THE IMPACT OF THE COST/SCHEDULE CONTROL SYSTEMS CRITERIA ON ELECTRONICS AND AEROSPACE CONTRACTORS

DISSERTATION

Presented to the Graduate Council of the
North Texas State University in Partial
Fulfillment of the Requirements

For the Degree of

DOCTOR OF PHILOSOPHY

By

Gary L. Richardson, B.S., M.S.
Denton, Texas

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PREFACE

The task of planning and control is constituting an in-reasing segment of the technical manager's job, owing imarily to dynamic technology and equally dynamic changes management information control systems. A manager in-lved in such activity is concerned not only with the ghly technical problem of information systems design and plementation, but also with the myriad of human problems sociated with such activity that can often dictate the entual success of any management activity. The develop-nt of a modern weapons system provides a significant allenge to the modern manager, owing to the large resource mmitment involved, the size of the total task, the high vel of uncertainty implicit in such activity, and the tal time required. Classical planning and control tech-ques are hardware-oriented because standards are established d tangible output is measured, thereby providing a com-rative measure. The modern research and development task is found to be more complicated than this, since many years may pass before a true hardware item of output can be mea-sured, yet the job of planning and control is even more vital in order to optimize resource expenditures. Indeed, more and more of the modern manager's time is spent performing planning and control tasks which do not have tangible outputs.

A disciplinary approach to such a problem is considered to be one of the most significant challenges for the manager of the seventies.

Initial stimulus for this research project was provided by the long-held desire to gain insight into the basic management functional areas of planning and control, as well as the desire to analyze the process of defense procurement. The Cost/Schedule Control Systems Criteria's entrance into prominence during the initial period of search for an appropriate subject seemed to offer common ground for exploration of both areas. It should be recognized that such a subject is dynamic in all aspects and exceptionally vulnerable to changing attitudes and interpretation. Also, the political force behind such a document changes with each presidential administration. In one administration emphasis may be placed on highly theoretical approaches, while the succeeding one may completely reverse direction in an attempt to abolish the "evils" of the previous system. Such political vagaries make the task of rational analysis increasingly difficult. This research effort is an attempt to capture the subject at present and theorize about its future impact, assuming that political forces remain stable. The validity of such an assumption can only be tested by time.

This research consumed much personal energy over an extended period of time. In spite of this effort, it would have been relatively fruitless except for the assistance of

many outside sources which are too numerous to be mentioned here. The initial exposure to this subject area was provided by Texas Instruments. Gratitude must be expressed for their willingness, as a company, to provide not only the financial assistance to start the research, but also the freedom to probe the organization for problem areas and to use such data for illustrative purposes. Specifically, Mike Sullivan and Dale Boyett gave freely of their time, assistance, and moral support during the early phases of this program. Ralph Darling and Ben Carroll of General Dynamics were also valuable sources during the stage of problem identification. C. E. Stewart and his associates at LTV Aerospace provided valuable insight into the problem during the questionnaire formulation stage. Finally, Edward Siebert of the Grumman Aircraft Corporation personally visited me in Florida to return his company's questionnaire and philosophize on the Criteria impact.

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CHAPTER I

INTRODUCTION

For the past several years the government, as a monopsonistic customer in the area of weapons systems procurement, has shown an increasing interest in the management control systems of its defense suppliers. Such action has been stimulated by consistent cost and schedule overruns, as well as by frequent deficiencies in resulting system performance. These phenomena occur throughout the broad spectrum of government procurement; however, the outstanding examples have been noticed in the aerospace and electronics industries. The magnitude of investment required in this industrial segment is often a multi-billion-dollar gamble on an untried product. Not only is the resource commitment gargantuan, but also the timely availability and subsequent performance of the resulting weapons system are critical.

Owing to this general state of affairs the government has recently taken steps to coordinate more closely efforts between itself and the vast network of prime and subcontractors. One significant outgrowth of this interest has been the *Cost/Schedule Control Systems Criteria*, also known as Department of Defense Instruction 7000.2, which was issued in December, 1967. This document is concerned with the control of cost, schedule, and technical performance parameters for certain selected high-impact weapons systems contracts. It was originally intended that this control specification would be imposed upon all applicable segments of weapons system procurement. The initial companies exposed to this document have been primarily Air Force contractors, although Army and Navy agencies have adopted similar approaches to weapons acquisition management.

The major departure from traditional government regulatory approaches indicated by this document is the concept of flexibility. For example, the Criteria requirements are meant to be a set of general guidelines, rather than a firm set of exact procedural specifications as used in most other military requirements. A series of basic source documents has been in the process of evolution and release since 1966; however, serious implementation has been delayed in an effort to resolve certain compliance problems with industry. In the interim period each service has approached the problem individually with varying degrees of emphasis. Most notable of these approaches is the Cost/Schedule Planning and Control System, AFSCM 70-5, currently being stressed by the Air Force in selected contracts. Through this system, the Air Force is approaching a planning and control concept similar to that envisioned by the broader Department of Defense Criteria document. Each of these regulatory devices is similar in concept and can be considered congruent with respect to the resultant impact on the using contractor.

The weapons system development process can be viewed as a highly complex and uncertain activity in which human resources play a vital productive and managerial role to accomplish constrained program objectives which are, in turn, reflected by cost, schedule, and performance parameters. It is the function of an operating Criteria-type planning and control system to supply information regarding these dynamic indicators to the systems analysts of the Department of Defense. A Criteria-type system is hypothesized as having a broad impact on the contractor's organization and its method of operation. Implementation of such a technique represents a significant undertaking by a very large industry *en masse*. Many of the techniques and concepts generated during this period of introduction might possibly influence future industry systems, philosophies, and performance.

Implementation of a Criteria-type system has many political as well as military consequences. The total area of impact is thus potentially large and may have significant bearings on the future process of weapons acquisition. Also, various contractor relationships may be significantly altered, assuming full implementation of the Criteria concept. It now appears that the actual character of the Criteria is taking on the structure of a power struggle between industry and its sole buyer. On the one hand, the government is prodding for increased engagement, while on the opposite side, vendor management would like to regain some of its prerogatives.[1] The attempt to implement DOD Instruction 7000.2 and the resulting power struggle appear to offer significant consequences for any enterprise involved in future government procurement.

The Objective

The primary purpose of this study was to analyze the capability and inclination of the aerospace and electronics industry contractors to abide by the general provisions of the Cost/Schedule Control Systems Criteria (C/SCSC). These Criteria are quite similar to the Cost/Schedule Planning and Control Specification (C/SPCS) now being adopted by the Air Force. A second objective was to analyze the current impact of this document on the total industry, the cost of implementation for the contractor, and the potential impact of the Criteria on future operations.

Most of the current documentation regarding this subject was issued either by the customer, a particular procuring agency, or the contractor. Obviously, each of these parties had a high level of bias toward the subject, thus the documentation lacks objectivity regarding needs and problems of the Criteria. Another purpose of this research was to evaluate the C/SCSC in its operating environment without bias. If such an analysis could be achieved, then the research should be of benefit to those involved.

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[1] "Engagement refers to government involvement in contractor management decisions and internal operating data. See Appendix A, "Glossary of Terms."

Hypotheses

Four basic hypotheses were tested in this research program. These are summarized as follows:

I. Implementation of the Cost/Schedule Control Systems Criteria will have a significant potential impact on most contractors involved in major weapons systems procurement.

II. Government contractors are generally adverse to further engagement by their customer, especially with regard to internal budgeting data.

III. The Cost/Schedule Control Systems Criteria represents a marked change in government philosophy regarding contractor performance measurement.

IV. There is currently no information technology which can universally satisfy Criteria requirements (*i.e.*, traditional accounting systems, PERT/Cost, production control techniques, *etc.*).

Methodology

Both primary and secondary sources were used in this study, with particular emphasis placed on case studies and questionnaire surveys within the industry. The primary research segment of this project consisted of case studies, personal interviews, multi-phase questionnaires, a seminar, and letters of inquiry to both industry and governmental personnel.

An individual research study performed at Texas Instruments, Inc., Government Products Division, during the summer of 1968 provided an initial opportunity to view the problem of planning and control in its working environment. Texas Instruments agreed to furnish financial assistance to the project in return for an in-depth analysis of problem areas associated with the development of highly technical and low-quantity production defense items. This study, associated with other case studies and personal interviews within the industry, provided much of the background material for the research. A series of questionnaires was used to substantiate and validate certain key concepts.

Associated with the interview and case study effort performed at Texas Instruments, a questionnaire was used within this same sample population to test the consistency of attitudes of these managers with their industry counterparts. Before attempting to use the questionnaire in a broad survey of the industry, it was deemed desirable to pretest the instrument using a well-known environment where predictability of the internal attitudes, as well as the technical environment, was available. This survey will be referred to throughout subsequent discussions as "case study questionnaire."

The total list of the applicable population for the questionnaire survey was taken from the top 100 contractors doing business with the Department of Defense for the fiscal year 1968. Eighty-six contractors were selected from the list on the basis that the companies appeared to be involved in aerospace or electronics work, except for engine manufacturers, which were excluded from the study. Seven large aerospace corporations were then chosen from this list, using internal industry information that each had been exposed to early Criteria requirements. The seven companies which constituted this control group are as follows: (1) General Dynamics, (2) Lockheed Aircraft, (3) McDonnell Douglas, (4) The Boeing Company, (5) LTV Aerospace Corporation, (6) North American Rockwell, and (7) Grumman Aerospace Corporation. The basic use of the control group was to test the type of questions being asked and to use their responses in revising the questionnaire for the remainder of the population sample.

The second phase of the survey consisted of rewording vague items in the control study questionnaire and then mailing additional questionnaires to the seventy-nine remaining corporations chosen to constitute the sample.

More specifically, the data collection process consisted of the following seven basic steps:

1. Collection of the basic source documents.--A set of Department of Defense literature which documents the total Criteria requirements.

2. Case studies.--An in-depth collection of data within a single company which is useful for analyzing individual approaches to the implementation of the Criteria.

3. Published sources.--Industry and trade sources which discuss and analyze the subject area.

4. Personal interviews.--Interviews with various government and industry experts, which are designed to elicit the opinions of both parties concerning the Criteria and the procurement process in general.

5. Search of the academic literature.--A background search to find previous relevant work in this area.

6. Field trips.--Visits made to Washington and various major contractors' installations with the intent of gaining broader personal insight into the attitudes and philosophies of both parties.

7. Questionnaires.--Techniques used to validate conclusions developed in other stages of the research effort.

(a) A written questionnaire distributed to approximately fifty managers within a case study company to establish a reliable data base.

(b) A control sample, seven large companies in the aerospace industry, used in order to test the total industry questionnaire.

(c) A similar questionnaire sent to the "top 100 DoD contractors" in a final attempt to measure broad industry impact.

Each of the steps indicated for data collection was not mutually exclusive and many do actually occur in parallel. In some cases, however, a specific research technique was used to validate or broaden previous hypotheses. For such occurrences a logical research rationale was indicated; otherwise, data inputs were collected primarily on the basis of availability.

Plan of the Paper

The existing structure of the paper was chosen for two major reasons. First, it was assumed that the primary reader would not have a profound knowledge of the weapons acquisition process. Second, an analysis of the Criteria's impact on an industry is meaningful only if there is some examination of certain key elements relating to planning and control problems associated with a major weapons system development program. In order to facilitate both of the objectives above, a top-down approach was used in the subject development.

Figure 1, "Subject development," depicts the research subject as it evolves within the constraining environment. For example, Chapter II is directed towards an orientation with the broad military acquisition environment. This area is felt to be ill-defined and vague; thus the irregular line in Figure 1 representing this section. Chapters III and IV continue to narrow the subject focus away from the broad

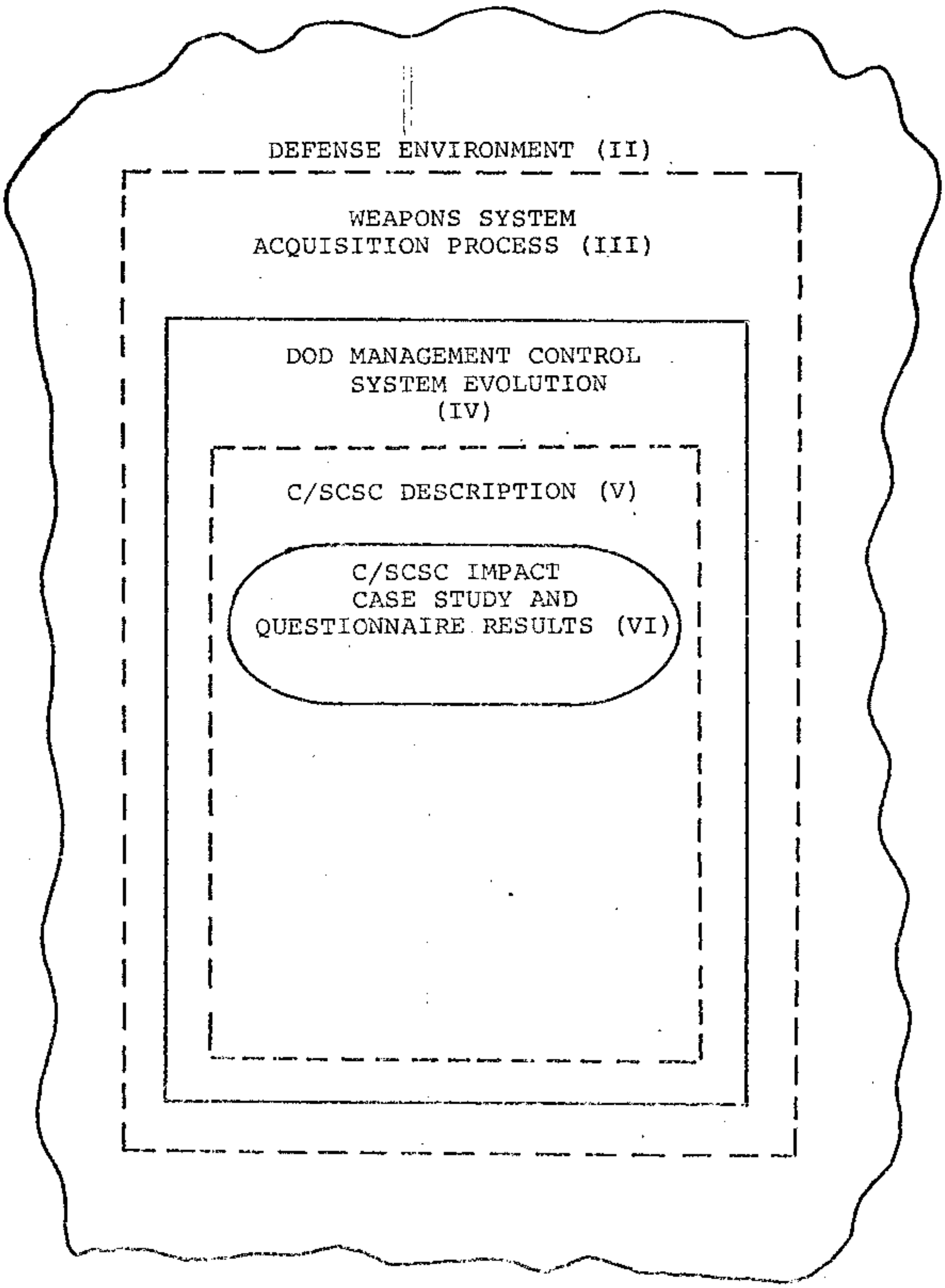

Fig. 1--Subject Development

acquisition and development process towards the process of managerial control through the use of management control requirements by the government. Chapter V completes this transition with a description of these criteria and their supporting documents. Chapter VI analyzes the current impact of the Criteria. Chapter VII contains a summary and conclusions of the entire research effort, as well as a discussion of the future implications of the Criteria.

Scope

The research effort was confined to the electronics and aerospace industries. Further, engine manufacturers were not considered as being part of this industry, although such a distinction is somewhat arbitrary. The reasons for choosing this segment of the total military procurement activity were twofold. First, the greatest difficulty in Criteria compliance is felt to occur within this segment, owing primarily to its dynamic technological factors throughout the development phase of the weapons acquisition process. Second, recent government efforts to analyze contractors' planning and control performance have occurred primarily within this segment, thus offering an increased availability of analytical data. Finally, due to the recent nature of the Criteria specification, some selection of contractor sources within the chosen industry was required to find the necessary familiarity with the subject to supply meaningful data inputs.

