "cost growth," and "schedule change."

Concurrency. In the sense in which it is used here, concurrency refers to the overlap between the development and production processes of a weapons system.[1] There is no agreement, however, on how to measure it. In order to calculate the overlap, it is necessary to measure the proportion of the development program that has been accomplished at the time production is started. Simple measures based on time and dollars spent may have limitations. For example, calculating concurrency on the basis of total development time may understate the significance of the overlap between development and production if development time includes interruptions and delays. Measurements based on dollars spent could reflect a similar bias in the case of extended development programs. Instead, this study assesses concurrency based on progress achieved in a weapons system testing program, because testing is closely related to the readiness of the system for production.

A weapons testing program consists of two phases: development testing and operational testing. Development testing verifies that a development version of a weapons system has met the technical performance specifications and objectives of the system (or subsystem or component) in a controlled testing environment. Operational testing, on the other hand, involves the use of a production version of the weapons system (or items representative of a production version) to conduct field tests under realistic operational conditions.[2] Success in operational testing is supposed to precede production approval. Thus the amount of operational testing that occurs after production begins is a reasonable measure of the overlap between development and production, and is this study's definition of concurrency.[3]

Operational testing and evaluation in turn consists of two phases: initial operational testing and evaluation (IOT&E) and follow-on testing and evaluation (FOT&E). The former uses initial production

1. There are other ways to define "concurrency." In general, they are more restrictive than the definition used in this study, but, although useful, do not address the concern of the Congress regarding weapons acquisition strategy. In a more restrictive sense, for example, concurrency can refer to the simultaneous development of primary and alternative (back-up) technologies or concepts. In addition, concurrency can refer to the simultaneous development and testing of separate subsystems. It can also mean the simultaneous production and integration of subsystems into a single weapons system. Alternatively, it may mean scheduling specific tasks to balance workload and personnel assignments so as to avoid duplication of effort. Concurrency, as used in this study, may be either planned or unplanned. Concurrency could be introduced or increased for a program already in development, for example, in response to a change in urgency.

2. Department of Defense Directive 5000.3, "Test and Evaluation," March 12, 1986, pp. 4-5.

3. See the discussion of current legislation and regulations at the end of this chapter.

items (or items representative of production) to demonstrate a system's operational effectiveness and suitability in the field. The latter uses more mature production items to validate achievement of program objectives.[4] FOT&E does not begin until after production has started. Consequently, the IOT&E phase provides a better measure of the overlap between development and production.

The limited availability of IOT&E data, however, places a constraint on the analysis. In theory, the proportion of total IOT&E tests completed after production begins is the preferred measure of the development variable in calculating concurrency. But complete data on the number of IOT&E tests for the programs examined were not available. As an alternative, the indicator used in this analysis is the percentage of all time spent in IOT&E that is to be completed after production is approved. Thus a percentage equaling zero indicates that no IOT&E testing is to take place after production is approved, in which case, by this study's definition, no concurrency is planned. A percentage equal to one hundred indicates that all IOT&E testing is to take place after production is approved, meaning that complete concurrency is planned.

Finally, in measuring concurrency, it is also necessary to identify the point at which production begins. Experts differ on how to define the start of production. Some consider that the allocation of funds for advance procurement of materials or long-lead items constitutes the initial commitment to production. For many programs, however, this advance procurement precedes authorization by DoD management to begin production by a year or more. Moreover, even if the Congress provides funds for advance procurement, there is no guarantee that production will actually begin. In a subsequent budget review, the Congress could conceivably choose not to fund actual production.

The DoD management decision to begin production seems a more appropriate measure of its actual beginning. Every weapons system goes through a series of phases, from initiation of the program through completion of production. Each major phase is preceded by a milestone denoting a decision that must be made by DoD managers. (The

4. Defense Sciences Management College, *Systems Engineering Management Guide* (October 1986), p. 6-5.

accompanying box defines the key phases and the numbered milestones that precède them.) Under present policy, an initial decision to begin production at a low rate can occur at Milestone II, the beginning of the full-scale development phase. Alternatively, Milestone III may be separated into low-rate (IIIa) and full-rate (IIIb) production milestones. Some consider the full-rate decision to be the actual beginning of production since it constitutes a "full" commitment to a program. On the other hand, few programs are canceled once production has initially been approved at a low rate. Thus, since initial production was planned to begin at Milestone IIIa for the systems being analyzed, this study uses Milestone IIIa as its measure of the start of production. (Figure 2 illustrates the relationship between phases and milestones.)

The formula used for measuring concurrency is:

$$C = \frac{t_2 - III_a}{t_2 - t_1} \times 100$$

where

t_1 = beginning of IOT&E,
t_2 = end of IOT&E, and
IIIa = date of production approval (Milestone IIIa).

Figure 2 shows the definition schematically.

Cost Growth. Defining a valid measure of the growth in cost of a weapons system is also problematic. In examining the relationship between concurrency and unit cost growth for a weapons system, it is desirable to restrict cost growth to increases associated with the basic production model and to exclude growth caused by model changes or improvements. Program cost information contained in the quarterly Selected Acquisition Reports (SARs) to the Congress on major weapons systems is satisfactory for this purpose. The SARs contain a baseline cost estimate consistent with initial plans plus current cost estimates for each major weapons system. The differences between the current and baseline cost estimates are categorized according to various sources of cost growth, including changes in the economy and in production quantities. By eliminating cost growth in these two

BOX
INITIAL ACQUISITION MILESTONES AND PHASES

Weapons systems go through a series of phases, from program initiation to completion of production. Each major phase is preceded by a managerial decision called a milestone. This box summarizes the milestones and phases that precede full-rate production.

Milestone 0--Program Initiation/Mission Need Decision

The Defense Resources Board reviews the need for a new major weapons system.

Concept Exploration Phase

Follows Milestone 0. Program office explores alternative approaches to fulfilling mission need. It draws up initial technical specifications and cost and schedule estimates. It also develops test and evaluation plan and identifies critical technical issues.

Milestone I--Concept Demonstration/Validation Decision

Defense Acquisition Board reviews and validates conceptual approach proposed by service to meet requirement. It establishes planning baseline cost, schedule, and performance thresholds to be met at Milestone II. It also reviews and validates test and evaluation and logistics and support plans and acquisition strategy.

Demonstration and Validation Phase

Follows Milestone I. Program office directs preliminary engineering and design work and analyzes cost, performance, and schedule trade-off options. Contractor develops prototypes to demonstrate feasibility of system, subsystems, components, and test and support equipment. Principal areas of risk and alternative solutions are identified. Initial designs are reviewed and development testing conducted.

Milestone II--Full-Scale Development

Defense Acquisition Board reviews results of the Demonstration and Validation Phase and recommends that program go ahead when system feasibility has been demonstrated. As appropriate, low-rate initial production of selected components or end items may be approved to verify production capability and to provide operational test resources. Program cost, schedule, and performance thresholds are updated and serve as development baseline for reports to the Congress. Test and Evaluation Master Plan, acquisition business strategy, and support and logistics plans are reviewed and updated.

Full-Scale Development Phase

Follows Milestone II. System is fully developed, engineered, and fabricated. Test items are built. Development and operational testing are conducted on the system, subsystems, and components. Engineering and design changes occur, and preparations for transition to production are made.

Milestone III--Production Approval

Defense Acquisition Board reviews results of full-scale development phase and recommends approval to enter production phase. (Decision may be delegated to service secretaries if Milestone II baseline thresholds have not been breached.) Milestone may be separated into low-rate (IIIa) and full-rate (IIIb) production milestones. Operational testing must be certified acceptable by the Director, Operational Test and Evaluation, before entering full-rate production.