Limitations of the Study

The most significant limitation of this study was the pre-established bias of the various participants and the resulting potential erosion of source data quality. A second limitation might have been that the Criteria are defined as a broad set of Department of Defense documents, yet the research was performed in only a portion of the total industry. For example, shipbuilding and engine manufacturers are omissions in the analysis. However, this omission of other defense industries is negligible owing to a general similarity of problems between this segment of the industry and that being analyzed. Also, the sample population is large enough to constitute a definitive portion of the total defense procurement environment.

CHAPTER II

THE DEFENSE ENVIRONMENT

The purpose of this chapter is to outline, in relatively broad terms, the environment within which a weapons system evolves from the original point of decision making to operational status. The Cost/Schedule Control System Criteria (C/SCSC) function within these bounds with significant variables and relationships. The military procurement market does not fit neatly into the atomistic model of Adam Smith. Key ideas will be introduced, concerning operation of the C/SCSC, as a basis for expanded discussion in following chapters.

Implicit factors in a discussion involving the defense environment are the growing size and cost of programs, advanced technology, and systems engineering. The contemporary scene reflects a growing awareness of military expenditures. Both the magnitude of the investment and the actual need of the item itself are discussed throughout broad segments of our society today. Not only is the United States presently involved with significant levels of military and space expenditures, but planners and funds allocators are also considering prodigious projects for the future. The project decisions range from the more traditional ones relating to new generations of ships, missiles, and airplanes, to anti-ballistic missile defenses and inter-planetary travel. In addition, rapidly changing technology is supplying a myriad of other smaller proposals, each of which is competing for a share of the government tax dollar.

The modern weapons system or space project can be characterized primarily by its tremendous complexity and diversity of technological skills. The engineering abilities are recognized and put in perspective, as reflected by Lyndon B. Johnson, former president of the United States, who stated, in a television interview following the successful launch of Apollo 11, that the status of the moon program was a tribute to technology, but even more a tribute to the United States' ability in systems engineering.[1] It is this area that will be dealt with here. Before elaborating on the concept of systems engineering and the Cost/Schedule Control Systems Criteria, some of the environmental factors need to be defined.

The first two sections which follow will describe certain key statistics regarding the aerospace industry and the military-industrial complex. Factors which distinguish the weapons acquisition process from other business ventures will be emphasized throughout the discussion. Finally, the uncertainties of the weapons system decision making and

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[1]Lyndon B. Johnson, interview with Walter Cronkite on CBS Television, July 15, 1969.

development process will be outlined in some detail to provide an essential framework for later discussion.

Defense Statistics

At present the United States is spending approximately 10 per cent of its gross national product on national defense. Department of Defense outlays in the 1969 budget are approximately $78.4 billion, with a planned outlay of $78.5 billion in the 1970 budget.[2] The cost of weapons systems procurement in 1970 is now estimated at near $22 billion for items such as aircraft, ships, missiles, and related equipment.

In 1968, employment in the aerospace industry averaged 1,392,000, which represented 7.2 per cent of all manufacturing employment in the nation.[3] The customer mix for the industry was the following:

Government obligations		78 per cent
National Aeronautics and Space Administration .	13 per cent	
Department of Defense . .	55 per cent	
Non-aerospace type products	10 per cent	
Non-government obligations		22 per cent.[4]

From the first two government components above, aircraft

[2]Donald C. Winston, "Laird Seeks Major Aircraft, Missile Cuts," *Aviation Week & Space Technology* (March 24, 1969), pp. 24-25.

[3]*Aerospace Facts and Figures, 1968* (Fallbrook, California, 1968), pp. 5-7.

[4]*Ibid.*, p. 20.

production constitutes approximately 58 per cent of the contract value, 35 per cent for missiles and 7 per cent for astronautics.[5] The profit margin on sales billed for the industry declined from 1965 until the first quarter of 1969. Table I compares the profit margins of the aerospace industry with those of other categories of manufacturing organizations.

TABLE I

NET PROFITS AFTER TAXES AS A PERCENTAGE OF SALES FOR MANUFACTURING CORPORATIONS*

Year	All Manufacturing Corporations (except Newspapers)	Non-Durable Goods	Durable Goods	Aerospace
1957	4.8%	4.9%	4.8%	2.9%
1958	4.2	4.4	3.9	2.4
1959	4.8	4.9	4.8	1.6
1960	4.4	4.8	4.0	1.4
1961	4.3	4.7	3.9	1.8
1962	4.5	4.7	4.4	2.4
1963	4.7	4.9	4.5	2.3
1964	5.2	5.4	5.1	2.6
1965	5.6	5.5	5.7	3.2
1966	5.6	5.5	5.6	3.0
1967	5.0	5.3	4.9	2.7
1968	N.A.	N.A.	N.A.	2.2**
1969	6.0**	N.A.	N.A.	2.6**

*Source: _Aerospace Facts and Figures, 1968_ (Fallbrook, California, 1968), p. 20.

**"Profits Lose a Little Savor," _Business Week_ (May 10, 1969), p. 102.

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[5] _Ibid._, p. 14.

Before leaving the subject of aerospace industry earnings, it should be pointed out that the relatively low rates of profit margin are somewhat misleading. If one were to examine the rates of return on invested capital, it would be found that an average profit of 3 per cent on sales generates a return on net worth of more than 20 per cent owing to the relatively low capital investment in this industry.[6] In comparison, a 6 per cent return on sales for all manufacturing corporations would yield a return on investment of approximately 10 per cent. The phenomenon of lower returns on sales yielding a higher comparative return on investment is the obvious corollary of the current large government investment in plant and tools. Without government assistance in facilities investment, profit margins would have to be increased in order to provide the equivalent return on investment. In recent years the government as a customer has shown decreasing willingness to provide capital facilities for its contractors; thus, it appears that firms will tend to find downward pressures on their return on investment. The picture is clouded by many factors, and present data will not justify a hypothesis that firms are actually earning less because of this single parameter. Many other pressures act upon the large contractors, each striving for maximum

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[6]Merton J. Peck and Frederick M. Scherer, _The Weapons Acquisition Process: An Economic Analysis_ (Boston, 1962), p. 168.

output per unit of resource input. The current controversy over procurement of the C-5A at Lockheed Aircraft Company reveals how a prime contractor can come under pressure from above in the form of congressional investigations and customer inspections, while from below subcontractors are bringing suit against the prime contractor for excessive design changes and breach of contract.

In addition to decreasing governmental financing of facilities and increasing political pressures already suggested, government contractors are being significantly influenced by three other trends. The first is an increased emphasis on tightly negotiated firm fixed-price contracts, with limited use of the Total Package Procurement concept, incentive clauses, and the ever-present renegotiation clause for excessive profits.[7] A second factor is the increasing cost and effort required for proposal preparation and related contract definition activities.[8] A final variable, more difficult to describe, is the proliferation of government regulations and specifications especially noticeable in the sixties.[9] Pentagon officials have recently identified approximately one hundred existing management and information

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[7] The contracting mechanism is discussed in greater detail in a later section.

[8] Peck and Scherer, p. 209.

[9] "The Pentagon Builds a Monster," Business Week (February 18, 1967), p. 198.

systems alone, not to mention other regulations pertaining to configuration management, value engineering, quality control, etc. The Cost/Schedule Planning and Control Criteria are meant to incorporate and standardize many of the data requirements now contained in most of the existing management and information systems.

A recent Government-Industry symposium discussing the problem of defense procurement during this decade listed the following reasons for low or declining profit margins since the early 'fifties: (1) increased cost in acquiring and executing military contracts; (2) excessive "holding" periods in total package procurement; (3) detailed progress-reporting requirements; (4) government-imposed management systems; (5) fixed-price research and development contracting; (6) unnecessary data package requirements; (7) government's lack of flexibility; and (8) government's insistence on management through procedures rather than through more effective motivational techniques.[10] The government's reply to this claim is that it is not trying to squeeze profits, only to accomplish the following: (1) maintain integrity of the total government procurement system; (2) increase the level of competition for military business; (3) motivate the contractors to better performance; (4) establish the

[10] "A Government/Industry Look at Procurement in this Decade," National Security Industrial Association (Washington, D.C., 1967).

reliability of contractors, through formal reporting systems; (5) ensure the use of well-conceived, formal estimating procedures; (6) establish program visibility so that external control can be taken if necessary; and (7) obtain sufficient information so that it can properly perform its moral and functional obligations to the services, the Congress, and the taxpayer.[11] It seems realistic to assume that both sides have a distinct point of view. The contractor is basically fighting the problem of external interference in his management system, while the Government as a customer has been dissatisfied by all too frequent cost overruns, late deliveries, and inadequate performance specifications on finished products. This conflict might be viewed as a two-party game in which each side is attempting to maximize his own interest. In this regard it is difficult to determine what is good and what is bad *per se*; cost of obtaining additional information notwithstanding, both industry and government stand to gain by a clearer understanding of each other in the future.

The Military-Industrial Complex

President Eisenhower's farewell address contained a subtle warning of things to come when he cautioned of the creation of a "permanent armaments industry of vast

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[11] *Ibid.*

proportions."[12] In this address he first warned of the imperative need for such a structure and followed this with the caution that

> . . . we must not fail to comprehend its grave implications. Our toil, resources and livelihood are involved; so is the very structure of our society. The potential for the disastrous rise of misplaced power will persist. We must never let the weight of this combination endanger our liberties or democratic processes. We should take nothing for granted.[13]

One sector of society follows this logic to the ultimate extreme in arguing for decreased military spending. The decision to invest in a new weapons system thus becomes an entanglement of technological, social, political, and economic factors.

The Nixon administration has walked into a period of great criticism with regard to military spending. Defense Secretary Melvin R. Laird seems to be quite willing to talk of cost overruns, since the opposing political party was involved with most of the original decisions. The Secretary has cited cost overruns of more than $2 billion on programs including the AH-56 helicopter, the Air Force's C-5A transport,and various shipbuilding programs.[14] In addition, the

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[12]George McGovern, "The Looming Spectre of a Permanent Arms Industry," Business Today, III (Summer, 1969), 33-38, citing President Eisenhower's farewell address to the nation in 1961.

[13]Ibid.

[14]"The Pentagon's Costly Mistakes," Business Week (April 5, 1969), p. 100.

Air Force's F-111 is still in financial trouble, and the Army's M-551 armored reconnaissance vehicle project is in serious trouble also. A summary of thirty-four current major weapons system programs indicates total cost overruns in excess of $16 billion over the next four years.[15] Related to this problem, one quite tangible benefit of implementing the Cost/Schedule Control Systems Criteria would be the availability of contract status on a fixed baseline such that deviations from contract amount or plans would be fairly obvious. In this light, the Criteria becomes an information vehicle to communicate weapons systems program status to external elements of the military-industrial complex.

Eisenhower's warning of unwarranted influence within the military-industrial complex appears to many to have a ring of prophecy. Congress and other interested parties are clamoring for "adequate supervision and control of Defense Department programs without hampering operations of the agency."[16] With this and the basic objectives of the defense procurement agencies in mind, it would appear that there is strong pressure for implementation of a very rigorous management information and control system. The Cost/Schedule Control Systems Criteria would seem to be

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[15] Tampa Tribune, December 2, 1969, Section A, p. 6.

[16] Ibid.

obviously useful in satisfying the requirements of both Congress and the Defense Department.

Decision Uncertainties

This section will summarize the significant uncertainties in the weapons system decision. Peck and Scherer studied these phenomena in the latter fifties and reported their findings in some depth in The Weapons Acquisition Process: An Economic Analysis. Their findings are reflected here, with changes made primarily to update the material.

Uncertainty in the weapons-system decision-making process is critical because of the resulting enormous investment and the potential consequences of a poor decision. Uncertainty is defined as the "relative unpredictability of the outcome of a contemplated action."[17]

External Uncertainties

Major external uncertainty factors that dominate weapons system decision making can be summarized as

> 1. The fluid state of affairs within the total external environment.
> 2. Increased awareness of external environment conditions through improved intelligence.
> 3. Increasing mobility of war-making potential forcing a broader look at the defense problem.

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[17] Peck and Scherer, p. 210.

4. Rapid technological advances to be met in some future time period.[18]

Decisions made in light of these considerations require considerable analysis to decrease the margin of error. The United States weapons system and defense strategy since Pearl Harbor have been to maintain an adequate force to forestall catastrophic attack on our country or those of our allies. Development of nuclear technology has heightened the potential dangers of omission in that a "spasm response" type of war would not give the defender an opportunity to build or produce a desirable defense before retaliation. The role of a defender is clearly less efficient than that of the aggressor, as choices of time, weapons, and strategy are on the aggressor's side. The United States has long advertised and practiced the role of defender; thus certain other countries have adopted an offensive mode in their defense philosophy. The United States is faced with four major alternatives, in varying combinations, to military superiority:

1. Development of a superior strategic weapons force such as Polaris-carrying submarines, Minuteman missiles launch facilities, and manned bombers such as the B-52 or the proposed Advanced Manned Strategic Aircraft (AMSA).

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[18] James R. Schlesinger, The Changing Environment for Systems Analysis (Santa Monica, California, 1965), p. 29.

2. A well-coordinated tactical force which will be primarily used to discourage "wars of national liberation" such as Viet Nam. Recently developed weapons in this area include the F-111, along with other systems which have not yet singly made a major financial impact on the procurement budget. The majority of systems procured for use in this area have been of low cost relative to major weapons systems found in other areas.

3. A sophisticated intelligence network to supply reliable data for the military decision-making system. Mechanized approaches to data gathering include reconnaissance, ground sensors, radar sensors, and more recently, space sensors of various types.

4. A defensive intelligence and operational system which is capable of maintaining the operational capability of our great production network while the systems mentioned above perform their various functions.[19]

The purpose of the Cost/Schedule Control System Criteria is not to evaluate the validity of the rationale surrounding the decision to develop a particular weapons system. The value of the initial decision will still be in doubt for years, but the efficiency with which the possibly inefficient

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[19]The approach to warfare as catalogued above is admittedly elementary, yet it does serve to focus attention on the defense capital allocation problem and the great variety of weapons systems alternatives with which a defense-minded country is faced.

device is made can be calculated with great accuracy. From this it can be seen that the major focus of these Criteria is directed towards the internal uncertainties associated with weapons system development.

Internal Uncertainties

The total internal environment of the weapons system procurement is quite involved in itself, bridging the bureaucracies of Congress and the Department of Defense on the major decision-making level. Other primary inputs to this system include the major military branches and their commands. The uncertainties of this situation may be divided into three segments, each interrelated with the other. First is the uncertainty resulting from the basic decision to fund the weapons system development. The critical elements in this phase of the decision are considered to be cost, time of availability, and performance of the system. Second is the market position of the government as a monopsonist on the one hand and politically oriented buyer on the other. With this orientation the buyer can wield significant power in the marketplace with regard to imposing requirements and source selection, among many other pressures. Finally, the bidder on a weapons system contract is faced with uncertainties peculiar to his own corporate situation.

Market uncertainties.--The purchase of a large weapons system occurs in a monopsonistic market environment; the government exerts a great deal of force as the sole buyer. In the past, the contractor benefited from the government-furnished facilities, progress payments, development funding, cost-plus contracting, and many other devices which, in essense, minimized the contractor's risk function. The situation today indicates that this environment is changing and, along with it, each of the elements listed above. In recent months the cancellations of major contracts for the Army combat helicopter, CH-46, at Lockheed Aircraft Corporation and curtailment of the F-111B contract at General Dynamics evidence that the government is becoming ever more conscious of cost and performance parameters.

At the highest levels of our government there is a perennial conflict between the various services, the Secretary of Defense, and congressional committees responsible for budget allocation.[20] In recent years there has been a noticeable shift in the Department of Defense toward centralized decision making with regard to weapons system selection and funds allocation within the department. This trend has stimulated improved techniques of information processing within the vast structure of the weapons acquisition process.

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[20] Peck and Scherer, p. 77.

The Cost/Schedule Control Systems Criteria is developing as the prime mechanism for translation of cost, schedule, and performance data for prime weapons systems. Basically, such data is used for selecting alternatives, determining continuation of programs, curtailing activities, or providing supplemental funding. In addition, future projections of funds requirements will be possible with successful implementation of such a system.