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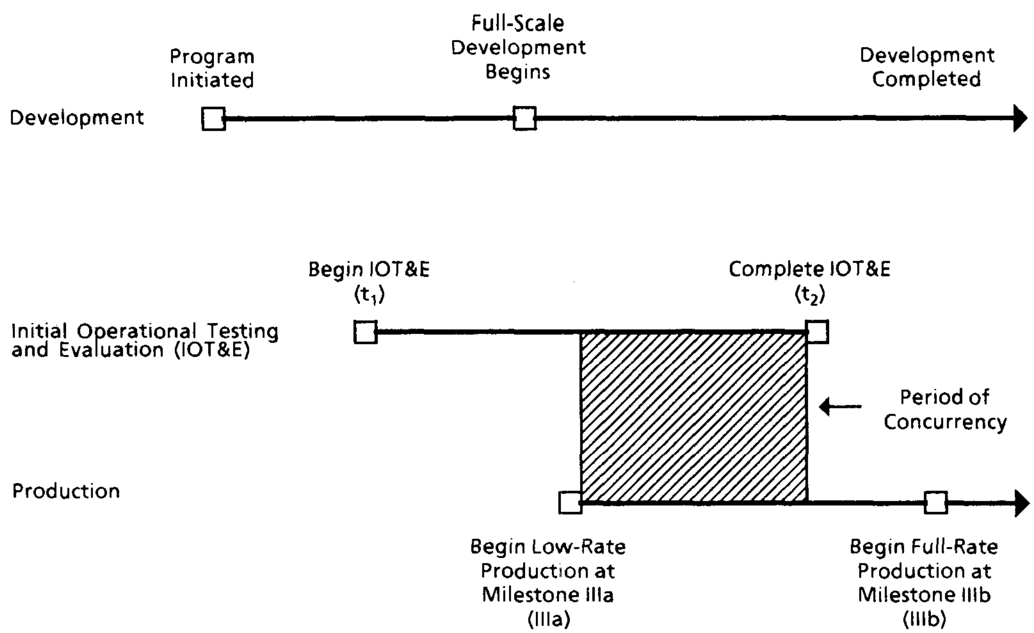
Figure 2.
Operational Schematic of Concurrency



SOURCE: Congressional Budget Office.

major categories from current estimates, it is possible to approximate the level of cost growth above the program baseline associated with only the basic production model.[5]

The formula used for measuring the cost growth variable is:

$$G = \frac{C - Q - E}{B} \times 100$$

5. The resulting indicator is only approximate since it retains all cost growth from engineering changes. Some engineering cost growth may have resulted from changes in the basic production model needed to meet program operational goals; such costs are related to concurrency and should be included in the cost growth measure. Other engineering cost growth, however, may have resulted from engineering improvements authorized subsequent to the beginning of production, and should not be included. The SAR data do not permit a distinction between these two types of engineering cost growth. Both, therefore, are included in measuring the cost growth variable.

where

C = current cost estimate,
Q = cost change due to change in quantity purchased,
E = cost change due to change in economic estimates, and
B = baseline cost estimate.

Schedule Change. The third major variable used in this study concerns program schedule changes related to concurrency. The most important schedule objective for a major weapons system is the time of its initial operational capability (IOC). An IOC is typically defined as the point at which an operating unit is trained and ready to use a new item of equipment that has been deployed. Thus, for example, the IOC for a new aircraft is achieved when a squadron begins operations. Any change in the IOC from its initially planned date is defined in this study as schedule change.[6]

A measure of schedule change should take into account not only change in the time of IOC but also the length of the program. A one-year delay in IOC for a program begun three years earlier is presumably more significant than a similar delay for a program begun ten years before. For purposes of defining schedule change, this study defines planned program length as the period from the beginning of full-scale development to the initially planned IOC. Full-scale development, beginning at Milestone II, is the period during which a prototype of the weapons system is developed. Thus, the period between full-scale development and IOC normally includes the major steps that are used to define concurrency in this study (IOT&E plus the beginning of low-rate production) and seems a reasonable basis for assessing schedule change.

6. For some weapons systems, the definition of an IOC may change during the course of development from its initial criteria established at the program baseline. In such cases, a delay or acceleration may not accurately express the degree of schedule change associated with a program's concurrency, since the definition of the IOC goal has been altered. Program data contained in the SARs and other program budget documentation do not define IOCs in sufficient detail to determine whether the cases selected for this analysis are affected. DoD officials indicate,however, that adjustments in IOC definitions are the exception to the rule. This analysis assumes, therefore, that no significant change in definition of IOC occurred for the subject programs.

The formula for the schedule change variable is:

$$S = \frac{I_a - I_p}{I_p - MII} \times 100$$

where

I_a = actual IOC,
I_p = planned IOC, and
MII = date of full-scale development approval.

Results of the Analysis

The analysis examined 14 major weapons systems that entered full-scale development during the 1970s and were subsequently produced and deployed.[7] The systems selected for analysis included a variety of types from each of the military services. The concurrency, cost, and schedule variables were measured for each system according to the criteria and formulas presented in the preceding section. The data are displayed in Table 1.

Ideally, an analysis of concurrency would include more than 14 programs in order to reveal details such as a preponderance of problems in one type of weapons system. Unfortunately, the historical data needed to assess concurrency for other programs that have reached deployment are either incomplete or do not exist, and an examination of programs currently in development would be premature from the standpoint of assessing the effects of concurrency.

For clarity, the systems in Table 1 are categorized according to three levels of concurrency. High-concurrency programs are defined as having 66 percent or more of the IOT&E program remaining at the time initial production is approved (Group I). Programs with a medium degree of concurrency (Group II) are those for which 33 percent to

7. These systems represent the total number of major weapons programs reviewed by the Defense Systems Acquisition Review Council that have been recently deployed, and for which all the necessary data were available.

TABLE 1. CONCURRENCY, COST GROWTH, AND SCHEDULE CHANGE FOR 14 MAJOR PROGRAMS

	Concurrency (Percentage of IOT&E testing to complete after production) a/	Cost Growth (Current/ baseline unit cost in percent) b/	Schedule Change (Change in IOC as percentage of program length) c/
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Patriot Missile	83	256	24
CH-47 Helicopter	67	141	22
Copperhead Shell	67	527	84
Average	79.3	288.0	49.0
	Group II (Medium concurrency)		
Bradley Fighting Vehicle	55	389	120
I2R Maverick Missile	50	249	100
UH-60 Helicopter	50	232	1
M1 Tank	39	176	6
Phalanx Gun System	33	118	126
Average	45.4	232.8	70.6
	Group III (Low concurrency)		
Hellfire Missile	32	172	47
Stinger Missile	25	300	69
SH-60 LAMPS Helicopter	19	174	0
CH-53 Helicopter	0	133	139
F/A-18 Aircraft	0	185	38
Average	15.2	192.8	58.6

SOURCE: Congressional Budget Office based on Department of Defense program data and budget and schedule information.

NOTE: Concurrency was defined as the percentage of initial operational testing and evaluation (IOT&E) planned for completion after initial production was authorized. Zero concurrency means that all testing was to be completed before production began, while a concurrency value of 100 percent means that all testing was to take place after the beginning of production. The study defined high concurrency as 66 percent or above, medium concurrency as 33 percent to 66 percent and low concurrency as below 33 percent.

a. IOT&E = Initial Operational Testing and Evaluation.

b. Calculated using current dollars.

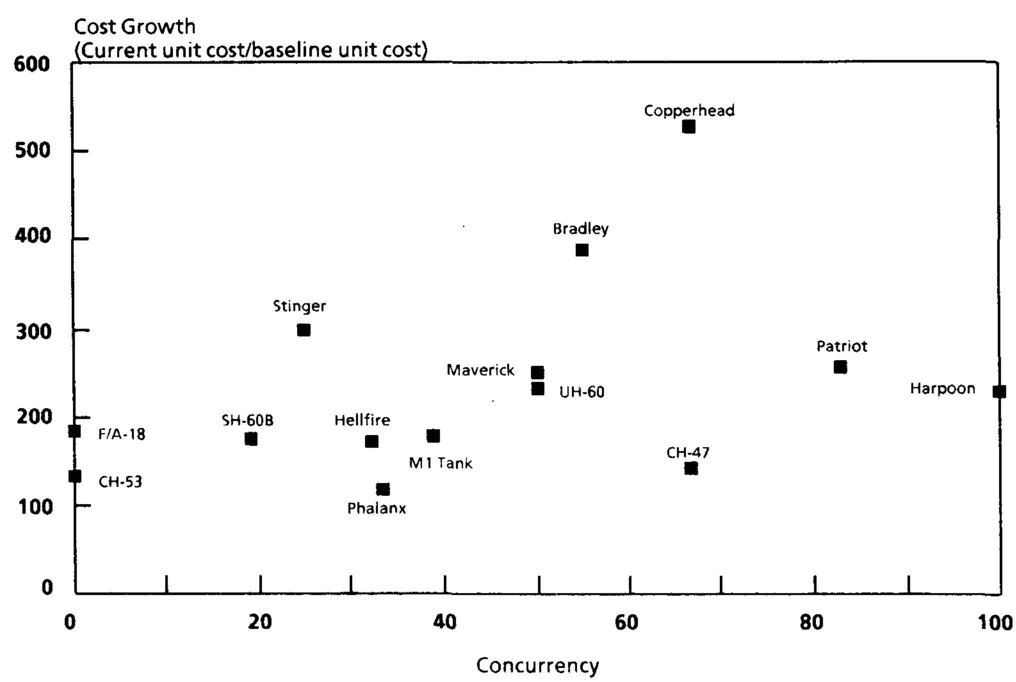
c. IOC = Initial Operational Capability.

66 percent of IOT&E remains. Low-concurrency programs (Group III) have less than 33 percent of IOT&E remaining.

The data show a modest relationship between concurrency and cost growth. For example, the most concurrent group of programs experienced a higher average cost growth (288 percent of the initial baseline estimates) than those in the medium (233 percent) and low (193 percent) concurrency groups.

Figure 3 corroborates this finding, but illustrates that less concurrent programs may also experience relatively high degrees of cost growth. Although several highly concurrent programs (Patriot, Harpoon, Copperhead) experienced a high degree of cost growth (current unit-cost estimates of more than 200 percent of the baseline), so did

Figure 3.
Concurrency and Unit Cost Growth



SOURCE: Congressional Budget Office based on Department of Defense program data and budget and schedule information.

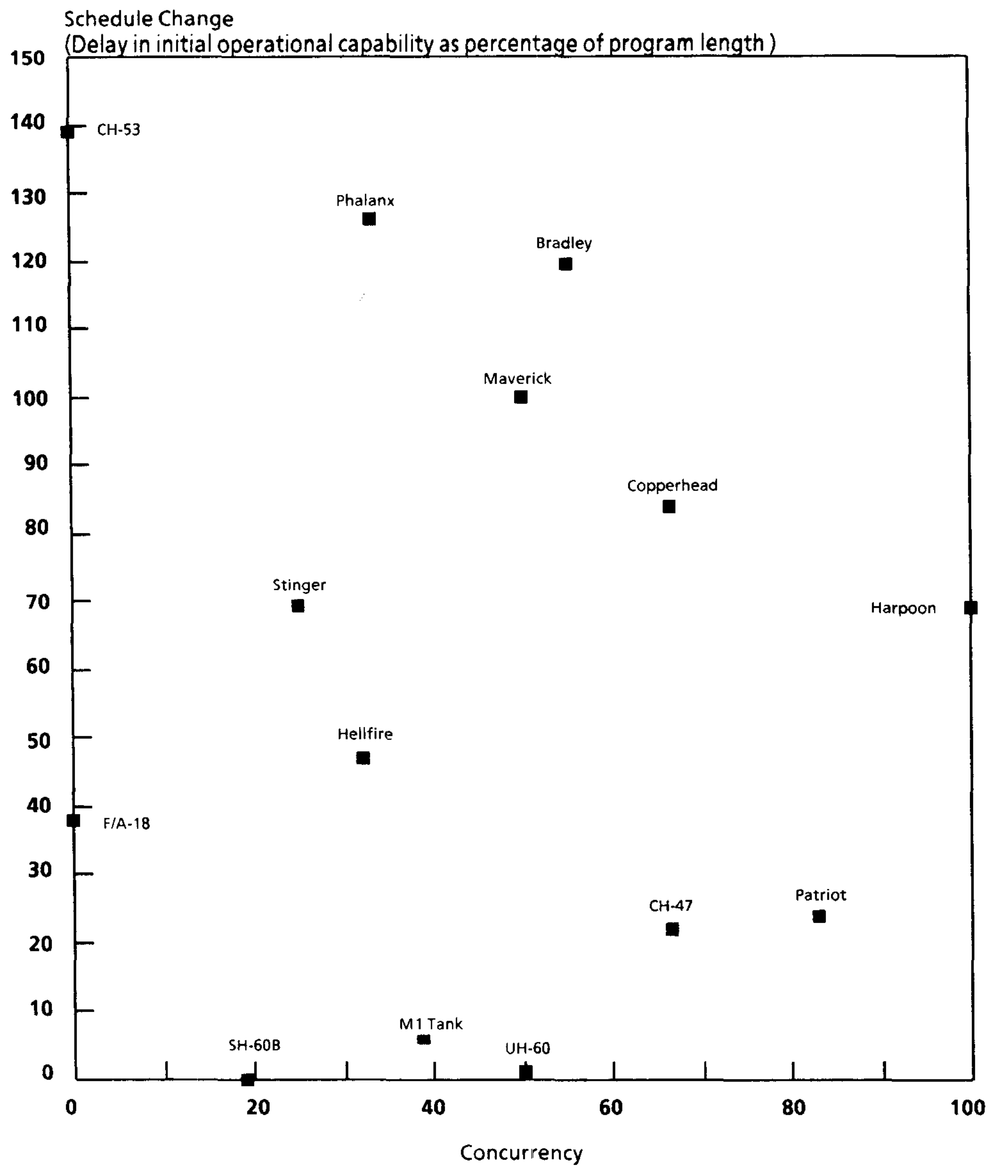
programs in the medium- and low-concurrency groups (Bradley, I2R Maverick, UH-60, Stinger). On the other hand, the CH-47 helicopter, a highly concurrent program, experienced significantly lower cost growth than most programs in less concurrent groups.

The relationship between concurrency and schedule change appears to be weaker than between concurrency and cost growth. The programs in the medium-concurrent Group II, for example, experienced a higher average rate of schedule delay than those in the high-concurrent Group I. For the programs in Group II, the average delay approached 71 percent of the time initially planned between Milestone II and the IOC. The average delay for programs in Group I was less: about 50 percent of the planned period between Milestone II and the IOC. Figure 4 illustrates this point graphically.

Simple regression analyses also corroborate the findings described above. Statistical indicators of correlation and determination demonstrate that concurrency is only modestly related to cost growth for the programs being examined. The correlation coefficient between concurrency and cost growth is only 0.38. This suggests that about 14 percent of the variation in cost growth from average levels is explained by concurrency. The correlation between concurrency and schedule delay is 0.12. This means that almost none of the variance in schedule delay from the average for this set of programs is explained by concurrency.

These findings appear consistent with at least some of the findings of an earlier study by the Defense Science Board (DSB)--an independent, high-level advisory group to the Secretary of Defense. In 1977 the DSB reviewed 62 acquisition programs that occurred between 1940 and 1977. It concluded that no correlation existed between concurrency and the meeting of cost, schedule, and performance goals. Since the DSB study did not present detailed data and definitions, this study has been unable to use the DSB data for comparison. In general, the statistical relationship of concurrency to cost growth and schedule delay for the programs examined is not compelling. Some highly concurrent programs experience major cost growth and schedule delays, however, and this suggests that closer Congressional review of such programs might be desirable.

Figure 4.
Concurrency and Schedule Slippage



SOURCE: Congressional Budget Office based on Department of Defense program data and budget and schedule information.