Monetary uncertainties are evident in the weapons procurement cycle from both ends of the funding chain. First, the allocation of budgetary funds is uncertain within the political process due to congressional attitudes toward a particular system. Second, the funding decisions within the Defense Department are uncertain since evaluations are continually being made of cost versus utility of the evolving system. The contractor is thus faced with a great deal of uncertainty regarding the future of a system even though it is currently being funded and he is performing as planned. Cancellation of a major contract has repercussions throughout the prime and sub- contractor networks. Due to the potential variability of human resource requirements on a weapons system contract, the industry is characterized by a high degree of mobility among professional and direct production manpower. Hiring and layoff of several hundred people on short notice is not an unknown occurrence within the electronics or aerospace industries. This industry trait appears to have an impact on the rank-and-file worker by creating an individual who is not strongly corporate-oriented.

Case study research indicates a strong functional centralization of managerial decision-making or strong project orientations. Regardless of the corporate philosophy, the uncertainties of funding have an impact on the way of doing business. If one could imagine for a moment a weapons system which was carefully conceived in the definition stages of the acquisition, then it might be possible to state that one result of more sophisticated planning would be to decrease the monetary uncertainties of weapons system contracts. Certainly the concept behind more detailed planning and reporting requirements is to decrease the uncertainties of development, which will then be reflected by a more stable contractual mechanism and subsequently by a more stable funding pattern on the part of the buyer. The Cost/Schedule Control Systems Criteria may decrease, with successful implementation, some of the uncertainties surrounding the acquisition process.

The impact of the strategic uncertainties of the weapons system acquisition occurs at the operating level within the Defense Department and the contractors' organizations. The strategic problem can be divided into two questions: (1) when will the weapons system be needed and (2) within what defensive environment will it be used?[21] Both of these paramaters will have further impact on the acquisition process through the resource allocation mechanism. The time span from research to operational status for the typical weapons system is eight to eleven years; thus decisions made in this decade constrain capabilities within the next decade.[22] Furthermore, since optimization is almost impossible to define, the uncertainty of the operating environment is further complicated. Herbert Simon has coined the word "satisficing" to describe the decision-making philosophy believed necessary in such an environment. The "satisficing" process is defined as a process of reaching "satisfactory" positions rather than optimal, where the final choice is dictated by certain psychological and sociological considerations.[23] Charles Hitch, a former assistant Secretary of Defense, affirms the philosophy above as representing the weapons acquisition process, yet establishes the point that "satisficing" and optimization models tend towards congruence in a dynamic planning context.

From another point of view, the acquisition process can be viewed in probabilistic terms in which various probabilities are assigned to alternatives and the weapons choices

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[21] Ibid., p. 303.

[22] Anton B. Schmaltz, Insights into the Changing Government Marketplace (El Segundo, California, 1969), p. 73.

[23] Peck and Scherer, p. 304.

are made with regard to hypothesized threat levels. Success of such an approach obviously depends upon the ability to forecast threat potential. Since the mid-fifties, the United States has been spending large amounts of budgetary funds for surveillance of potential enemies. Charles S. Sheldon of the Library of Congress, the only expert on military space traffic without DoD classification, calculates that the United States made 243 launches for military purposes between the period 1957 to 1969.[24] During this same period the Russian count was 162 for military purposes. Early attempts at space surveillance were primarily photographic in nature, but more recent series use radar, ultraviolet, radio and infrared receivers, each with a unique set of intelligence capabilities. The United States satellite reconnaissance program consumes most of the $1.9 billion space research budget for the military and another $2 billion may be hidden in various military funds and funds from other intelligence agencies.[25] The point to be made here is that the United States is well aware of the effect of external uncertainties, and a significant amount of money is being expended to identify, monitor, and assess potential military threats. A systems analyst in the defense department was recently overheard to say, "we may be wrong in the future

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[24] "The Price of Arms Control," Business Week (July 12, 1969), p. 70.

[25] Ibid., pp. 69-70.

but it won't be because an attempt was not made to assess the situation." This would seem to summarize the prevailing attitude within the Department of Defense.

Cost, time, and performance uncertainties.--Cost, schedule, and performance reflects the general status of the weapons system program at any point in time. Actually, the cost, time, and performance variables reflect the resources allocated to accomplish the program. Figure 2 illustrates the concept of the "Isoquality plane under uncertainty."[26] The major purpose of this graph is to illustrate that program outcomes rarely match planned cost or time even if the required objective was met. Historical evidence reveals wide variance in time outcomes for programs which are similar in both objective and cost budgets. Conversely, similar objectives may be accomplished within an equivalent time frame, but with widely divergent cost results.

The factors influencing the variability of the technical performance parameters discussed here appear to be quite complex and will be dealt with in a separate section titled "Resource Allocation." What is being emphasized here is that the ability to predict future outcomes of these three variables is very weak. For purposes of analysis, three ratios will be defined to quantitatively represent the ability to plan complex programs. In each case the ratio is defined

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[26] Peck and Scherer, p. 301.

as the actual parameter divided by the planned parameter value. For example, if the planning ratio is 2.0, it would indicate that the actual time duration was observed as two

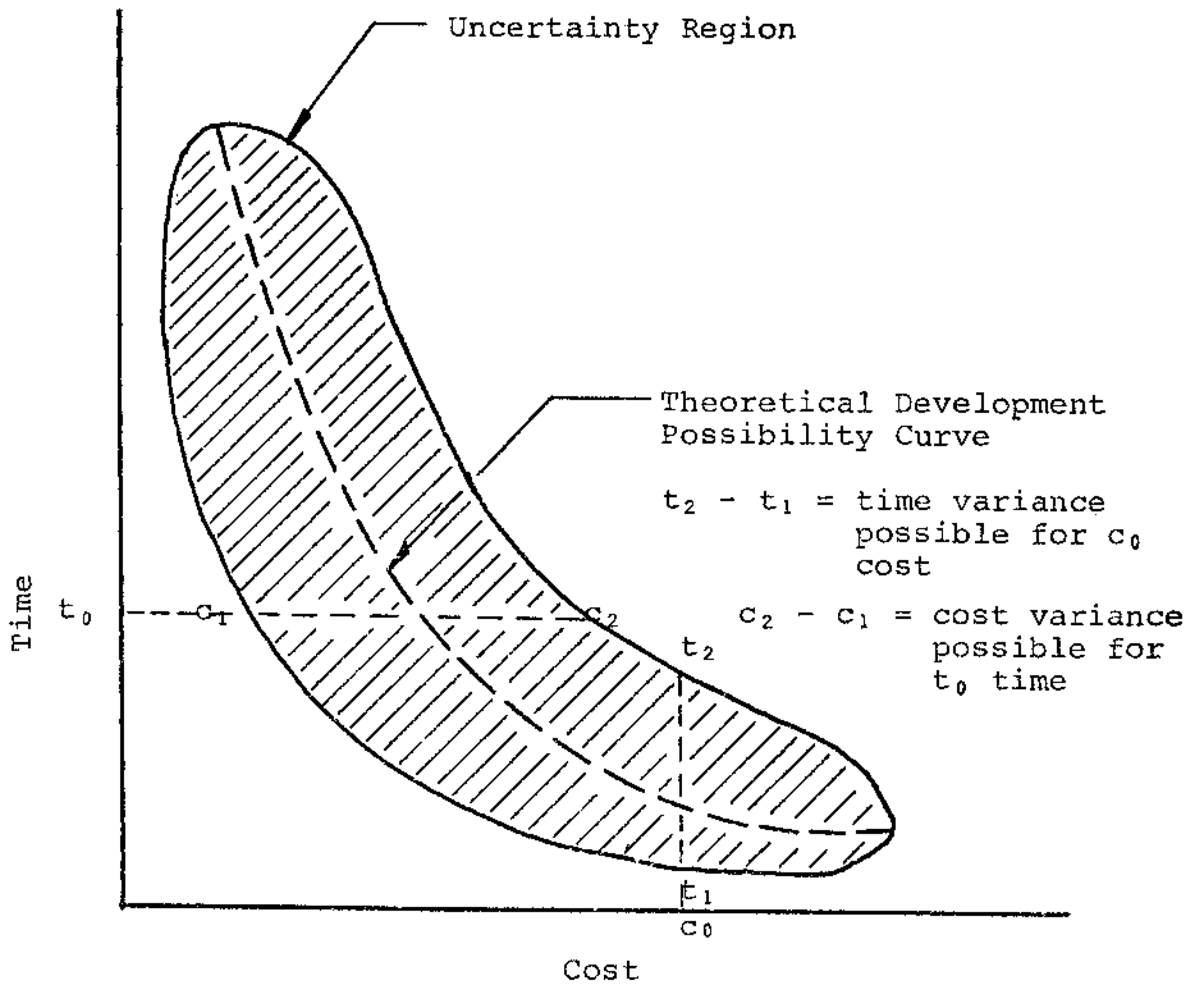

Fig. 2--Isoequality plane under uncertainty

times the original plan. These planning ratios will be used for analysis throughout the remainder of this work. Table II summarizes data on the history of cost for twenty-two major items of military equipment. The factors A and B represent an independent analysis of the same data by two different researchers and are calculated as actual system cost divided by original planned cost. The data are then catalogued in decreasing overrun order into four groups consisting of fighters, bombers, cargoes, and missiles. Means for each group indicate lowest overruns in the cargo class and highest in the missile class, with an average overrun on each project of 140 per cent to 220 per cent, depending upon the researcher. Marshall and Meckling studied this phenomenon in 1959 with the following results:

TABLE II

FACTOR INCREASES IN AVERAGE CUMULATIVE COST OF PRODUCTION*
(ADJUSTED FOR PRICE LEVEL CHANGES)

Fighters	Factors		Bombers	Factors		Cargoes	Factors		Missiles	Factors	
	A	B		A	B		A	B		A	B
1	3.9	4.0	1	6.2	4.0	1	1.4	1.6	1	14.7	6.4
2	2.6	2.5	2	2.8	2.8	2	1.5	1.5	2	9.4	6.0
3	2.0	2.0	3	1.1	1.2	3	1.0	1.9	3	4.4	2.7
4	1.5	1.5				4	1.0	0.8	4	7.2	7.1
5	1.7	2.1							5	1.5	1.3
6	1.2	1.2							6	1.1	0.8
7	1.0	0.8									
8	1.0	1.0									
9	1.1	0.6									
Means	1.8	1.7		3.4	2.7		1.2	1.2		6.4	4.1

Means--all classes: A, 3.2; B, 2.4

*Source: A. W. Marshall and W. H. Meckling, Predictability of the Costs, Time and Success of Development (Santa Monica, California, 1959), p. 14.

Items are presented in decreasing order of cost overrun.

Other conclusions which are drawn from the Marshall and Meckling study were, first, that the estimates were decidedly biased towards optimism and, second, that cost overruns appeared to be the result of attempts to advance existing technology. Fuller discussion of these aspects of the resource allocation problem will be reserved for later discussion.

The operational availability of the weapons system is also a critical variable for military planners, although not as widely advertised as the cost variable. Table III represents time overrun ratios from ten of the same twenty-two

TABLE III

FACTOR INCREASES IN AVERAGE PRODUCTION TIMES*

System	Slippage (yrs.)	Slippage Factor**
1	5.0	2.5
2	3.0	1.6
3	3.0	1.5
4	3.0	1.5
5	2.0	2.0
6	2.0	1.5
7	1.3	1.3
8	0.7	1.2
9	0.5	1.2
10	0.3	1.1

*Source: A. W. Marshall and W. H. Meckling, Predictability of the Costs, Time and Success of Development (Santa Monica, California, 1959), p. 19.

**A slippage factor of 2.5 indicates that the actual program consumed 2.5 times the originally planned value.

weapons systems mentioned above from which usable data were available. This variable is decidedly more complex to define than the cost variable since the time of operational availability is subject to much interpretation. The data in Table III are considered conservative.

In spite of the conservative approach, the forecast time of operation for the weapons system averaged two years delinquent, and slippage factors averaged 1.5. Analysis of this variable reveals a similar bias towards overoptimism similar to that found in the cost overrun factors. An in-depth analysis of these programs further indicated that both cost estimates and availability estimates tend to be more accurate the less ambitious a particular program. The Marshall and Meckling study revealed that factors could be better defined in the latter stages of development than in the early stage.[27]

The final variable to be discussed is the performance factor, or the ability to estimate the performance characteristics of a weapons system before it is produced. This parameter is very complex to define or measure and is subject to much controversy within the industry at the present time. Cost and time factors have been discussed previously, using a single vector to denote performance; however, this cannot be done for performance due to the many ways in which

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[27]Marshall and Meckling, p. 20.

performance can be stated, _i.e._, altitude, speed, kill probability, maintainability, _etc_. Some of the performance variables are quantifiable and others are only qualitative.[28] It has been supposed that most weapons systems produced meet military requirements; however, Richard Stubbings, a government official within the Bureau of the Budget, recently shook the military procurement world with his revelation that only four of the thirteen complex weapons systems built for the Navy and Air Force since 1955 have met 75 per cent or better of their performance goals.[29] "The other nine items, which cost $35 billion, fell short, in some cases as low as 25%."[30] Stubbings used as a performance indicator the system reliability variable, mean time between failure (MTBF), in making his analysis of the various weapons systems. His logic is that a system is of no value to perform its function if it is inoperable. The blame for these failures was placed on the "crash" developments instituted to get the weapons system in operation so that its technological lifetime would be maximized.

Although the problem of how to measure quality of a weapons system cannot be explored in any great depth here, it is possible to say that performance is the variable which

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[28] _Ibid_.

[29] _The Washington Post_, January 26, 1969, Sec. A, p. 16.

[30] _Ibid_.

has been maximized at the expense of the other variables. The generally accepted priority for the three variables has been performance first, time second, and finally, cost. It is this line of reasoning that defense spenders have been using for years to justify gigantic cost overruns of various weapons systems programs. The reasons for variances in the factors studied here are optimism on the part of the contractor who wants to have the government buy his design and the general level of uncertainty associated with all development work. Present systems ability in the aerospace and electronics industries indicates that the main constraint to more sophisticated planning estimates is the inability to forecast the state-of-the-art advance represented by any particular project. Given the uncertain character of these estimates, the task of making more accurate forecasts is potentially restricted by at least these factors: proper definition of the task, careful evaluation of uncertainty, valid cost histories for planning purposes, and performance reporting systems for proper control.

Weapons System Development Uncertainties

During the developing and producing cycles of a weapons system, three variables are identified as critical and each, in turn, influences the resultant time, cost, and performance parameters of the weapons system. These variables are state-of-the-art advance of the system, interface complexity of the various "black boxes" and lead time desired. It is these variables that dictate the future outcome within the system itself.