HISTORY OF CONCURRENCY

The use of concurrency has varied since World War I and has been the subject of continuing debate. During wars or periods of national emergency, the need for weapons has put a premium on the accelerated development and production of weapons. During peacetime, however, the use of concurrency has often been debated. During the past decade, some have argued that the Soviet military threat justifies concurrent scheduling, while others consider the threat to be less immediate and therefore favor a measured acquisition approach. Some believe in holding weapons acquisition costs to a minimum during peacetime, while others are willing to risk higher costs in the pursuit of national security. The following discussion summarizes the historical use of concurrency, and traces the policy debate since the 1960s.

The Use of Concurrency During Wartime and National Emergency

The development and production of weapons have customarily been accelerated in wartime or national emergencies. During World War I, for example, the Navy developed and produced depth charges within four months in order to meet the German submarine threat to allied shipping.[8]

After the delayed entry of the United States into World War II, urgent military requirements led to widespread use of concurrency. Many examples can be cited. A crash program to develop and produce radars, for instance, was undertaken in November 1940. By the end of the war, scientists at the Massachusetts Institute of Technology Radiation Laboratory had designed, developed, and produced 150 different radar systems for use on land, ships, and aircraft.[9] Research on the proximity fuse--a technological advance enabling destruction of enemy aircraft without a direct hit--was initiated in 1942, and the fuse

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8. Wayne C. Foote, "History of Concurrency: The Controversy of Military Acquisition Program Schedule Compression" (Thesis, Air Force Institute of Technology, Wright Patterson Air Force Base, Ohio, 1986), p. 31.

9. Bernard Brodie and Fawn Brodie, *From Crossbows to H-Bomb* (Bloomington: Indiana University Press, 1973), p. 209.

entered production in 1943.[10] Numerous aircraft programs were also accelerated; in some cases, such as the P-47, aircraft entered production within a matter of months after beginning development.[11] Perhaps the most famous concurrent program during World War II was the Manhattan Project, in which the design, development, and production of the world's first atomic bomb were telescoped into three years.

Soviet progress in space during the 1950s led to the acceleration of U.S. ballistic missile programs. The Thor intermediate-range missile, for example, entered development in December 1955; it was designed, built, and tested within two years, and was operationally deployed in June 1959. The Atlas and Titan missiles were also accelerated during the 1950s to achieve the earliest possible production and deployment dates.[12]

Weapons programs were accelerated to meet military requirements during the Vietnam War. The history of the Cobra helicopter is a good example. In September 1965, after only six months in development, a prototype of the AH-1 Huey Cobra helicopter was flight tested in order to meet an urgent requirement for a gunship escort for CH-47 helicopter transports. The Army signed an initial production contract six months later, and began deployment of Cobras in the fall of 1967, less than three years after the program had been undertaken.[13]

Programs designed to interdict enemy logistics and support lines in Southeast Asia were also accelerated. Forward Looking Infra-Red (FLIR) detection, Moving Target Indicators (MTI), and night vision devices were concurrently developed and produced for use against the Ho Chi Minh trail. "Smart" bomb programs were accelerated to provide needed military capability against critical military targets.[14]

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10. Ibid., p. 214.

11. Foote, "History of Concurrency," p. 33.

12. Wernher Von Braun and Frederick Ordway, *History of Rocketry and Space Travel* (New York: Thomas Crowell Company, 1966), pp. 133-135.

13. Bernard Nolty, Jacob Neufeld, and George Watson, *An Illustrated Guide to the Air War Over Vietnam* (New York: Arco Publishing Inc., 1981), p. 16.

14. Raphael Littauer and Norman Uphoff, eds., *The Air War in Indochina* (Boston: Beacon Press, 1972), p. 152.

Concurrency During Peacetime--Debating the Policy

Until recent years, weapons were generally developed and produced sequentially during peacetime. This was particularly true following World War I during a time of demobilization, limited defense budgets, and broad political support for disarmament and international cooperation. No military requirement existed during the postwar period that justified accelerating the weapons acquisition process.

During the interwar period, weapons were typically built as prototypes and subjected to extensive testing. The T-4, the only tank to enter serial production before 1935, was developed, tested, and produced sequentially.[15] Indeed, even when production of a weapon was started during the interwar era, relatively small quantities were manufactured. Aircraft such as the Curtiss Goshawk, the Helldiver, and the B-17 were produced in limited quantities.[16]

Following World War II, weapons acquisition generally returned to a sequential approach with a few exceptions such as the B-47 aircraft and the missile programs of the 1950s. In some cases, weapons such as the Terrier, Sparrow, and Nike missiles were kept in development in order to incorporate the latest technological advances before initiating production. Other programs were kept in development in order to avoid the post-production problems being experienced by concurrent programs such as the B-47. Indeed, the Air Force adopted a policy during the mid-1950s that restricted production for 18 to 24 months until testing was completed.[17]

The introduction of Total Package Procurement (TPP) by Secretary of Defense Robert McNamara in the early 1960s represented a major shift in weapons acquisition policy and practice. Previously, the Department of Defense had issued separate contracts for research and development and production. Under TPP, the DoD awarded a single fixed-price contract for the entire program. This provided contractors

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15. Peter Chamberlain and Chris Ellis, *British and American Tanks of World War II* (New York: Arco Publishing Company, 1969), p. 105; and Arthur Alexander, *Armor Development in the Soviet Union and the United States* (Santa Monica: The RAND Corporation, 1976), p. 79.

16. Enza Angelucci, ed., *Rand McNally Encyclopedia of Military Aircraft 1914-1980* (New York: Rand McNally and Company, 1980), pp. 153-155 and 288.

17. Foote, "History of Concurrency," pp. 41-42.

with an incentive to accelerate a program and to minimize development costs. In effect, TPP encouraged the use of concurrency.

Experience with programs such as the C-5 cargo aircraft demonstrated the risk of TPP, even for programs with only moderate technological difficulty. The C-5 entered production in 1968, after an abbreviated development phase had been compressed to meet an IOC that had been advanced from 1972 to 1969.[18] In July 1969, six months after the Air Force agreed to purchase a second lot of C-5 aircraft, the wings developed cracks. An expensive wing modification program was required.[19]

Other concurrent programs also experienced significant difficulties during the 1960s. The B-70 bomber and the Skybolt missile were canceled because of excessive costs. The MBT-70 tank, the Cheyenne helicopter, and the Condor missile were unable to meet cost, schedule, and performance objectives. The MBT-70 was replaced by a less ambitious program, the XM-803, which in turn, was terminated in 1972. The Cheyenne helicopter was canceled in favor of the AH-64 Apache helicopter program.

Early in 1969, Deputy Secretary of Defense David Packard reviewed the acquisition practices of the previous decade and concluded that "program after program was in trouble from a common fault--production had been started before engineering development was finished."[20] Packard favored the development and testing of prototypes before beginning production--a "fly before buy" approach to weapons acquisition. In 1970, the Fitzhugh Blue Ribbon Defense Panel supported Packard by recommending that the DoD adopt "a general rule against concurrent development and production efforts, with the production decision deferred until successful demonstration of developmental prototypes."[21]

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18. Berkeley Rice, *The C-5A Scandal* (Boston: Houghton Mifflin Company, 1971), p. 41.

19. Ibid., p. 150.

20. Foote, "History of Concurrency," pp. 53-54.

21. Blue Ribbon Defense Panel, *Report to the President and the Secretary of Defense on the Department of Defense* (July 1970), p. 8.