Most major weapons systems now being produced for the United States military inventory are envisioned as being complex, yet they are desired in less time than the contractor would like to have in order to assure the desired output parameters with regard to cost and specifications. The prevailing and historical acquisition philosophy in the aerospace industry has been to continually push the state of the art on each new generation of aero system.[31] This concept is illustrated by Figure 3. The technology curve illustrates

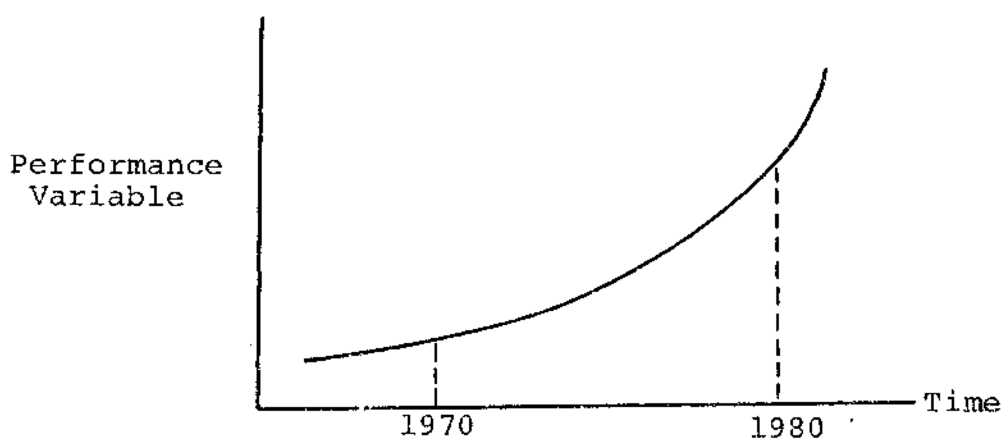

Fig. 3--Technology curve

[31]An interview with Mr. A (anonymity requested), aerospace manager, March 12, 1969.

that performance variables, such as speed or accuracy, are increased over time. For example, the production of a plane which travels mach five and carries 600 passengers is certainly not attainable today, but could be reached at some future date. To push the state of the art in producing engines large enough to achieve this performance and fuselages sufficient to meet requirements, it would cost more today, relative to tomorrow, if one were only to consider the uncertainties of development. The Russians are currently flying a supersonic transport capable of carrying 180 passengers and traveling at 1500 miles per hour, while the United States version, with forecast performance parameters of 320 passengers and 1800 miles per hour, is still on the drawing boards. There has thus been a trade-off of time for higher operating characteristics. For the military situation, this would be a crucial decision. Engineers at LTV Aerospace were able to quote readily cost, time, and performance capabilities for low state-of-the-art projects, such as the A-7 Crusader. Typical figures given for such a development were twenty-one months for development, 1.5 million man hours of engineering, 1.0 time forecast ratio for availability, 1.0 cost forecast for budgeting, and 0.97 for ability to meet system performance specifications.[32] Various aerospace

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[32] C. E. Steward, Ling-Temco-Vought Aerospace, interview held at Grand Prairie, Texas, March 21, 1969. Ratios indicate planning ability for the specified parameter (i.e., 0.97 indicates that the original performance specifications are typically 97 per cent achieved).

and electronics industry managers interviewed indicated differing levels of confidence in their abilities to forecast the future outcomes of their activities. Most of these agreed that the critical problem in forecasting, and the one in which they were least successful, was that of cost, since time and performance are contractually fixed. Also, technical managers consistently agree that state-of-the-art advances represent the most significant and least controllable variable in program management. One fact which makes this variable difficult is the apparent lack of creditable cost data available to managers in the industry at the detailed planning level. Often, the data are collected in the raw state, but sufficient manpower is not available to synthesize them into meaningful information. The result of this is usually that the data are lost at the lower organizational levels and only used by management for broader functional or project reporting. Another problem is that the work being done is often of a classified nature, either by the customer or by the company. A result of this is that many of the data which would be useful for future cost estimating or decision-making are not readily available to those who can make the best use of them.

The second major source of uncertainty within the development cycle is that of lead time, which may be defined as the period of time required for the physical and administrative actions to translate desiring into achieving.[33] From the engineering and manufacturing point of view, the modern weapons system is characterized by "special" or "made to order" activities. Also, the sheer size and number of component parts creates engineering and management problems. Studies of major weapons systems development by the RAND Corporation have yielded the following results:

TABLE IV

TIME CYCLES FOR NEW EQUIPMENT*
(YEARS)

	Basic Re-search	Product Re-search	Product Develop-ment	Applica-tion Engineer-ing	Manu-factur-ing	Total
Optimistic	0	2	1	1	2	3-6
Possible	0	3	2	2	2	5-9
More Likely	0	4	4	2	3	8-13

*Source: David Novick, Lead-Time in Modern Weapons (Santa Monica, California, 1957), p. 11.

Times indicated for the various states of development are not additive because parts of some of the stages can be done in parallel. Attempts to shrink the overall cycle time below five years generally have great impact on the resulting cost and performance parameters. Case studies in the electronics industry revealed that the typical research and

[33] David Novick, Lead-Time in Modern Weapons (Santa Monica, California, 1957), p. 1.

development cycle was from nine to thirty-six months; manufacturing cycles of approximately six months were most frequent.[34] The total lead time for an electronic "black box" can generally be assumed to be within a 1.5 to 3.5 year range. Evaluation of selected projects within the electronics industry during the case study analysis lead to the conclusion that attempts to compress the "normal" cycle time often lead to significant compromises in performance. In one very notable case, a complete restart of the program was required after more than one year of ill-managed design effort. Accepting the quality variances, it appears that generally most design programs could be satisfactorily completed given more time.

By comparing development techniques in Russia with those in the United States, one finds that it has been noted that the Russians appear to emphasize "simplicity and ruggedness" in their weapons and space systems. This means that they are not as interested in making a significant push into the state of the art as in developing a highly reliable and workable system.[35] The Rockefeller Report of 1958 concluded that, "One of the major weaknesses in our strategic posture has been our inordinately long lead times."[36] The Stubbings Report, studies by The RAND Corporation, and various other

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[34]Results of questionnaire survey at electronics company B.

[35]Peck and Scherer, p. 480. [36]_Ibid._

knowledgeable sources have criticized the basic philosophy of our weapons system development. It is not the objective here to explore this subject in depth, but the awareness is needed that other countries have dissimilar philosophies with regard to state-of-the-art advance, which apparently results in weapons lead times of approximately five years, or three years ahead of that noted for the United States. Regardless of the development philosophy, however, it appears obvious that the longer the system is in the development phase, the more sunk cost with increased potential for limited utility. The annals of weapons system development are filled with instances where the completed product was obsolete before production, and sunk costs in these circumstances often exceeded $500 million.

The third and final variable to be discussed as a major contributor to uncertainty in the development of weapons systems is that of the interface problem. The interface problem can be defined as the physical, electrical, or mechanical characteristics of integrating two or more modular systems into a larger system. American weapons system design concepts since World War II can be characterized as building-block or "black box" oriented. During this period, the level of sophistication and complexity of these components has increased significantly. For example, the B-29 of World War II contained approximately 10,000 electronic component parts, while the B-58 developed in the mid-fifties contained nearly 100,000 parts.[37] Missile development is a more recent phenomenon, but the same general trend is evident there also. Management techniques used during the early forties have been found inadequate to meet this problem. No longer can a designer or manufacturer work in a relatively isolated environment, since changes in one product or component may have far-reaching impact on other segments within the total system. Form, fit, and function of each modular component must be considered throughout the total development life cycle.

The subject of configuration control became a watchword of the industry in the late fifties and early sixties. In an effort to control this mammoth problem, computerized planning and control techniques began to evolve in the early sixties and are continuing into the present period. Most notable of these is the Program Evaluation and Review Technique (PERT) developed for use by the Navy in the Polaris development. This network management tool enables a control group to monitor the overall program status through one centralized reporting system. Unfortunately, the success of this tool is limited, as is any such device, by the quality of the input data. Early application of the method led planners to believe that it was a salvation in controlling complex programs, but later experience left the issue

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[37] Ibid., p. 43.

in doubt. More will be said of this evolutionary period in a later discussion. One of the objectives of the Cost/ Schedule Control Systems Criteria is to focus attention on the interface problem and identify cost and schedule problems well in advance for cognizant management. The final control variable, technical performance, is not yet under control for large weapons systems, but there are attempts presently being made to merge a "technical tracking" concept into the cost and time control systems. This concept will be further illustrated in Chapter VI. Overall, technical complexity influences various other areas of uncertainty, and, in part, underlies the unpredictability of time, cost, and performance parameters.

Corporate Uncertainties

Within the performing enterprise there are uncertainties which also have an impact upon the acquisition process, even beyond the elements previously described. The following five factors are considered to be significant for the successful performance of a weapons system contract: (1) technical capability; (2) availability of sufficient manpower and proper skill mix; (3) project coordination within the firm and within the industry; (4) availability of required hardware, or data, furnished from external sources; and (5) availability of sufficient physical and capital resources. Generally, it is the technical and managerial ingenuity of the performing firm that creates a successful market within the military spectrum. Most of the uncertainty connected to the weapons system is found in the contractors' environment. The uncertainties of resource allocation and development are especially dominated by actions within the contractor's organization, neglecting changes imposed by the customer. An analysis of the problems confronting aerospace and electronics industry managers reveals that the factors listed above present problems which are prevalent in these industries.

The study by Peck and Scherer in the aerospace industry indicated a sufficient number of technically trained people to perform the tasks of weapons system development, but the absence of quality appears frequently.[38] The availability of highly talented individuals affects the performance of a firm much more than salary differential would indicate. As Peck and Scherer noted, ". . . two $10,000-a-year engineers are not usually the equivalent of one $20,000 engineer."[39] The availability of these "key" individuals appears to have significant impact on the resultant performance of the weapons system or subsystem. Frequently, it is a high level decision within a company as to which program will get the

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[38] This conclusion is consistent with Peck and Scherer, but has been additionally documented during the case work of this study.

[39] Peck and Scherer, p. 501.

talent of the organization. Many organizations appear to use future profit potential as an indicator for the assignment of their critical technical resources. During the period before and during World War II, management emphasis was towards current programs which were in the production stage. The more recent trends indicate that contractors are becoming more involved with future efforts. It would appear that this changing emphasis is an indication of the increasing complexity of the weapons system and the critical impact that new business has on the company's ability to survive in the industry. Many managers interviewed in both the aerospace and electronic industries felt that the key to future growth was in the ability to accurately predict and quickly apply technical advances to the current weapons needs. Within the electronics industry many seem to feel that a large weapons system can be updated by the installation of a refined "black box" to meet a new threat. Due to jungle-type warfare, many manufacturers have developed small subsystems to modify larger existing systems which were designed for more traditional warfare applications. This trend has often led to a closer working relationship between large systems contractors and smaller subsystems contractors with advanced expertise in one particular area. In summary, the technical capability of a company seems to be the key to its future success. Availability of "key" technical personnel is most often critical and lacking, except in the highest priority projects. The deficiency is thus viewed more as a qualitative problem than as a quantitative one.

The complex technical characteristics of the weapons system means that technically trained individuals constitute the most critical resource of the industry. It is interesting to note that the weapons industry employs about one-quarter of all engineers and scientists available.[40] With the traditional fluctuations of manpower skill requirements throughout the weapons system life cycle, it is often a problem to recruit the necessary technical and skilled production resources. Advertisements in most large city newspapers will testify to this fact. In order to meet the large requirements for technical people, 25,000 or so for a large weapons system, technical manpower must be mobile and salaries above average, relative to more stable occupations. Due to the strong bias towards skill specialization, problems often appear in the areas of skill mix within the resource pool. Aerospace labor variance data indicate that the technical resource component within this industry is willing to be mobile in return for a higher than national average salary. Even though the industry is destined to be somewhat variable in nature, there does seem to be a changing philosophy emerging. Many corporations are establishing a policy of maintaining a hard core of high caliber technical

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[40] Peck and Scherer, p. 172.

people and subcontracting much of the low profit and low state-of-the-art development work. The impact of this approach is, first, to decrease the overhead expense of hiring and training a relatively new work force with each new contract and, second, to increase dependence upon subcontractors. The ability to monitor the activities of subcontractors is currently a significant management problem, and it is also a potential deterrent to the implementation of a Cost/Schedule Control Systems Criteria.

The internal interface problem is created by the functionally specialized approach to weapons system development. As weapons systems have become more complex, the approach has been to compartmentalize the development effort into small and highly skilled tasks. The result of this approach has been to require the coordinative effort of a program or system manager to integrate the various functional and specialized elements. In many cases it has been found that existing information systems have been oriented to the organizational structure, but have been deficient in information regarding the status of the weapons system development or production. Innovation in management control systems since 1960 have focused on this deficiency and current efforts are designed to implement systems which will satisfy organizational reporting and control requirements while maintaining the necessary internal control capability. The network management techniques would appear to offer the brightest hope for short term solution to this problem. In addition, integration of management concepts between the elements of the weapons system contractual chain is necessary to provide cost, time, and technical performance data from the various cognizant groups. As a customer, the government is concerned with a proper level of visibility in the development process. Industry, on the other hand, is concerned with how to give visibility without also giving away certain management prerogatives and some of their power to negotiate future contracts. The interface problem thus has many dimensions and variables. Interfirm, intrafirm, and inter-environmental coordinative techniques have been developing within this industry for many years and now constitute one of its most significant problems.[41] The increasing technical constitution of weapons system development and the resulting decrease in production volume has heightened interface problems between the various elements of the process. The current trend in weapons system development appears to be towards larger systems contracts which result in one integrative contractor and many subcontractors, each often having their own unique management systems. Without compatible reporting criteria, it is not difficult to envision great problems in future development. Fortunately,

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[41]The complexity, size, and scope of the weapons acquisition process necessitates a much higher level of coordination than in other types of product development.

this problem is recognized within the industry, and an effort is being made to achieve a solution. The current approach to a common reporting base is the Work Breakdown Structure, Military Standard 881. This device is an outgrowth of network techniques and provides the cost and reporting network for large weapons systems.

Availability of required hardware from external sources is item four from the list of corporate uncertainties. Government-furnished equipment and technical change approval constitutes a large portion of this segment. Evidence from the case study companies indicates that this problem is most noticeable for prime contractors awaiting contractually promised government-furnished equipment or change approvals and, second, for subcontractors awaiting equipment from either the government or another contractor. A significant result of this problem is its impact on the internal operations of the enterprise. Often, work groups will have to evade a problem while awaiting approval to proceed, or await the arrival of equipment which is vital to the effort. Monetary and schedule data is not available to reflect the actual impact of this problem; in fact, the problem is felt to be quite variable within each contract. The only consistent comment noted throughout the case study concerned the governmental approval cycle taking longer than tolerable. Most managers have circumvented this by accepting the responsibility for the change and proceeding as if it had been approved. Success of this approach is obviously dependent upon a good working relationship between the contracting parties. The future trend of this problem is dictated by the attitudes of the contracting parties. If the customer becomes liberal regarding changes, managers will likely take initiative and make decisions which they feel will improve the development cycle. If the information flow becomes oriented around the placement of responsibility for these changes, then this problem area can become unmanageable. If the contractor feels locked into an approach, his initiative will be decreased and the resulting output possibly constrained.

Perhaps the most controversial aspect of contractor uncertainties is that of the availability of sufficient physical and financial resources. This area also involves the greatest amount of change. From a historical point of view, the government has improved the position of the defense contractors by providing facilities. During World War II, the Army and Navy provided some $8 billion in facilities and machinery to suppliers.[42] The Korean War period further emphasized the attitude. During the period 1950 to 1956, the services furnished about $3 billion worth of new facilities. Although the level of peacetime investment has been less, the magnitude of government-furnished facilities was still

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[42]Peck and Scherer, p. 164.

large into the early sixties. Additionally, the government has offered the tax benefits of accelerated depreciation and lease of facilities constructed by the Defense Plants Corporation.[43] The traditional view towards government-furnished facilities was that it constituted an offset to the other drawbacks of the weapons business. In the sixties a trend became apparent. From 1962 to 1967 the total net plant investment for the aerospace industry increased by \$1.3 billion to a 1967 level of \$2.85 billion.[44] This appears to reflect the increasing requirement that large weapons systems contractors increase their investment in plant and facilities. Due to the changing skill mix required to produce a large system, shortages often appear in research and development facilities, while surplus is evident in conventional production facilities. Approximately 200,000 non-production workers have entered the aerospace industry since 1959, and many of the facilities necessary to support this influx have been provided by internal corporate funds.[45] To date, facility availability has been no problem, but the future may add a new dimension to the contractual proposal cycle. With high sunk costs in capital facilities, many corporations will

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[43] Ibid., p. 165.

[44] Aerospace Facts and Figures, 1968, pp. 92-93.

[45] Ibid., pp. 80-83.

likely become increasingly conscious of employment level fluctuations, and the contractors' risk function will increase. Electronics and other small contractors are seldom furnished equipment and must rely on private financing. With the increased interaction between prime and subcontractors, the government apparently feels that subsidizing the first and not the latter is unjustifiable; therefore, the current trend should continue toward higher contractor investment.