The DoD began to implement the "fly before buy" approach during the early 1970s. Deputy Secretary Packard established a formal management process under the Defense Systems Acquisition Review Council (DSARC) to review weapons acquisition and ensure that a weapon did not proceed from one acquisition phase to the next without successfully completing the previous phase. Under the DSARC system, a decision to begin production could not occur until the full-scale engineering phase had been completed.[22]

As a result of Packard's new approach, acquisition became more sequential during the 1970s. Flyoffs between prototypes of weapons or their components preceded production decisions for major weapons such as the A-X attack aircraft, the Lightweight Fighter, the F-15, and the AWACS aircraft. Test program results for major weapons in development during the late 1970s indicate that performance parameters were more thoroughly tested before beginning production than they had been previously.[23]

As the pendulum swung toward more sequential acquisition, however, the policy process generated another reversal. In 1977, the Defense Science Board (DSB), an independent, high-level advisory group to the Secretary of Defense, observed that the acquisition process was taking too much time and ought to be shortened. The DSB reviewed 62 acquisition programs between 1940 and 1977 and determined that no correlation existed between the use of concurrency and the ability of a program to meet cost, schedule, and performance goals. Consequently, the DSB recommended that DoD encourage the use of concurrency.

The recent difficulties with two highly concurrent programs, the B-1B bomber and the DIVAD gun, have again generated concern over the use of concurrency. In 1985 the President's Commission on Defense Management, under Chairman David Packard, reviewed the acquisition process and recommended a return to more sequential acquisition practices. For example, the Commission concluded that the most reliable approach to procuring high-technology weapons systems

22. Although the acquisition milestone system established by Packard has been modified many times, it continues to function. See Box, p. 11.

23. Edmund Dews and others, *Acquisition Policy Effectiveness: Department of Defense Experience in the 1970's* (Santa Monica: The RAND Corporation, 1979), p. 21.

was through developing and testing competitive prototypes before awarding a production contract. The Commission further recommended that prototype competitions be applied to all major weapons and critical subsystems.[24] It also recommended early operational testing in order to ensure that the design was satisfactory before beginning production.[25]

CURRENT LEGISLATION AND REGULATIONS

The outcome of these ebbs and flows of policy, together with the ambivalent evidence concerning concurrency, is a set of laws and regulations that do not prohibit concurrency, and in some cases encourage it. (Appendix A discusses the laws and regulations in more detail.) Indeed, DoD's basic acquisition regulations favor concurrency by emphasizing the need to reduce the time required to acquire weapons. One regulation explicitly states that the services can reduce weapons development or "lead" time through concurrency (DoD Directive 5000.1). In addition, a recent change in DoD Regulation 5000.2 permits authorization to begin production earlier in the acquisition process than ever before--at the start of full-scale development.

On the other hand, the Congress has enacted legislation that constrains concurrency. The 1987 Defense Authorization Act, for example, states that "a major defense acquisition program may not proceed beyond low-rate initial production until IOT&E of the program is completed." That same law requires that testing of a weapon's ability to survive enemy attack must be satisfactorily completed before the program may begin full-rate production.

Other legislation and policies seem intended to discourage concurrency. The 1987 Defense Authorization Act requires that, absent a Congressional waiver, the DoD must develop and test competitive prototypes of a major weapon before awarding a production contract. Competitive prototyping, which is also encouraged by several DoD

24. President's Blue Ribbon Commission on Defense Management, *A Quest for Excellence: Final Report to the President* (June 1986), p.56.

25. Ibid., p. 50.

instructions, is likely to lead to sequential rather than concurrent programs because time must be allowed to complete a competition between two or more contractors before production begins.

CHAPTER III

SHOULD THE CONGRESS TAKE ACTION?

Given the ambivalent evidence on the effects of concurrency, the Congress may wish to take no further action regarding concurrent programs as a group. Limits have already been set, both in law and in DoD regulations, to the use of concurrency. The policy pendulum in DoD may be swinging back toward less concurrency if the recent Packard Commission report is an indicator, and the risk factors in specific programs for which concurrency is proposed could be evaluated against the benefits of accelerating those programs.

Since some members of the Congress have expressed concern about concurrency-related problems in specific programs, including the B-1B bomber and the DIVAD gun, this chapter discusses several possible actions, noting the pros and cons of each.

GETTING INFORMATION ON CONCURRENT PROGRAMS

The documents routinely sent to the Congress do not identify programs that DoD regards as concurrent. Nor is there a definition of how DoD measures concurrency or what criteria it uses to identify a highly concurrent program. The data to make such judgments are available, however, and the Congress may wish to ask that a measure of concurrency accompany the Selected Acquisition Report (SAR) for each program. A letter accompanying the first such SAR could define DoD's measure and indicate its criterion for classifying a program as highly concurrent or less so.

Such a measure would not only inform the Congress as to which programs are concurrent; it might also focus DoD management attention on such programs. In general, DoD managers are in the best position to judge whether the benefits that can come from concurrency are worth its risks. Having such a measure in the SARs would also allow the Congress to note when concurrency is being planned or when programs are becoming more concurrent. A sharp rise in a program's concurrency above the level initially planned might suggest a need to review that program with added care.

A preliminary examination of current and recent programs suggests that the list of concurrent programs would include a substantial number of major programs (see Table 2).

TABLE 2. PLANNED CONCURRENCY LEVELS OF SELECTED MAJOR WEAPONS PROGRAMS

High-Concurrency Programs	
Army Helicopter Improvement Program	F-15 Aircraft
Harpoon Missile	Patriot Missile
NAVSTAR Satellite	B-1B Aircraft
C-17 Aircraft	AMRAAM Missile
MK-50 Torpedo	CH-47 Helicopter
T-45 Aircraft	Copperhead Artillery Shell
	V-22 Aircraft
Medium-Concurrency Programs	
Phalanx Gun System	UH-60 Helicopter
ASW SOW (Nuclear) Missile	I2R Maverick Missile
Bradley Fighting Vehicle	SRAM II Missile
	M1 Tank
Low-Concurrency Programs	
AV-8B Aircraft	Stinger Missile
F/A-18 Aircraft	ISA-AMPE Communications System
HARM Missile	F-16 Aircraft
CH-53 Helicopter	ASW SOW (Conventional) Missile
SH-60 Helicopter (LAMPS III)	Airborne Self-Protection Jammer System
Hellfire Missile	

SOURCE: Congressional Budget Office, based on Department of Defense program data.

NOTE: For a definition of concurrency, see Chapter II.

A measure of concurrency should at most add modestly to the workload of DoD managers. If it were analogous to the measure proposed in Chapter II of this study, it would require only a few computations for each program.

NONCONCURRENT BENCHMARKS

For programs that reflect substantial concurrency, the Congress might ask the Department to propose an alternative plan that would reduce or eliminate concurrency. This would provide a benchmark for judging concurrency's effectiveness. If the nonconcurrent benchmark, updated for experience acquired as the weapon was developed and produced, showed lower costs and the same or lower time to completion, then concurrency would clearly have failed. If the opposite proved true, then concurrency would be seen to have met its key objectives. As noted earlier, without such a benchmark it is very difficult to determine whether concurrency succeeds, and at what cost.

There is precedent for requiring such a benchmark estimate. When the Congress approved DoD proposals to expand multiyear contracting, it required the Department to estimate the costs of the program in the absence of a multiyear contract. (Multiyear contracting allows DoD to commit itself to buying a weapon for more than one year and to pay contractors to buy key components in economic quantities and stockpile them for later use.) These dual cost estimates have enabled analysts to estimate the effects of multiyear contracting.[1]

Making benchmark estimates could add substantially to DoD's workload. To be useful, such estimates would require careful judgments by DoD and its contractors concerning schedules and costs. This takes time and is not routinely done at present. If it requires such estimates, the Congress may wish to restrict them to selected programs.

1. Congressional Budget Office, Staff Working Paper, "Alternative Strategies for Increasing Multiyear Procurement" (July 1986).

ENSURING ADEQUATE OPERATIONAL TESTING

Adequate operational testing is important for all weapons programs, whether or not they feature concurrency. The Congress emphasized this point in 1983 when it established the office of the Director of Operational Testing and Evaluation as an independent adviser to the Secretary of Defense and as a rapporteur to the Congress on issues regarding operational testing.

But operational testing is particularly important for concurrent programs. By definition, these programs will be producing weapons at a time when operational testing is not yet complete. Testing problems must be identified quickly in order to minimize the number of weapons that will have to be refitted with modifications. Also, delays in operational testing can disrupt a concurrent program--which by definition operates under a compressed time schedule--more than a nonconcurrent program.

For these reasons, the Congress may wish to ensure adequate operational testing by examining the testing plans for major programs that feature substantial concurrency. That could be accomplished by reviewing the testing plan during hearings or, for weapons of particular concern, by asking for staff reports on the plan.

Several guidelines would be needed to assess the adequacy of a testing plan. The plan should:

- Establish clearly the objectives that must be met by a weapon for its operational testing to be judged successful. A recent GAO study found that, out of 63 reports concerning testing issued in the period from 1970 to 1986, test objectives and the criteria and plans for the tests were incomplete in 25 cases.[2] It is important that test personnel be involved in setting objectives since they must judge the tests' adequacy.

2. General Accounting Office, "Operational Test and Evaluation Can Contribute More to Decisionmaking" (December 1986), p. 14.

- Provide enough funds to buy adequate weapons for testing, a continuing problem according to reports by GAO and the DoD Inspector General.[3]

- Ensure that all operational tests are made on weapons representative of those that will actually be produced for use by operating units, and, particularly during later operational tests, ensure that actual production versions are used in testing.

- Ensure that targets simulating enemy forces represent the threat realistically. The DoD Inspector General found this not to be the case in some recent tests, such as those of the new Aegis antimissile system.[4] Ranges over which a system is tested must also be realistic, a problem in recent testing of the air-launched cruise missile.[5]

- Ensure that test facilities are available in a timely manner. In concurrent programs in particular, testing delays can wreak havoc in an already compressed schedule.

As with all actions in the complex arena of defense procurement, efforts to ensure adequate tests entail potential problems. Program costs could increase if adequate provisions have not been made for testing during initial program planning. Difficult choices may have to be made if required testing facilities are not available.

ENSURING ADEQUATE RISK ANALYSIS

Among the most important factors to consider in allocating resources for any weapons system is the risk that the program will not achieve its planned goals. Contributing to this risk are the chances of major

3. General Accounting Office, ibid., and Senate Committee on Government Affairs, *Hearings on the Management of the DoD*, 98:1 (June 23, 1983), Part 5, p. 21.

4. Senate Committee on Government Affairs, *Hearings on the Management of the DoD*, 98:1 (June 23, 1983), Part 5, p. 55.

5. Ibid., p. 19.

cost increases, delays in schedule, or performance that falls below planned levels. Any of these could have a serious effect on military capability.

DoD regulations encourage, but do not require, an assessment of risk. Evidence suggests that risk analysis is not widely used. None of the programs reviewed for this study provided a documented comprehensive risk analysis for the acquisition milestones. A GAO audit in 1986 found that only 12 of 48 program managers who were queried indicated that a formal, quantitative measure of program risk had been used in preparing their programs' budgets.[6] Even when systematic assessments of risk are performed, they are not made available to the Congress. For example, no such assessments appear in the Selected Acquisition Reports that are sent to the Congress regarding major weapons systems. (Appendix B discusses more fully DoD's risk analysis policies and their implementation.)

The Congress may wish to require a comprehensive, systematic risk assessment for selected major programs. Since such assessments would involve considerable effort, they could be limited to key programs, perhaps focusing on those that have substantial concurrency.

Identifying Risks

In reviewing any risk assessment, it is necessary to be sure that all major sources of potential risk have been considered. Table 3 shows six key sources of risk and the factors to consider in assessing the importance of each.

For example, an important source of risk is the potential for changes in the enemy threat. During the development and production of a weapons system, which may take 10 years or more, the enemy may acquire new technology; other changes may occur in the scope or characteristics of the threat. Any change in the threat may substantially affect the program's cost, schedule, and performance. Assessing this sort of risk is difficult, since it requires examining the historical experience of requirements for similar types of weapons, the degree of

6. General Accounting Office, "Status of the Defense Acquisition Improvement Program's 33 Initiatives" (September 1986), p. 17.

confidence one can have in threat assessment projections, and the possibilities for alternative technical or policy solutions.

Techniques for Analyzing Risk

Once the main sources of risk have been identified, various analytic techniques can be used to quantify them. Several of these techniques focus on the risks of increased costs or delayed schedules. The Program Evaluation and Review Technique (PERT) identifies key deci-

TABLE 3. MAJOR RISK FACTORS IN CONCURRENT WEAPONS SYSTEMS ACQUISITION

Source of Risk	Factors to Consider in Assessing Risk
Change in Enemy Threat	Historical experience with similar system Experts' confidence in their threat assessments Possibility of need for new weapon design
Type of Contract	Fixed price for highly technical systems inherently risky
Manner of Funding	Likely variation from planned funding (because of budgetary constraint or unanticipated inflation)
Technical Elements	Level of technology being attempted Feasibility of implementing system design concepts
Weapons Testing	Availability of adequate test assets, including facilities
Transition to Production	Feasibility of planned manufacturing process Lead time for materials, special tooling, labor

SOURCE: Congressional Budget Office.

sion points that are critical to program completion. Regression analysis can be used to predict costs based on experience with historical systems that have similar characteristics such as weight, speed, and range.

Other techniques have more general application. Decision analysis, for example, identifies important decisions and assigns the probabilities of various outcomes. It could be used to assess cost and schedule risks as well as the risk of technical problems arising that might prevent the system from meeting its performance goals. The Delphi methodology used in marketing analysis can also be used to assess systematically a range of expert opinion bearing on any type of risk.

APPENDIXES

APPENDIX A

CURRENT LEGISLATION, POLICIES, AND REGULATIONS AFFECTING CONCURRENCY

Existing laws and federal regulations, including Defense Department and service regulations and instructions, permit concurrent development and production of weapons systems. Recent legislation and changes in DoD acquisition policies, however, have placed certain constraints on the acquisition process to reduce the risks associated with concurrency. The following discussion summarizes the relevant recent legislation and outlines current defense acquisition policies that could affect the use of concurrency.

LEGISLATION AND GOVERNMENTWIDE REGULATIONS

In recent years, the Congress has acted to constrain the risks of concurrency by placing increased emphasis on operational testing of weapons systems. In 1983, the Congress established an independent office of Operational Testing and Evaluation (OT&E) to advise the Secretary of Defense on operational testing matters and to report to the Congress concerning operational testing of major weapons systems. Chapter 4 of Title 10 of the United States Code requires that, before beginning full-rate production of a major weapons system, the Director of the office must report to the Congress concerning the adequacy of the system's OT&E. The Director must also assure the Congress that the items or components that were tested are effective and suitable for combat.[1] Such assurances should minimize the risk of having to make costly alterations in weapons systems after full-rate production has begun.

Several provisions in the 1987 Defense Authorization Act are also intended to reduce the risks of concurrency. Section 909, for example,

1. Senate Armed Services Committee, *National Defense Authorization Act for Fiscal Year 1984*, Report No. 98-213, 98:1 (1983), pp. 74-76.

requires that, unless the Congress grants a waiver, the DoD must develop and test competitive prototypes of major weapons systems under realistic conditions before awarding a production contract. This provision reflects the Congress's belief that competition between prototypes will provide an incentive to contractors to improve system performance beyond levels that could be expected in a sole-source contracting environment. Such competition, together with the requirement for realistic testing, should reduce the risk that production models may need expensive retrofits or changes.

Chapter 139 of Title 10, United States Code, specifies that testing of the survivability and lethality of a weapons system must be satisfactorily completed before a program may begin full-rate production. In addition, the legislation states that "a major defense acquisition program may not proceed beyond low-rate initial production until initial OT&E of the program is completed."[2] The successful completion of survivability, lethality, and initial OT&E before beginning full-rate production should also reduce the risk that major retrofits will be needed.