Summary

This chapter has outlined the breadth and scope of the defense environment. The first part of the discussion was quantitatively oriented in an attempt to describe the size of the industry and of each major weapons system. Second, it was shown that the current American environment appears to be relatively unfavorable to uninhibited growth of the military-industrial complex, or at least to the free-wheeling atmosphere of the past. The expenditure of funds for defense is coming under criticism stronger than ever before and even the lay citizen is aware of cost and performance deficiencies of the weapons acquisition process. Our society is cognizant of the magnitude of defense expenditures and the growing cries from within are for larger social expenditures. It is not difficult to understand the pressures on military contractors for improved reporting techniques, primarily for cost, but also for availability dates and performance. The Stubbings report added a new dimension to the subject by questioning the quality of our major weapons systems, the final pillar of logic for large expenditures. Increasingly, the Department of Defense is having to justify its decisions to various funding agencies, and thus there is a definite need for increased involvement with the contractor to assure efficient performance and valid data.

The weapons acquisition process was found to be unique in American business in that a highly specialized and complex device is being developed essentially for a one-customer market. Recent events indicate that this customer is becoming extremely critical of contractual deficiencies, as evidenced by the cancellation of the AH-56 and F-111B contracts. Also, cost overruns are being investigated in Congress and advertised to the public. It is the keen interest noted here that lends support to the hypothesis that an information mechanism is needed and will be demanded by external forces if not created within the Department of Defense. The Cost/Schedule Systems Criteria are thus a product of the prevailing environment and these, or some similar techniques, will be forced into existence by this environment.

The uncertainties of the process were traced from the initial point through the entire acquisition cycle, ending with the subcontractor and the work performed there.

Throughout this process, the level of uncertainty is found to be an inverse function of the level of definition. Given certainty in the definition of an external threat and the definition of defense philosophy, then initial decisions could be near optimum. Given fixed parameters within the state of technology, higher quality prediction could be made on resultant outcomes and so on through the sequential chain of events. Uncertainties are found throughout the decision making and development phases of the weapons system process. First, the external uncertainties are significant since the environment is continually changing and the dollar commitment required to finance major weapons decisions is often a multi-billion venture with significant risk associated. The existence of a broader weapons program also complicates the decision making task and often creates a sub-optimum approach to the defense venture. Second, the market structure of the weapons system acquisition process is monopsonistic in nature with the government essentially acting as the sole buyer through its many agencies. In this environment the funding process is clouded with uncertainties which significantly impact on corporate attitudes. Third, cost, time, and technical performance are found to be the most commonly used parameters for contractual evaluation. These indicators represent common reporting parameters throughout the external and internal boundaries of the acquisition process. Rather than being uncertainties themselves, they may actually be viewed as the outward reflections of the uncertainties. Corporate uncertainties typically hinge upon the ability to allocate the proper quantity and quality of human resources to the task and the ability to handle the inter-coordinative and intra-coordinative activities associated with a large system. Other organizational constraints are hardware availability from external sources and the availability of adequate facilities for performance of the task. The decision magnitude and time frame represents managerial effort of gigantic proportion which is difficult to parallel in any other industrial segment.

The level of uncertainty also pervades the weapons system development itself. The next chapter will focus attention on the weapons system and the complex set of decisions surrounding their development.

CHAPTER III

THE WEAPONS SYSTEM ACQUISITION PROCESS

The concept of what constitutes a weapons system has evolved over the last few years. Current thoughts on this subject have expanded from the traditional idea that a weapons system was merely physical hardware to the broader idea that the total system consists of many supporting functions, each of which is necessary for the system to perform. Section one, then, will discuss the current thinking on weapons system definition, the basic types of weapons systems from a model point of view, and cost trends of major aircraft systems over the last thirty years. Section two will define the life cycle concept and attempt to show how this has a direct bearing on the resultant type of planning and control system used. Section three will describe the basic contracting patterns for major weapons systems and attempt to record certain key changes in the military market which have potential impact on the contractor's way of doing business. Subcontractor relationships are introduced in section four, along with some discussion of how a structured management system dictated to a prime contractor will have direct bearing and impact on its subcontractors. Uncertainties of resource allocation were briefly discussed in

Chapter II, but will be reiterated here to describe in specific terms why the military agencies feel justified in demanding closer cost control over their purchases. The resource allocation variables of cost, time, and performance are implicit in any sophisticated planning and control system; thus they represent the common threat throughout the paper for relating much of the material back to the Cost/Schedule Control Systems Criteria and its impact on the acquisition process. Finally, section five of this chapter will briefly catalog some of the contemporary weapons systems now being developed or currently in debate. The imposition of any new requirement should be first noted in the contracting framework of these large programs.

The Weapons System Concept

A commonly accepted definition of a weapons system is "a composite, at any level of complexity, of operational and support equipment, personnel, facilities, and software which are used together as an entity and capable of performing and/or supporting an operational role."[1] In application, this concept means that control data are no longer restricted to hardware. An aerospace manager recently used the following example to illustrate this point:

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[1] _System Safety Program for Systems and Associated Subsystems and Equipment: Regulations for, Military Standard 882 (Proposed)_, 4 February, 1969.

> We were once concerned only with the cost of the arrow, but now cost for such elements as the bow, supporting ground equipment, facilities, data, and training are all integrated for consideration.[2]

The existing concept of a weapons system leaves something to be desired in that size, or some other qualifying parameter, is not used. The Cost/Schedule Control System Criteria avoids this pitfall by segregating the weapons system into major impact categories. A primary military indicator of a major weapons system is $25 million in research, development, test, and evaluation, or $100 million in production.[3] Almost all aircraft and space vehicles fall in this category, as well as many smaller system contracts in the electronics and aerospace industries.

The Aerospace Technical Council, a study group formed by the Aerospace Industries Association to study the impact of technical considerations upon profitability and risk, found that the weapons system development process can be characterized by four basic product models. These models are illustrated below:

> Model 1--Low technical content, high production volume. Examples--ordnance items such as unguided rockets, rifles, trucks, ground power units.

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[2]Speech by C. E. Stewart, Ling-Temco-Vought Aeronautics, Denton, Texas, January 20, 1969.

[3]C/SPCS: The Specification Approach to Performance Measurement (Washington, D.C., 1968).

Model 2--High technical content, low production volume. Examples--missile and aircraft systems, ground radar systems.

Model 3--High technical content, high production volume. Examples--space and research vehicles, ships, communication systems.

Model 4--Subsystems. Examples--engines, navigation systems, ECM systems.[4]

Each of the above models represents unique characteristics of such variables as total dollar commitment; ability to forecast performance, cost, and availability parameters; and, most important, the basic requirements for planning and control systems. For example, management control systems of a "Model 1" program would be easier to design and more sensitive to deviation than those required for the uncertain task of controlling "Model 2" or "Model 3" programs. The task group studying the development process concluded that "the existing contractual policies and regulations are not compatible with the inherent technical uncertainty in the weapons systems development because they do not give appropriate or adequate recognition to the unanticipated technical unknowns."[5] Recent changes in the military procurement attitude indicate, at least verbally, that contractor contingency reservers are considered to be prudent and acceptable, but must be specifically identified. The Cost/Schedule Control System Criteria requires that contractor

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[4]Aerospace Technical Council, Essential Technical Steps and Related Uncertainties in DoD Weapon Systems Development (Washington, D.C., 1968), p. 5.

[5]Ibid., p. 7.

management establish realistic budgets for contractual items and use an identified reserve fund to indicate the level of uncertainty. If this policy were actually practiced, it would mean industry management would be under pressure to establish tighter standards for control purposes. In this hypothesized environment, future contract negotiations would include more realistic estimates of the task to be accomplished and a separate reserve account to identify the level of uncertainty. This would represent a departure from the approach taken today.

Inflation is not solely culpable for the astronomical rise in procurement cost of military equipment since the forties. The procurement philosophy of buying highly complex devices which significantly advance the state-of-the-art is assumed by most industry sources to be the basic cause for the increase. Tong's research at the RAND Corporation revealed that the unit cost of electronics systems for aircraft and missiles had risen fifteen-fold from 1955 to 1967.[6] The cost of increasingly sophisticated "black boxes" has risen so that approximately 89 per cent of the development cost of one recent fighter plane was for electronic and hydraulic subsystems, while only 11 per cent was required for

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[6] C. Tong, <u>An Estimating Relationship for Fighter Intercepter Avionic System Procurement Cost</u> (Santa Monica, California, 1966), p. 13.

airframe development.[7] Nonetheless, it is not difficult to obtain reliable unit costs of various aircraft since World War II. These data are presented in Figure 4, showing two different categories of aircraft and their associated unit cost trend lines. Table V uses the same basic source data to show cost ratios of current systems versus the corresponding cost of a similar system during World War II. Preliminary forecasts for the next generation of equipment are used to show relative price changes into the next decade. In Table V ratios and the indicated values should be considered primarily as ranges, rather than discrete values.

Several significant points are revealed by the cost phasing relationships developed in Table V. These can be summarized as follows:

1. Unit cost for aircraft systems has increased significantly in the last thirty years, primarily because of increased complexity, optimistic technical objectives, and decreased quantities of procurement.

2. Service procurement philosophy is reflected in smaller cost increases for Navy equipment as compared with similar equipment for the Air Force. It is a common impression that Navy planes were often relatively straightforward in design concept as compared with optimistic Air Force program attempts.

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[7] An interview with Mr. A (anonymity requested), aerospace manager, March 12, 1969.

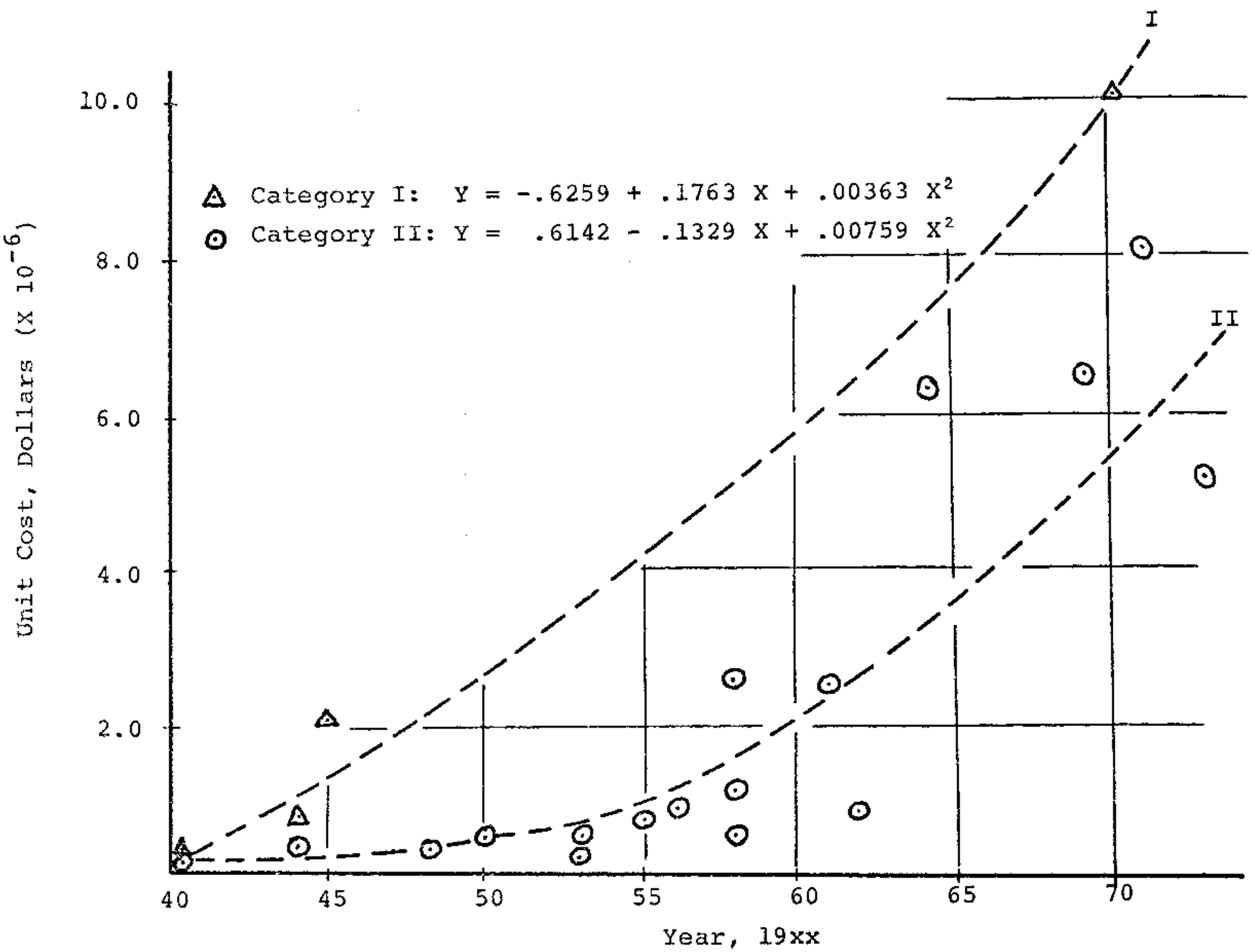

Fig. 4--Unit cost trends of various aircraft (1939-1973)

TABLE V

COST PERFORMANCE OF VARIOUS AIRCRAFT TYPES[a]

	R_1[b]	R_2[c]
Air Force Med. Transports	32	N.A.
Air Force Fighters	89[d]	N.A.
Air Force Bombers	67	3.5
Navy Fighters	8 (30)[e]	4.1 (1.2)[e]
Air Force Hvy. Transports	N.A.	(4.2-5.1)

[a]Source: Authorization for Military Procurement, R&D Fiscal Year 1969, and Reserve Strength Hearings, 90th Congress (Washington, 1968), 2450.

[b]The ratio R_1 is calculated by dividing the World War II cost of a comparable system into the existing system cost.

[c]The ratio R_2 is calculated by dividing the cost of a current system into the future projected cost of the next generation system (i.e., B-52 cost divided into AMSA, C-133 into C-5A, etc.). Data shown for R_2 merely indicate preliminary planned constant dollar values. These ratios will be conservative if historical overrun patterns are indicative of the future.

[d]This value is highly suspect since the F-111A system is experiencing cost overruns at present. The 6.4 million dollar unit price used here is an early 1969 estimate made by the president of General Dynamics.

[e]F-111B contract was cancelled by the Navy, thus lowering the cost used in calculating existing system values. A more realistic range, using this latest data would be as indicated in associated parentheses (i.e., F-111B unit cost at 6.4 million dollars).

3. The next generation of weapons systems will apparently experience additional factor increases in unit cost of 15 per cent to 510 per cent, thus reflecting continuing emphasis on technological advance. This point will

be useful for framing future conclusions in regard to management control techniques.

Historical studies of weapons system cost performance reveal an unimpressive pattern. Even with consideration for inflation and production quantity adjustments, the average cost overrun was found to be 220 per cent of the contract price based on a sample size of twenty-two systems.[8] The causes of these increases have already been stated. The real contribution of the Marshall and Meckling study was the sophisticated statistical analysis performed on the various variables to obtain certain conclusions regarding the producer's ability to accurately estimate costs.

A hypothetical cost model will be presented in the following section in quantitative terms. The reason is twofold. First, the model indicates that one of the major contributions of well catalogued cost data is reliable historical data for comparison and predictive use. Surprisingly enough, this is not available today. Second, the application of a model represents a shorthand summary method of discussing the significant variables which have impact on cost estimates.

The weapons system cost distribution curve has been shown to be positively skewed, as illustrated in Figure 5. It should be emphasized that there is strong evidence to

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[8] Marshall and Meckling, p. 14.

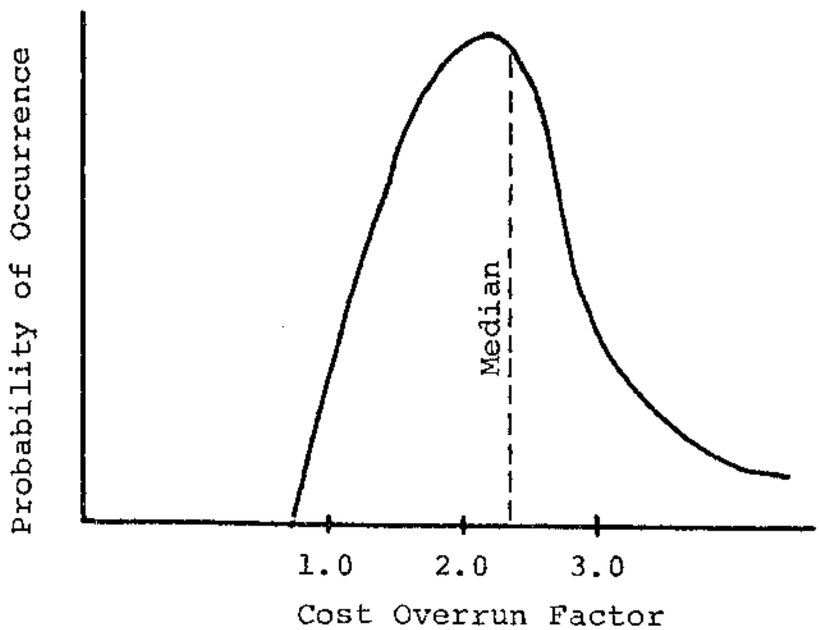

Fig. 5--Weapons system cost distribution curve

support the statement that cost overruns are decreasing in magnitude through time. This would mean that the distribution curve is tending to normalize away from the positive direction. In part, the cost overrun phenomenon represents optimism in contractor management and the desire to be accepted for a major development effort. Although cost overruns on most recent major contracts have been less than 100 per cent, the tendency is still on the optimistic side. The unit cost estimate (C_e) of an aircraft, space system, or electronic device is felt to be governed by the same basic concepts. The resulting cost can be expressed symbolically as

$$C_e = f(X_T, X_S, X_I, X_Q, X_C, X_D)$$

Where, C_e = Estimated unit cost, \$/unit;

X_T = Operational time reference, yr. (i.e., 19xx);

X_S = State-of-the-art advance (i.e., zero for no advance, to strongly positive for significant advance);

X_I = Inflationary variable (i.e., an index which represents cost changes due to changes in the monetary unit);

X_Q = Quantity adjustment (i.e., decreasing unit cost due to the learning curve phenomenon and the broader base over which to amortize development costs);

X_C = A qualitative measure of the contractor's ability and desire to perform (i.e., positive for poor performance, or negative for good performance);

X_D = Length of development period as compared to optimum. Cost increases as "crash" development is undertaken.

Using the Greek letters α, β, γ, Δ, θ, ε, and λ as empirical constants, a possible cost model may be postulated as follows:

$$C_e = \alpha + \beta X_T + \gamma X_S + \Delta X_I - \theta X_Q \pm \varepsilon X_C - \lambda X_D.$$

The cost equation represented above could then be developed to make unit cost estimates, given projections for the following variables: (1) operational date (X_I), (2) state of technical advance (X_S), (3) inflationary trends (X_I), (4) force size (X_Q), (5) contractor performance estimates (X_C), and (6) an estimate of optimal development time (X_D). If a system were to be developed under static economic conditions and optimal development, then variables two through six above would exert little corrective influence on resulting cost. Under such circumstances, the cost estimate would be essentially dominated by the operational time reference variable, X_T. A second degree regression equation was developed in Figure 4, using an assumption and systems cost found to be closely correlated to operational data. Such an exercise should not be construed as attempting to show cause and effect relationship, but it is significant to note how time has functioned as a bivariate independent cost estimating variable.

There are two reasons for showing unit cost versus time and describing abstract cost model equations. First, the regression line dramatically illustrates cost trends for various types of aircraft since the forties and, second, both sides of the acquisition process--buyer and seller--are looking at empirical relationships of this type. The recent effort has been severely hampered by the lack of reliable cost data at the lower levels of the acquisition system. The success of future attempts to derive valid cost estimating relationships appears to be dependent on the availability of structured, reliable, and easily retrievable data at any level of interest (*i.e.*, system, fuselage, wing, subsystem, *etc.*). In the companies interviewed, the problem of retrieval is being approached by use of high speed computer systems; however, at this time, neither the buyer nor the average producer is taking the myriad of raw data and developing meaningful cost relationships. Future improvement will undoubtedly come in all phases, leading to more sophisticated cost estimating models. Successful implementation of the Cost/Schedule Control Systems Criteria is certainly a vital step in this development and a key reason why many contractors fear such a system. Cost constraints generated by valid costing models should have a tremendous impact on operating methods in the aerospace industry and possibly in the electronics segment also. Constraints on price negotiations affect the contractor's bargaining position.

Although a future cost model may not make use of the format presented, attempts in the future are likely to use similar empirical relationships developed from historical data. The RAND Corporation, for example, is working on cost models, but documentation on the form or structure is unavailable. Finally, the weapons system concept has been viewed as expanding the traditional focus beyond that of the hardware itself into a broader analysis of such other elements as personnel, facilities, training, support equipment, and operations cost. Much traditional thinking has been invalidated through this broadened approach. Regarding cost increases, perhaps the unit cost may not be as significant a variable for analysis as some other relationship, such as "boom per buck." Although these questions cannot be dealt with here, they should be recognized as impinging on the subject.

Life Cycle Concept

The life cycle concept of a weapons system is an innovation of the sixties, apparently having its origin in the early writings of the Rand "brain trust." The realization that a weapons system cost encompassed more than its production expense forced military planners to require data other than functional defense budget categories such as personnel, procurement, and operations.[9] Little effort was made to collect and forecast cost by mission, which was the basic *raison d'etre* of the military. Various weapons systems were funded one year at a time with little apparent planning for future requirements and overall systems cost.[10] To alleviate these two problems, the weapons system life cycle, "cradle-to-grave," concept was developed. System costs were identified and grouped as (1) research and development, (2) investment or procurement, and (3) annual operating costs, then further categorized by major function.[11] Figure 6 illustrates the impact of these expenditures over the total of the life system. Additionally, the time cycle of this expenditure incurrence is indicated.

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[9] David Novick, editor, *Program Budgeting* (New York, 1969), pp. 85-86.

[10] *Ibid.*

[11] J. D. McCullough, *Cost-Effectiveness: Estimating Systems Costs* (Santa Monica, California, 1965), p. 11.

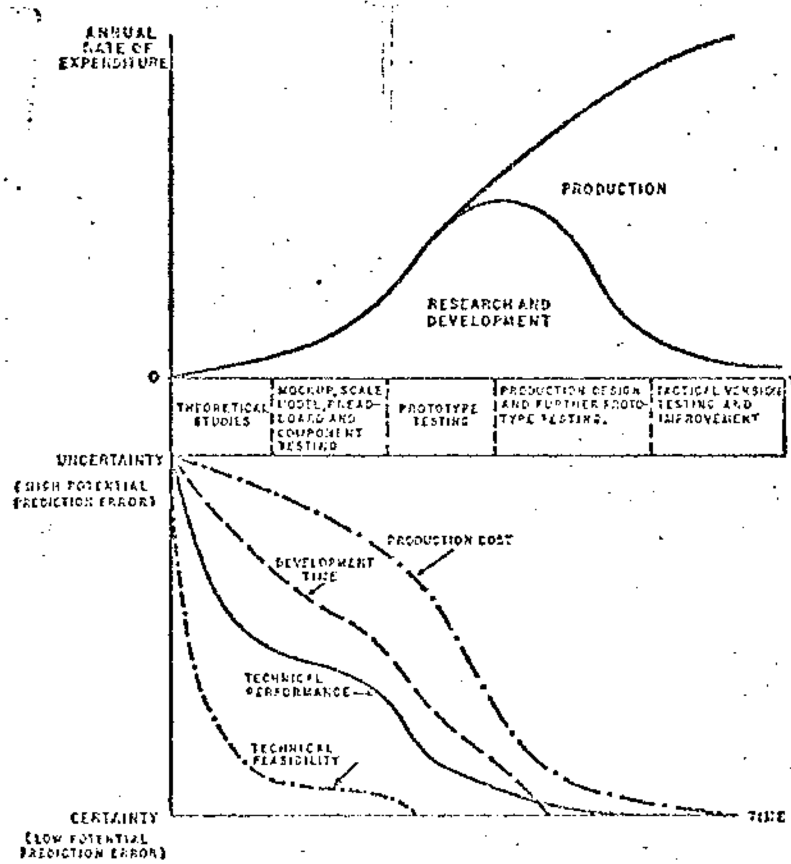

Fig. 6--The relationships among time, expenditures, and uncertainty in a weapon system development. Source: Peck and Scherer, I, 313.

World War II saw marked increases in the cost of performing weapons system development work. The cost of producing a prototype aircraft increased from $10,000 in the twenties to $600,000 by the early forties.[12] One year's funding of the current F-14 development amounted to $130 million,[13] while a six-year research and development effort

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[12]Peck and Scherer, I, 350.

[13]Department of Defense Appropriations, Senate Hearings before the Committee on Appropriations, Fiscal Year 1969, 90th Congress (Washington, 1968), p. 2520.

for the F-111B amounted to $72 million.[14] This comparison illustrates the increasing development expenditure required for a modern weapons system. Figure 7 indicates the increasing importance of development cost as a ratio of the overall system costs. This trend is typically caused by increasing complexity of the system and decreased quantities of production. From an analysis of historical procurement practices it appears that military planners today hesitate to name systems and their primary developers. This has the effect of holding project focus and its cost data together. In the past, unsuccessful ventures were merely cancelled and the sunk costs were often not identified with a particular mission.

Some of the increased cost of development is illusory, then, since much effort, fragmented in the past, is now combined into one package for presentation.

The current approach to system development is to envision a system, formulate the necessary performance parameters which the system must meet, and then proceed into a contractor proposal stage to analyze individual approaches. Throughout the initial conceptual stage, design emphasis is placed on mission and basic performance parameters. Subsequent stages of the conceptual effort are designed to

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[14] Authorization for Military Procurement R & D, Fiscal Year 1969 and Reserve Strength Hearings, before a subcommittee of the Committee on Armed Services, U.S. Senate, 2d Session (Washington, 1968), p. 1114.

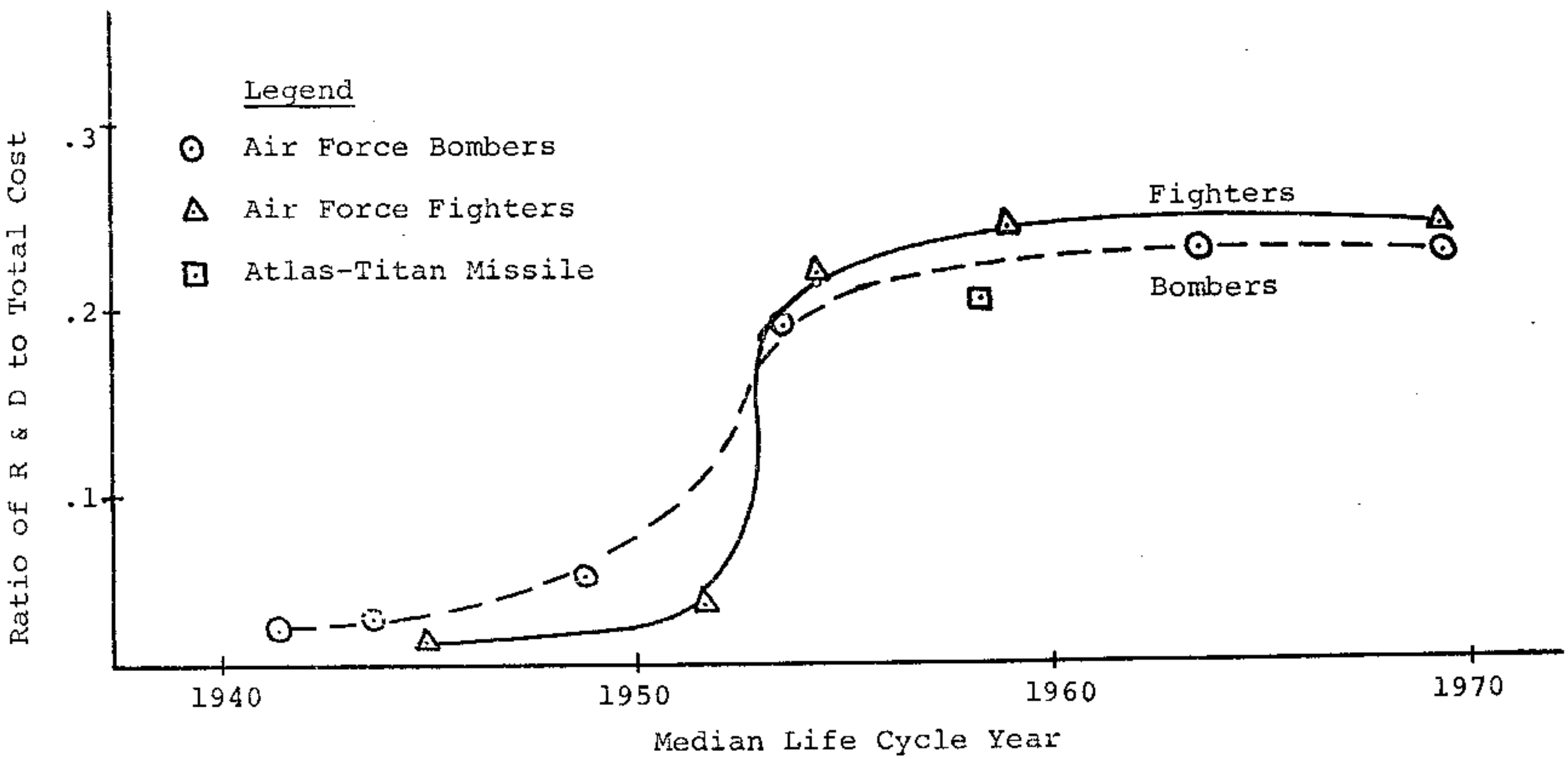

Fig. 7--The relationship of development costs to total investment. Source: David Novick, _Identifying R & D: A Management Problem_ (Santa Monica, California, 1960), p. 10.

to further refine design concepts, cost estimates and other related factors. A characterization of a "typical" large weapons system with regard to time, cost, and element mix is summarized as follows:

1. Total system cost for a major aircraft system is of the order of $3 billion.

2. The time cycle for development, production, and operation for a successful system is ten to eighteen years.

3. Total life cycle element cost mix appears to be approximately 20 per cent for development, 45 per cent for production and 35 per cent for operation.

None of the data given above are fixed; there is some opportunity to make resource trade-offs among these variables. For instance, it is possible to invest more money in development to decrease production or operating costs. Modification programs are often used to update a system at reduced cost over a complete redesign effort. Regardless of the objective or the technique, the government as a buyer is vitally interested in total cost of the system and not just flyaway unit cost. Future contractor data requirements will have to be made with consideration of this bias and attempt to supply meaningful input data for total systems analysis. Production planning and control systems are relatively well designed and reliable, but the same cannot be said of development techniques in this industry. Industrial engineers, military planners, and cost analysts have long felt that the key to system efficiency lay in proper control of the development cycle. Control improvement opportunities for technologically innovative or experimental systems are found in the early stages of the life cycle and not necessarily on the production floor or flight line. Thus, the focus of this problem will be narrowed in scope to the research and development cycle, with little investigative attention given to the production or operations cycles. Omission of discussion relating to the areas of operation and production is further justified by the fact that the Cost/Schedule Control Systems Criteria will be used primarily in the development stage.

Hitch and McKean feel that the three root causes of error in the management of military research and development are

> 1. The failure to properly treat and evaluate uncertainties.
> 2. The tendency to undervalue future outputs relative to current ones (research for tomorrow is not recognized to be as important as hardware today).
> 3. Certain tendencies of bureaucracies such as the tendency to overcentralize.[15]

Point one above has been mentioned frequently and will not be discussed further. Point two is less obvious and does need some elaboration. It is relatively easy to measure the benefit of a system as it comes off the assembly line and

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[15]Charles J. Hitch and Roland N. McKean, _The Economics of Defense in the Nuclear Age_ (Boston, 1967), p. 248.

goes into the operational inventory, but the benefits to be derived from research and development are not so immediate and certain. It is this logic that congressmen have used to cancel appropriations for future systems. Hitch and McKean indicate that decisions of this type should be made in light of future savings, thus future savings must be discounted back to the present in order to justify expenditures. Once again, the systems and life cycle concepts are implicit in this analysis and vital to its implementation. In recent years econometricians have become more vital to the weapons selection mechanism, and it is in the areas of least cost system and least cost combinations that they have made the greatest theoretical contributions. Systems analysts, widely used during the McNamara era in the Department of Defense, attempted to apply basic economic concepts to the complex problem of weapons system selection. These decisions, which are being subsequently implemented today, offer little definite proof that man is capable of modeling complex situations in search of optimum solutions. Nevertheless, the basic management and operating techniques of military procurement today reflect this approach. The subject matter of this research is a direct outgrowth of this approach, as will be illustrated in the next chapter. Although one can do little more than speculate about the tendencies of bureaucracies to overcentralize, the third point made was that there seems to be a trend to more centralized decision-making in the Department of Defense. If this trend is to continue, it would imply an additional need for systems data which could be furnished by implementing of the Cost/Schedule Systems Criteria and related reporting requirements.