Aside from these legislative constraints affecting concurrency, current governmentwide acquisition regulations neither prohibit the use of concurrency nor provide detailed guidance concerning its use. The basic federal instruction on major system acquisition policy (OMB Circular A-109), for example, states that limited production of a system may begin when a system's design concept has been satisfactorily demonstrated. Full production, the instruction continues, can begin when the "mission need and program objectives are reaffirmed and when system performance has been satisfactorily tested . . . and evaluated in an environment that assures demonstration in expected operational conditions."[3] In either case, the meaning of "satisfactory" is not specified. Consequently, considerable latitude exists for program planners and managers regarding the extent to which concurrency can or should be used.

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2. House Armed Services Committee, *National Defense Authorization Act for Fiscal Year 1987*, Report No. 99- 1001, 99:2 (1986), pp. 111-113.

3. Office of Management and Budget, "Major Systems Acquisition - Circular A-109," April 1976, p. 10.

The Federal Acquisition Regulations (FAR) also fail to provide specific guidance on when to use concurrency. In its discussion of acquisition planning, the FAR simply requires that "if concurrency of development and production is planned" the agency should "discuss its effects on cost and schedule risks." Concerning testing, the FAR requires a discussion of the "extent of testing to be accomplished before production release."[4]

DOD POLICIES AND REGULATIONS

The basic acquisition regulations of the Department of Defense emphasize the need to reduce the length of the acquisition process. Department of Defense Directive 5000.1, for example, states that "a primary goal in developing an acquisition strategy is to minimize the time it takes to satisfy the identified need consistent with common sense, sound business practices, and the basic management policies of this Directive."[5] Service regulations also refer specifically to the need for reducing acquisition time.[6] Both DoD and service regulations permit the use of concurrency as a means to achieve this goal.

DoD's basic acquisition regulations provide service and program planners with considerable flexibility in using concurrency. DoD Directive 5000.1, for example, directs the services, "commensurate with risk," to reduce lead time through concurrency, and to combine acquisition phases and development and operational testing "when appropriate."[7] Additional flexibility exists since few prerequisites for production are specified. DoD Instruction 5000.2, for example, lists program areas to be considered by the Defense Acquisition Board (DAB) before the approval of production, but does not identify specific

4. Federal Acquisition Regulations, Subparts 7-1 and 7-2.

5. Department of Defense Directive 5000.1, "Major and Non-Major Defense Acquisition Programs," September 1, 1987, p. 5.

6. Army Regulation 70-1, "System Acquisition Policy and Procedures," November 12, 1986, p. 3; and OPNAV Instruction 5000.42C, "Research, Development and Acquisition Procedures," May 10, 1986. p. 4.

7. Department of Defense Directive 5000.1, p. 5.

requirements within these areas.[8] The instruction does require, however, that adequate testing and "operational effectiveness and suitability" be accomplished before beginning full-rate production. "Adequacy," "effectiveness," and "suitability" are not defined, however.[9]

Although DoD acquisition policy regulations encourage the use of concurrency "commensurate with risk," they also contain provisions that endorse using a sequential acquisition approach. For instance, they encourage the use of competitive prototyping before beginning production and early OT&E.[10]

The basic DoD regulation concerning testing and evaluation, DoD Directive 5000.3, endorses reducing acquisition time by combining development and operational testing. According to the directive, combined testing "may be used when cost and time benefits are significant . . . provided that test objectives are not compromised."[11] Combined testing is characteristic of concurrent programs in that it can be a primary means to reduce acquisition time and accelerate a production decision.

On the other hand, DoD Instruction 5000.3 also contains guidance supporting sequential acquisition. For example, the directive requires that, before a Milestone III production decision, testing results must confirm that all significant design problems have been identified; that solutions are available; and that items tested are "effective and suitable for their intended use."[12] The directive also states that, before a production decision, operational testing must be completed on a representative item for production and must "ensure that it meets required operational thresholds."[13] An important ambiguity exists, however, since the directive does not distinguish between testing prerequisites for an initial, low-rate production decision (Milestone IIIa) and a full-

8. Department of Defense Instruction 5000.2, "Defense Acquisition Program Procedures," September 1, 1987, p. 4.

9. Department of Defense Directive 5000.3, "Test and Evaluation," March 12, 1986, p. 7.

10. Department of Defense Directive 5000.1, p. 6.

11. Department of Defense Directive 5000.3, p. 8.

12. Ibid., p. 7.

13. Ibid.

rate production decision (Milestone IIIb). If the above prerequisites apply only to a full-rate production decision, they do not constrain the use of concurrency vis-a-vis an initial production decision.

APPENDIX B

RISK ANALYSIS POLICIES AND THEIR IMPLEMENTATION

In general, government and Department of Defense policies support, but do not require, the use of a comprehensive, formal risk analysis of major weapons programs as part of the acquisition and budget processes. The federal government's basic acquisition policy guidance, for example, encourages, but does not require, agencies to include "methods for analyzing and evaluating contractor and Government risks" in developing acquisition strategies for major systems.[1] The government's basic acquisition regulations, including the Federal Acquisition Regulations (FAR) and the DoD Supplement to the FAR, do not require the use of risk analysis for major procurement programs.

Corresponding acquisition regulations for the DoD also encourage, but do not require, the use of risk analysis for acquisition milestone or annual budget reviews. For example, DoD Directive 5000.1, "Major and Non-Major Defense Acquisition Programs," encourages program managers to "consider" conducting studies to assess technological risk and to develop alternatives for high-risk areas.[2] Further, DoD Instruction 5000.2 indicates only that the senior DoD acquisition review board, the Defense Acquisition Board (DAB), may "consider" whether a procurement strategy is appropriate to program cost and risk assessments.[3]

The latter instruction, it should be noted, requires that key areas of technological and producibility risk be identified in a System Concept Paper for review by the DAB at Milestone I (System Concept Demonstration and Validation) and that test and evaluation results concerning risk areas be reported in the Decision Coordinating Paper

1. Office of Management and Budget, "Major System Acquisitions Circular A-109," April 5, 1976, p. 5.

2. Department of Defense Directive 5000.1, "Major and Non-Major Defense Acquisition Programs," September 1, 1987, p. 5.

3. Department of Defense Instruction 5000.2, "Defense Acquisition Program Procedures," September 1, 1987, p. 5.

at Milestone II (Full-Scale Development).[4] The DoD Instruction 5000.2 does not, however, specify that risk analysis be used to fulfill these requirements.

The DoD also requires that the DoD Product Engineering Services Office (DPESO) conduct an assessment of production readiness before a commitment to produce a weapons system, and that DPESO "identify potential problem areas which constitute production, cost, or schedule risks." The DoD directive concerning production readiness reviews also states, "Each risk will be expressed in terms of its relative magnitude and potential consequences."[5] The instruction does not provide specific guidance, however, concerning the methodology used to determine the magnitude and consequences of producibility risks.

The DoD Instruction 7041.3 concerning economic and program evaluation methods for resource management requires that risk assessments be made for major programs, but does not direct that formal risk analysis methods be used. The directive states that "special degrees of risk/uncertainty associated with a particular program/ project, may be pointed out quantitatively in an analysis and used for program review purposes."[6] The directive also requires that program schedules and funding should be structured to accommodate program uncertainties, but does not require that such uncertainties be measured and identified separately.[7]

Service regulations and guidance also support, but do not require, the use of formal risk analysis to support program and budget reviews for major programs. Army Regulation 70-1, for example, states that development and procurement programs may be funded, "if appropriate," using a risk analysis method called Total Risk Assessing Cost

4. Ibid., p. 4-2.

5. Department of Defense Instruction 5000.38, "Production Readiness Reviews," January 24, 1979, p. 3.

6. Department of Defense Instruction 7041.3, "Economic Analysis and Program Evaluation for Resource Management," October 19, 1972.

7. Ibid.

Estimate (TRACE).[8] (The TRACE method uses a risk factor approach to risk analysis.) The Navy requires that programs must "include efforts to identify, control, and reduce program risk," but does not specify the use of risk analysis to support program and budget reviews.[9]

Both through legislation and through management reforms, the Congress and the DoD have initiated a number of measures to reduce program risks. Requirements now exist for using performance warranties for major weapons systems; for reporting on operational testing results before approval for full-rate production; for using independent cost estimates; for developing and testing prototypes of systems and subsystems; and for using lower-risk, more gradual approaches to weapons system development (Pre-Planned Product Improvement). The services are permitted to budget for program risks through funding for anticipated program changes (Engineering Change Orders) or management reserves.[10] Little, however, has been accomplished in carrying out measures designed to ensure that program risk is identified, measured, and analyzed in a systematic way to support other risk-reducing policies.

Past attempts by the DoD to require risk analysis have achieved only limited success. In 1981, for example, the DoD undertook a management initiative to budget for technological risk as one of 32 ways to improve defense acquisition (the "Carlucci Initiatives"). Under this initiative, the Deputy Secretary of Defense emphasized the need for the services to evaluate, quantify, plan, and budget for program risk. He requested the Navy and Air Force to review the Army's TRACE program and "either adopt it or propose an alternative . . . ."[11] None of the other services subsequently adopted the TRACE program as a budgeting requirement. Moreover, the Army currently applies TRACE only to a limited number of its programs.

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8. Department of the Army, Regulation 70-1, "System Acquisition Policy and Procedure," November 12, 1986, p. 16.

9. OPNAV Instruction 5000.42G, "Research, Development, and Acquisition Procedures," May 10, 1986, p. 3.

10. See General Accounting Office, "Defense Budget--Contingency Funds in Three Aircraft Procurement Programs," October 1987.

11. Deputy Secretary of Defense Memorandum, "Improving the Acquisition Process," April 30, 1981, p. 12.

Despite DoD's policies, initiatives, and regulations supporting the use of risk analysis, indications (such as the limited application of TRACE) are that it is used only occasionally, or at least that it is not reported or reviewed at higher levels of management in the DoD. According to a recent GAO audit of DoD's implementation of the "Carlucci Initiatives," only 12 of 48 program managers who were queried indicated that a formal, quantitative measure of program risk had been used to derive their program budgets.[12] Another GAO review of DoD's risk assessment efforts observed that, although qualitative assessments of risk were usually made at acquisition milestones, none of the acquisition milestone documentation reviewed for 25 major weapons systems contained any quantitative analysis of program risk.[13] Program milestone documentation for the weapons systems examined for concurrency in Chapter II confirmed GAO's findings; qualitative assessments were made for some, but no quantitative risk analysis was cited.

Currently, the Congress is not informed about program risk based on risk analysis conducted by the Department of Defense. Program and budget documentation provided by the DoD to the Congress, such as the SARs and the Congressional Data Sheets, do not contain data based on risk analysis. In the past, the DoD has suggested that providing information on program risk to the Congress would result in disapproval for any funds requested to cover risk.[14]

12. General Accounting Office, "Status of the Defense Acquisition Improvement Program's 33 Initiatives" (September 1986), p. 17.

13. General Accounting Office, "Technical Risk Assessment: The Status of Current DoD Efforts" (April 1986), p. 49.

14. Deputy Secretary of Defense Memorandum, "Improving the Acquisition Process," April 30, 1981, p. 12.

GLOSSARY

Bradley Fighting Vehicle. The Army's light armored fighting vehicle that can be used to transport troops on the battlefield (the Infantry Fighting Vehicle--IFV), and also for scouting, reconnaissance, and security missions (the Cavalry Fighting Vehicle--CFV). It is armed with a 25mm automatic cannon that can be fired on the move, and also carries the TOW antitank guided missile system. The Bradley entered full-scale development in June 1976, was approved for production in January 1980, and achieved initial operational capability (IOC) in December 1983.

CH-47 Helicopter. A medium-lift helicopter used by the Army and the Marine Corps to move troops, ammunition, repair parts, petroleum, artillery, and other weapons. A modernization program was initiated in October 1975 to improve the helicopter's performance capabilities. Initial production of the modernized CH-47 was authorized by the Army in August 1980, and IOC occurred in February 1984.

CH-53 Helicopter. Used by the Navy and Marine Corps to perform heavy lift operations including transporting equipment, supporting construction, removing damaged aircraft from carrier decks, and providing an airborne mine countermeasure capability. The CH-53 entered full-scale development in May 1975, was authorized for production in January 1978, and reached IOC in June 1982.

Copperhead Artillery Projectile. A cannon-launched 155mm laser-guided projectile used by the Army and the Marine Corps against armored vehicles or hardened targets. The Copperhead was approved for full-scale development in June 1975, was authorized for production in February 1979, and became operational in December 1982.

F/A-18 Aircraft. The Navy's newest fighter aircraft, designed primarily for air-to-air combat. It can also perform light attack, reconnaissance, and training missions. Full-scale development of the

F/A-18 was authorized in December 1975, production was approved in June 1981, and IOC was achieved in March 1983.

Harpoon Missile. The Navy's tactical radar-guided missile designed for use against surface naval targets and launched from aircraft, surface ships, or submarines. Harpoon entered full-scale development in June 1973, was approved for production in June 1975, and achieved IOC in July 1977.

Hellfire Missile. A tactical air-to-surface missile used by the Army and the Marine Corps that is guided by a laser designator and employed against armored targets. The Hellfire missile entered full-scale development in February 1976, was approved for production in November 1981, and achieved IOC in July 1986.

Imaging Infrared (I2R) Maverick Missile. A tactical air-to-surface missile developed by the Air Force to locate and strike ground targets including armored vehicles, fortifications, gun positions, communication centers, and aircraft shelters. The I2R Maverick entered full-scale development in September 1976, was approved for production in September 1982, and became operational in February 1986.

M1 Tank. The Army's primary main battle tank, armed with a 105mm gun and capable of traveling 45 miles per hour. The tank has a fire control system that permits daytime or nighttime operation, and can fire at armored or unprotected targets while on the move. The M1 began full-scale development in November 1976, was approved for production in April 1979, and achieved IOC in January 1981.

Patriot Missile. The Army's land-mobile air defense system, deployed in fire units consisting of a radar set, a control station, a power source, and eight launching stations armed with four missiles each. It is capable of intercepting high-performance aircraft at all altitudes. Patriot entered full-scale development in February 1972. A decision was made to restructure the program in 1974, and approval was given to resume engineering development in 1976. The missile was approved for production in September 1980, and was initially deployed in the United States in June 1983 and in Europe in March 1985.

Phalanx Gun System. The Mark 15 Phalanx (or Close-in Weapon System) is an automatic gun fire-control system used on surface ships to defend against antiship missiles. The system automatically searches for targets, evaluates and tracks the threat, and orders and adjusts firing of a Gatling-type gun. Phalanx was authorized for full-scale development in December 1972 and for production in September 1977, and its IOC occurred in February 1980.

SH-60B Helicopter. Also called LAMPS III--Light Airborne Multi-purpose System III. It is deployed on Navy surface ships to detect, identify, track, and interdict enemy surface vessels and submarines. LAMPS III is also used for search and rescue, supply replenishment, medical evacuation, and other fleet support missions. The SH-60B was authorized to begin full-scale development in February 1978, initial production was approved in November 1981, and IOC was achieved in July 1984.

Stinger Missile. A man-portable, infrared-seeking guided missile used by the Army and the Marine Corps against low-altitude, high-speed aircraft. The basic Stinger missile was approved for full-scale development in May 1972 and for production in November 1977, and was first deployed in February 1981.

UH-60 Black Hawk Helicopter. The Army's multipurpose helicopter capable of transporting troops, weapons, and supplies. It can also be used for air assault, rescue, and evacuation missions. The Black Hawk was approved for full-scale development in May 1971, authorized to begin production in November 1976, and achieved IOC in November 1979.