Contemporary thinking about the proper management of a large weapons system is undergoing considerable evolution. On the one hand, overwhelming evidence is now available to indicate that research projects must be relatively unstructured in order to maximize results, while, on the other hand, centralized planning and decision making are dictating specific requirements for the next generation system. In order to satisfy both of those trends, the government current practice is to fund one or more bidders through the formulation stage of development where the following prerequisites are established:

> 1. An evaluation of the technology is made and risk elements are identified.
> 2. A thorough analysis of various alternatives are made.
> 3. Basic mission and performance parameters are established.
> 4. Cost-effectiveness of the proposed item is determined to be favorable in comparison with any other existing or proposed system.
> 5. Cost and schedule estimates are creditable and acceptable.[16]

Contracting Mechanism

The next area of consideration is the evolution of the contractual relationships between buyer and seller in the

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[16] Schmalz, p. 76.

weapons acquisition process. Not only is the contractual mix of products purchased by the government changing, but the way in which these items are procured is also changing. Since World War II, two major events, which are important background for this study, have occurred in government procurement. First, the changeover of weapons development and production from arsenal to private firms during World War II significantly altered the business relationships between producer and consumer. Second, a more recent and relatively subtle trend towards cost consciousness in the government segment is now emerging. The present procurement environment can be essentially summarized as a convergence of the two events outlined above. The government now operates as a multi-billion dollar spender in a capitalistic economy where the contractual relationships between the parties are undergoing change in the direction of more complicated and incentive oriented techniques. The stated purpose of these methods is to assume restrained noninterference when the contractor is doing well, but quick and effective intervention when performance begins to lag.[17] A recent Aerospace Industries Association (AIA) report summarized the procurement environment as follows:

> Many changes have taken place in government procurement over the last several years. Contractor's risks have increased as a consequence of policies regarding fixed-price contracting, cost ceilings,

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[17] Peck and Scherer, I, 575.

> multi-incentives, schedule incentives, warranties, correction of deficiency clauses, total package procurement concept, etc., without realistic consideration for the balance between proft and loss potential.[18]

The Cost/Schedule Control Systems Criteria fit into the procurement picture primarily as information devices with regard to cost, schedule, and performance for designated contracts. The established intent of these criteria is their use for major contracts of a non-fixed price nature. All of the large contemporary weapons systems now in the development process are committed to applying the Criteria approach to cost, schedule, and performance management.

In theory, the contractual mechanism should become more binding on the producer as the level of uncertainty is decreased in the development process. The logic for this is that cost and time estimates should become more accurate as the system approaches the production stage. Figure 8, "Timing in the Department of Defense system life cycle," indicates the traditional approach for weapons system procurement. It should be noted that this contractual form tends to become more fixed-price oriented as the system evolves through its life cycle. Key decision points, or milestone events, are being increasingly used to monitor program performance. Also, in an attempt to insure creditability of contractor estimates,

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[18]Aerospace Technical Council, Essential Technical Steps and Related Uncertainties in DoD Weapon Systems Development (Washington, D.C., 1968), p. 4.

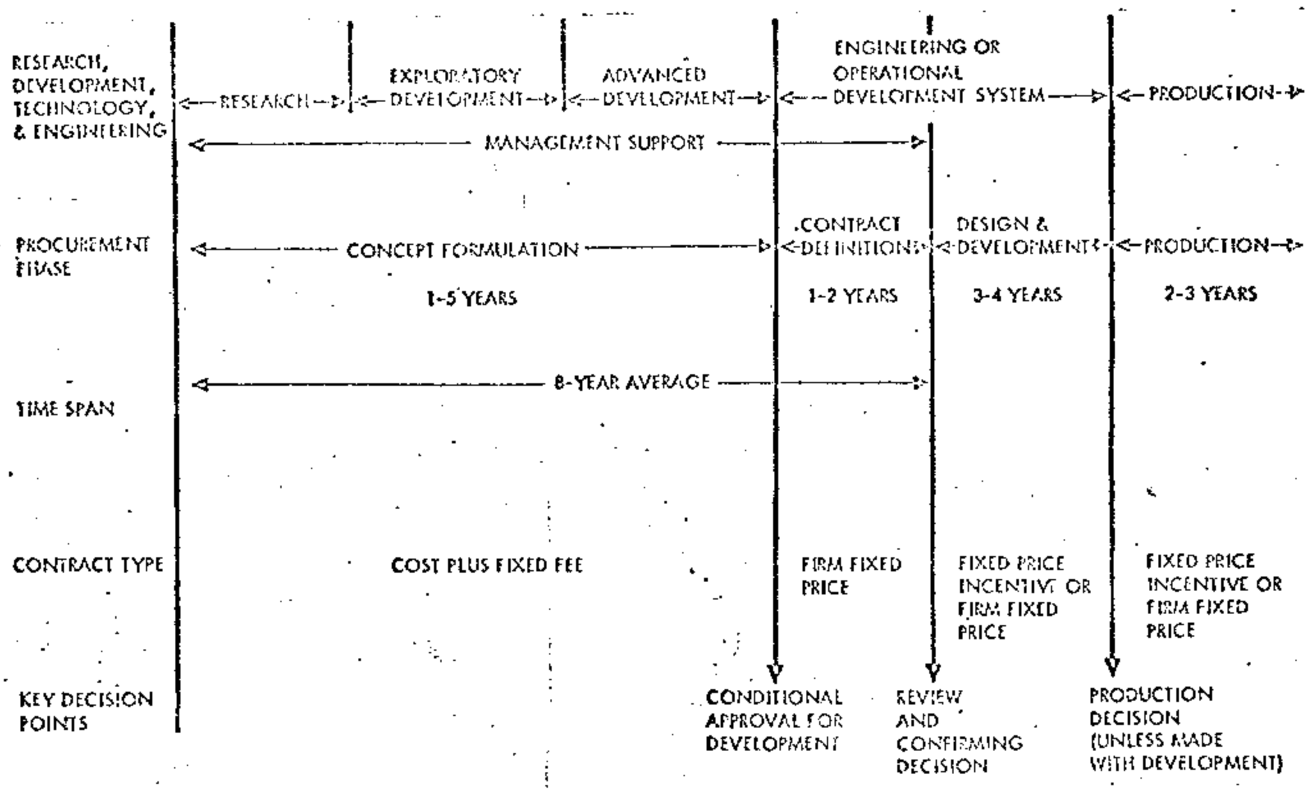

Fig. 8--Timing in the Department of Defense system life cycle. Source: Anton B. Schmaltz, Insights into the Changing Government Marketplace (El Segundo, California, 1969), p. 75.

various performance incentives are often superimposed on the basic contractual document. For example, the development of the A-7A aircraft by LTV Aerospace Corporation included the following penalty incentives:

1. $75,000 penalty for failure to meet the weight-empty specification.
2. $500,000 penalty for failure to meet the maximum speed at sea level specification.
3. $65,000 per day penalty for failure to meet the delivery schedule requirements.
4. $750,000 penalty for failure to meet the maintainability requirements.[19]

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[19] Statement by Clyde Skeen, President of Ling-Temco-Vought Corporation, February, 1967.

The effect of such penalty and incentive clauses is to force the contractor to do detail planning before committing the corporation to such critical clauses which could jeopardize profit-incentives. Definition stage proposals also create an additional contractor's cost of doing business with the government.

The considerable attention currently paid the weapons system contracting mechanism is designed to encourage improved contractor performance. Life cycle contracting under Total Package Procurement, mentioned earlier, is designed to stimulate competition among contractors in order to obtain system prices which resemble those that would be generated in a competitive market. A secondary impact of this is the provision of usable cost histories applicable to establishing meaningful costs for future contracts.[20] The question now being asked is "How much should the system have cost?" rather than "How much does the accounting system say it did cost?" Over the last decade the government has been a pacesetter in establishing highly sophisticated management systems and processes to deal with these and other related questions.[21] The Cost/Schedule Control Systems Criteria is the continuation of this effort, tightly intertwined in the contracting mechanism.

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[20] Irving N. Fisher, A Reappraisal of Incentive Contracting Experience (Santa Monica, California, 1968), p. 43.

[21] Schmalz, p. 159.

Two basic types of contracts are used in defense contracting: fixed-price and cost-reimbursable contracts.[22] Within each of these categories there are multiple options concerning cost liability. The following are the major varieties of pricing arrangements:

- Fixed-price contracts
  - Firm-fixed-price (FFP)
  - Fixed-price-incentive (FPI)
  - Fixed-price-redeterminable (FPR)
- Cost-Reimbursable contracts
  - Cost-plus-fixed-fee (CPFF)
  - Cost-plus-incentive-fee (CPIF).[23]

Fixed-price-redeterminable contracts are no longer used extensively; moreover, it is somewhat erroneous to classify them as fixed-price contracts, since they provide for periodic price renegotiation during the life of the contract. Table VI illustrates a summary of the contractual pricing arrangements for defense expenditures for various years. The most obvious trends indicated by these data are the increasing affinity, since 1960, for firm-fixed-price contracts and the decreasing importance of cost-plus-fixed-fee contracts. Former Secretary of Defense Robert McNamara has stated that procurement costs are 10 per cent lower under the new system than they would have been, given the cost-plus-fixed-fee contract for similar purchases.[24] The shift towards incentive

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[22] Fisher, p. 1. [23] *Ibid.*

[24] See statement of Secretary of Defense Robert S. McNamara before the House Armed Services Committee on the Fiscal Year 1966-1970 Defense programs and 1966 Defense Budget, February 18, 1965, Senate Subcommittee of DoD Appropriations, p. 187.

TABLE VI

TOTAL DEFENSE EXPENDITURES BY TYPE OF PRICING ARRANGEMENT

Contract Type[e]	Fiscal Year 1960[a]	1966[a]	1968[b]
Fixed-Price			
FFP	31.4%	57.5%	52.7%
FPI	13.6	15.9	18.7
Other[d]	12.4	5.8	6.2
Cost-Reimbursable			
CPFF	36.8	9.9	10.8
CPIF	3.2	8.3	9.0
Other[c]	2.6	2.6	2.6
Totals	100.0	100.0	100.0

[a]Directorate for Statistical Services, OSD, Military Prime Contract Awards, Fiscal Years 1960 and 1966.

[b]Directorate for Statistical Services, OSD, Military Prime Contract Awards, July 1968-March 1969.

[c]Includes cost sharing contracts.

[d]Includes FPR contracts.

[e]Contract abbreviations are discussed in the preceding pages of the text.

contracting places greater financial risk on the contractor since the government no longer stands ready to absorb completely cost overruns.[25] Associated with the increased risk function is the government pledge to allow commensurate profits to be earned for superior performance. Fisher's study, conducted at the Rand Corporation, indicates that the

[25]Fisher, p. 3.

average profit margin for fixed-price contracts was approximately 10 per cent, while cost-plus contracts generated profits less than 6 per cent.[26] Actually the picture is more complicated than these statistics indicate. It appears that many companies often increase cost-plus development costs and show low point margins in order to "buy in" to fixed-price production contracts which are negotiated using the inflated development cost data. Profit margins versus contract type may thus be illusory.

Cost overruns are also found to be a function of the contract type and the individual contractor. The RAND study, A Reappraisal of Incentive Contracting Experience, noted that the average per cent overrun on cost-plus-fixed-fee contracts was 1.90 per cent of the original target price, while fixed-price-incentive contracts underran the established target price by an average of 3.18 per cent.[27] The current trend in procurement, in consideration of this historical trait, is toward the increased use of fixed-price contracts and tightly established target costs for use as a cost control device. Beyond the increased use of fixed-price contractual types and incentive devices, certain other techniques are being used which essentially increase the contractor risk function. One device which has received a great deal of notoriety is the concept of "Total Package Procurement."

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[26] Ibid.

[27] Ibid., p. 21.

Total Package Procurement (TPP) is an innovation which the Air Force first undertook in the C-5A heavy transport aircraft procurement in September, 1965. Basically, this method differs from traditional approaches in that the development and production contracts were contracted simultaneously using fixed price techniques with performance and cost incentives.[28] It should be noted that the full history of this technique is yet to be completed, and the conclusion as to its value is not yet clear. Nevertheless, the concept of limited life cycle procurement is now recognized and is consistent with the prevailing theory of considering total life cycle cost. The establishment of a true cost can be best accomplished by purchasing a significant part of the total requirement on a fixed price basis and not allowing the original decision to be eroded by consistent price overruns. Total Package Procurement (TPP) thus becomes a "bundle bidding" process for both the contract definition phase (CDP) and a substantial portion of the following production run. In addition, certain change-inhibiting clauses are used in the contract which make the overall development process more binding on both the government and the producer.

Early experience with Total Package Procurement projects indicates two basic conditions which must exist in order to

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[28] Thomas K. Glennan, Innovation and Product Quality Under the Total Package Procurement Concept (Santa Monica, California, 1966), p. iii.

develop successfully a system using this contractual method: First, it must be possible to define the performance requirements in great detail and with high accuracy. Second, the system development should not attempt to advance significantly existing technology.[29] Although large cost overruns resulting from attempts to advance technology have been reviewed, there are added dimensions. For example, the Air Force has continually tried to update weapons systems during the development cycle. This attitude has significantly structured the operating methodology of the industry, but Total Package Procurement promises to influence such practices. Major impacts which TPP techniques could have on contracts are

> 1. Both parties should benefit from the long-run stability and continuity implicit in the method.
> 2. Emphasis on the total life cycle dictates that the user study more thoroughly actual system requirements prior to contract signing.
> 3. The very essence of Total Package Procurement discourages changes in contractual agreements.
> 4. Total Package Procurement forces good management planning at the outset.
> 5. Greater financial risk is forced on the contractor, and possibly even down to the subcontractor.
> 6. Due to an increased need for definition proposal costs have increased significantly.
> 7. The early design freeze implicit in this method may stifle innovation and creativity by the contractor.

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[29] General W. A. Davis, "Management Systems for Package Procurement," <u>Defense Industry Bulletin</u>, II (December, 1966), 1.

8. TPP approaches place greater emphasis on the cost variable in relation to performance objectives.[30]

Three significant programs have been requisitioned using the TPP concept. These are the C-5A heavy transport, the Short-Range Attack Missile (SRAM) and the Mark-2 avionics package for the multiple configuration F-111 aircraft. It is interesting to note that each of these programs ran into significant cost problems, with profit margins for the contractors either small or non-existent. For example, the C-5A contract is currently overrunning original target by approximately $2 million per unit, a cost ratio of 1.6; the Short-Range Attack Missile (SRAM) project is overrunning original target by at least $50 million, a cost ratio of 1.45.[31] The Mark-2 avionics system is in equal trouble on cost, in addition to technical and subcontractor problems.[32] The original contract for this system was $145 million, but this was renegotiated in the summer of 1968 to $196 million in recognition of the Air Force directed changes to the system.[33] Further changes in the contract are contingent

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[30]Most of these items are expressed, in essence, by General Charles H. Terhune, "Total Package Procurement Advantages and Disadvantages," Defense Industry Bulletin, II (November, 1967), 26-27.

[31]"DoD Defends C-5A Cost Overrun," Aviation Week & Space Technology (January 27, 1969), p. 17.

[32]Cecil Brownlow, "Mk.-2 Hits Severe Cost Problems," Aviation Week & Space Technology (March 3, 1969), p. 16.

[33]Ibid.

upon fixing the responsibility for expensive specification changes. Nonetheless, the contractors and subcontractors are being severely limited in profit on these contracts and will probably be quite wary of such arrangements in the future. It is pertinent to note that the innovator of this technique, Robert H. Charles, who was assistant Air Force Secretary for installations and logistics, has been relieved of his job due to allegations that he altered cost figures on the C-5A program in an attempt to conceal development cost overruns. His motive, it was charged, was to avoid damaging Lockheed's stock market position.[34] With this action, the government began to question seriously the further use of Total Package Procurement. However, the method has made a lasting impression on government procurement philosophy and appears to have found some permanence under other titles. As an example, the F-14 fighter development is being performed under much the same concept. A source[35] at Grumman Aircraft, the prime contractor on this system, states that the company has every confidence of meeting the requirements of this development and production contract on target due to the tremendous amount of planning undertaken before the contract was finalized. Much of the management technology which plays such a

[34] "More Questions About the Pentagon," Business Week (May 10, 1969), p. 182.

[35] An interview with Edward Siebert, Director of Operations Planning and Scheduling, Grumman Aerospace Corporation, August 21, 1969.

vital part in this initial planning effort is reflected in the Cost/Schedule Control Systems Criteria (C/SCSC). The network planning techniques and the Work Breakdown Structure, implicit in the Criteria approach, begin as required planning tools in the early life cycle of the system and become control oriented devices in later stages.

The future form of military procurement contracts will likely continue to place emphasis on total system procurement, with sharing and incentive clauses remaining in broad use. It would appear that efforts to provide the government with program visibility into cost, schedule, and performance parameters will be increased. The ramifications of such a system would enable the government to maintain an increased level of disengagement from the contractor while, at the same time, being relatively sure that the contract effort is progressing satisfactorily. The current state of management art does not allow this approach to exist for all cases since many tasks cannot be accurately preplanned at the outset. Future evolution would seem to be directed towards greater recognition by the government of total systems requirements; and the contractors will likely be forced to make the same recognition within their own spheres of interest. Information devices to satisfy total system needs, both from the weapons system and organizational points of view, will conceivably be oriented toward more automated techniques in order to satisfy the reporting requirements of internal and external sources. Theoreticians have been writing about the "total systems concept" for several years now, but the C/SCSC is the first known broad-scale attempt to actually implement such a system. The Air Force C/SPCS had previously been applied on a smaller scale.

Subcontractor Relationships

A recent listing of the major defense contractors since World War II revealed that only seven of the top twenty contractors were primarily occupied with the development and production of large weapons systems.[36] The remaining thirteen occupying these top positions were generally in the subcontractor category. The economic impact of weapons system cost is almost equally distributed between the prime or system contractor and the multitude of subcontractors who significantly contribute to the overall success or failure of the undertaking. System contractors typically subcontract between 29 per cent and 65 per cent of the total contract dollar value.[37] A weighted average over the past several years for large aerospace companies has been approximately 50 percent.[38] These data are significant and pertinent to the discussion because of the control problem created by

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[36] Aerospace Facts and Figures, 1968, p. 94.

[37] Figure based on responses to questionnaire survey associated with this research.

[38] Peck and Scherer, I, 131.

subcontracting. A control system which applies only to the prime contracting firm will obviously be ineffectual to the extent that one-half of all contractual expenditures occur at the subcontractor level. However, because of increasing complexity in weapons systems, government procurement is forcing greater dependence on prime and lower level contractors.

There is a significant trend toward the relatively small and highly technical company having great expertise in specialized areas such as radar, infra-red, lasers, optics, avionics, etc. The problems indigenous here are similar to those previously expressed as existing in the larger contractor's organization. There are several examples in recent years where the cost, performance, or timing of a subsystem became the pacing item for the total system. For the most part this interface problem has been recognized within the aerospace industry and large expenditures to provide technical and administrative liaison with the subcontractors are common. Much of the current effort has been oriented towards the solution of technical or schedule problems. Subcontractor financial problems are becoming increasingly important. There is evidence available to indicate that subcontractors are now being "squeezed" on prices in many contracts. For example, the new "Total Package Procurement" concept, mentioned earlier, has created significant financial problems for the Norden Division of United

Aircraft Corporation.[39] A $35 million writeoff on the Mark-2 avionics system reduced overall company profits. Similar reports have been made by other subcontractors who have been left wanting on the financial side of the contract, with relief difficult to find. One corporate official, S. C. Pace, the executive Vice-President of TRW Incorporated, feels that the subcontractor must be given some relief in future contracts or smaller companies will look elsewhere for business.[40]

In the subcontracting firms the types of contractual documents are just as varied as those noted for large systems contracts, and there appears to be a significant trend towards fixed-price relationships at all levels of defense procurement. For purposes of this study a subcontractor is considered to be any external firm that expends resources in return for financial consideration from the prime contractor.[41] The multitude of subcontractors can be catalogued in four basic groups:

1. Contractors that sell standardized materials for use in system fabrication or development. Examples are raw material, valves, gages, wire, etc.

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[39] Brownlow, p. 16.

[40] "A Government/Industry Look at Procurement in this Decade," p. 7.

[41] Engine manufacturers do not fit the above definition as they often contract directly with the customer.

2. Contractors that handle the overflow work of the prime contractor. This work is usually well defined in advance, although may still require considerable technical skill.

3. Producers of special items which are manufactured to prime contractor specifications and which usually take specialized knowledge or equipment to manufacture. Examples are tooling, castings, hydraform parts, etc.

4. Subsystem contractors who perform design and production effect on complex "black boxes" or major system components. This type of subcontractor differs from the others in that the firm engages in significant technical effort at relatively high financial investment. Examples are radar, avionics, tail assemblies, computers, etc.

Figure 9 schematically represents the subcontractor relationship placed in perspective with the total resource effort.

From a funds allocation point of view, three important elements are design effort (20 per cent), production effort (30 per cent), and the external subcontract of subsystem design and development (35 per cent). A cost control system should provide adequate visibility into these major areas to insure proper allocation of resources. In actual practice, the problem of visibility is one of achieving results without generating excessive cost control for the type of contractual agreement used. Fixed-price contracts should require little external cost reporting; however, cost-plus relationships might go into great documentation. The question of control depth appears to constitute a significant power struggle among the various contracting parties. Each side of the contractual agreement--government and contractor--

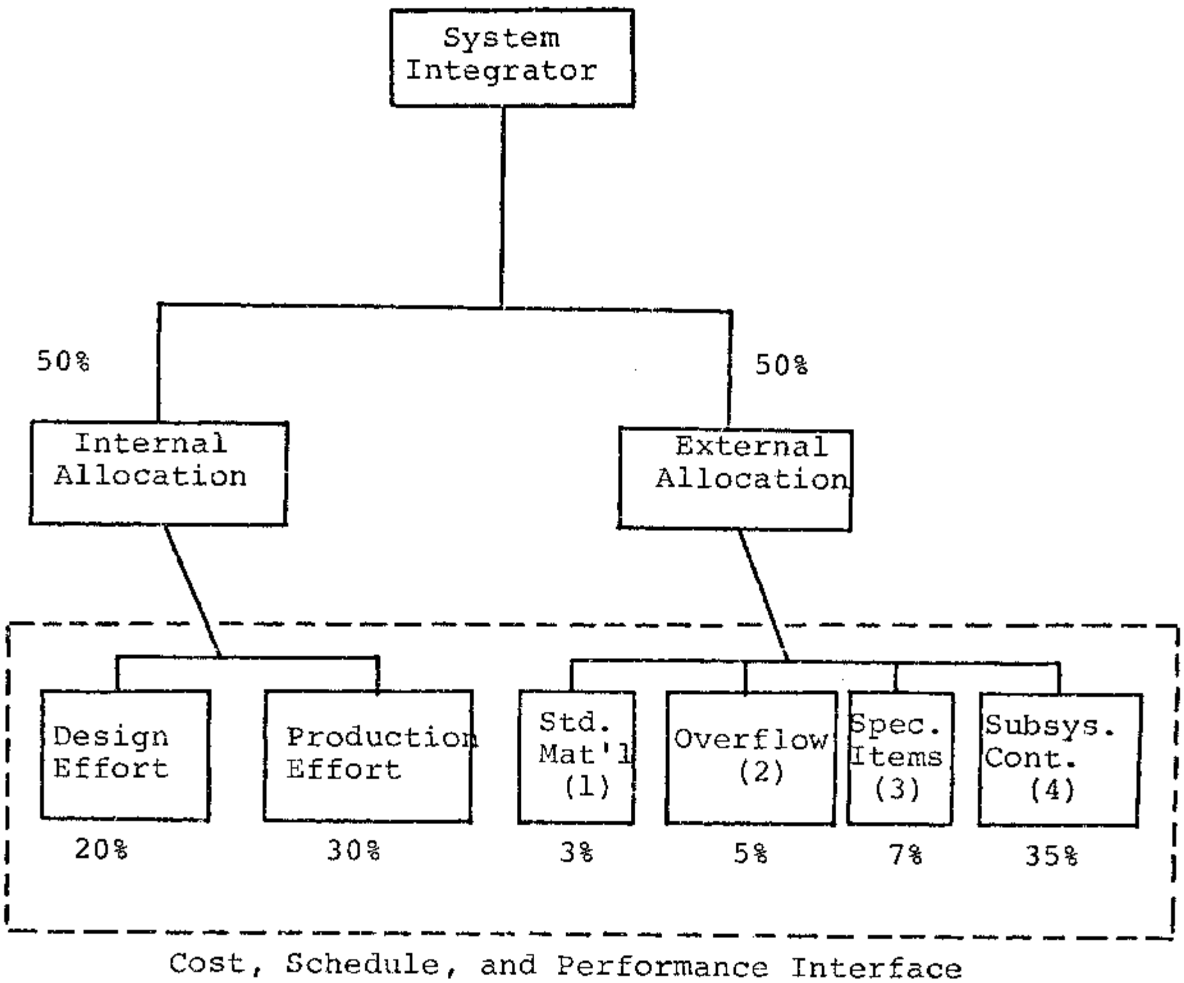

Fig. 9--Diagrammatic representation of subcontractor system relationships. See Robert E. Johnson and George R. Hall, Public Policy Towards Subcontracting (Santa Monica, California, 1965), pp. 6-10.

feels adequate to the developed task. For analysis of future trends it will be necessary to hypothesize various consequences which are dependent upon the emerging control philosophy.

The complexity and magnitude of the problems of a subcontractor are considerable. Two examples have been chosen to illustrate common occurrences. Subsystems contracts observed in the case study analysis often had a total life cycle value in excess of $10 million, and values larger than this are becoming more common. A second example is found in the KC-135 production effort which, on subcontract, had the following specifications: (1) a 43-foot section of the fuselage containing 23 major assemblies, (2) 510 subassemblies, (3) 4,000 different parts, and (4) 10,000 different tools.[42] Both of these examples indicate that the general scope of subcontracting is increasing in physical size, complexity, and cost. Future control systems will have to recognize this fact. In addition, it would seem that a future system would be further complicated by organizational personality factors, or by the traditional reporting patterns ingrained within each organization. It appears that such a system would alter the present established concepts of management prerogative, and make reliable and

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[42] Novick, p. 9.

current information available for use in decision making. Decentralization practices, so widely advertised in the industry, could also come under attack and might actually be reversed altogether to an extremely centralized decision-making body.

In recent years the government has increasingly insisted on a configuration control system which would guarantee compatibility of the subsystem parts with the overall system. There is also the requirement that detailed records be kept of component parts and procurement sources down to very low levels in the production structure.

There appears to be an emerging trend in the relationship of the prime contractor and its major subcontractors. This trend is a team approach to proposal and development relating to large systems contracts. Although there have been isolated exceptions, the government generally will accept the proposal as a total team package, not merely the prime contractor's portion. Given this set of circumstances, it is not difficult to envision the subcontractor occupying a miniature position quite similar to that of the prime contractor. In this activity the major subcontractor becomes an extension of the prime contractor, although the scope of liability seems more limited. The subcontractors visited or interviewed, which fit the above description, had varying degrees of expertise in management control systems and organizational philosophies. The smaller companies tended toward the typical functional organization, while the larger companies, such as Texas Instruments, Collins Radio, General Electric, and others in this size class, relied on project organizations. In all cases, the management control philosophy was functionally oriented, in that existing systems were designed to report status by functional unit or organization element. Those companies that had automated reporting systems did have the ability to sort data by other parameters which would yield limited program or project data. However, it should be emphasized that this capability was quite often very limited. The key point of this discussion is that subcontractors, due to the wide variety of customers and contracts, often have limited ability to provide external data by automated means. Manually-based data, other than schedule information, is universally slow in being generated and lacks auditability. With this in mind it appears that a requirement for generating sophisticated data regarding cost, schedule, or technical performance significantly strains the current ability of the typical subcontractor. There is strong reason to believe that this capability will be expensive to develop and could change the contractor's traditional way of doing business. The actual capacity of a contractor to develop such a capability was examined in the case studies and will be discussed in some depth in Chapters VI and VII. At this point, however, an effort has been made only to outline the general problems and establish a framework for subsequent analysis.

Resource Allocation

The cross-section of technical disciplines and complexity of resources required to produce a modern weapons, or space, system are unequaled in any other known endeavor of man. From the overall systems point of view there is an increasingly complex problem with the coordination of development and production activities among the various parties involved. A great deal of organizational experimentation has been conducted in the last decade to better accomplish this task and yet maintain the established functional approach. The result of this effort has been the evolution of a project management structure within most defense contractor organizations and a broader weapon-system management concept at the service level.[43] In recent years the overall coordination of resource allocation has been called systems engineering. Weapon-system management and "systems engineering" are concerned with the traditional problem of organization relationships, as well as the recently recognized problem of information by which coordination is attained.

Peck and Scherer classify the resource factors of a weapons system as

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[43]Richard A. Johnson, Fremont E. Kast, and James E. Rosenzweig, The Theory and Management of Systems (New York, 1967), p. 138.

1. Scientists, development engineers, and technicians.
2. Management.
3. Entrepreneurship.
4. Production plant, machinery, and equipment.
5. Research and test buildings, machinery, and equipment.
6. Hourly production labor.[44]

This study concluded that items one and two were the most critical to success of the enterprise. Factor three, entrepreneurship, is difficult to measure in defense systems since the customer has traditionally assumed much of the risk for the undertaking and been involved with many of the major decisions. The aerospace industry has a relatively low capital investment per employee (items four and five) as compared with the average for American industry. Comparing the data below with $20,000, which represents the national average for American industry, one can see that the aerospace industry has high costs per manpower hour, although the government does supply some additional capital to the contractor. Approximately one-half of each sales dollar is paid out in salary for production and design employees.[45] Professional salaries were $3.7 billion in 1968, and production workers earned $5.6 billion during this same period. Professional salaries have traditionally been the most difficult to manage from the contractor's viewpoint and the

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[44] Peck and Scherer, I, 160.

[45] Aerospace Facts and Figures, p. 2.

TABLE VII

CAPITAL INVESTMENT PER EMPLOYEE[a]

Firm	Investment
North American Rockwell	\$3140[b]
The Boeing Company	4000[c]
General Dynamics	2500[d]
Sample average	\$3210

[a]Investment equals total corporate property, plant, and equipment at cost divided by the average number of employees.

[b]Annual Report 1968, North American Rockwell.

[c]Annual Report, 1968, The Boeing Company.

[d]Annual Report, 1968, General Dynamics.

most difficult to audit from the customer's. More rigorous reporting requirements will probably change much of the past flexibility that contractors have had in allocating professional charges among various cost accounts. Traditional industrial engineering concepts have long been used on aerospace production lines, and this segment of the overall effort does not appear to suffer the same problems of uncertainty noted during the earlier development process. It seems logical to hypothesize that future control systems in this industry will attempt to update technically the existing information systems within the production area, plus to exert pressure upon the engineering organization to pre-plan their effort in a more rigorous manner. This appears to summarize the intent of implementing a cost and schedule control system for the Department of Defense. With such a system in existence, the resource allocation process would become more regimented than at present.

Traditional Theory of Weapons Systems Development

Under the traditional theory of weapons system development, the concept and components of the development possibility curve are the same variables as those in Cost/Schedule Control Systems Criteria. Therefore, it is appropriate to discuss the generally understood concept of weapons systems development. From a classical viewpoint, the development of a weapons system was felt to constitute varying mixes of time and total resources in order to assure some fixed level of performance. The system development possibility curve was thus viewed as a trade-off of available time with resource availability constraints. This concept is illustrated in Figure 10. This figure illustrates the possibility for trade-offs between time and resources in developing a weapons system of given performance. Point B indicates the minimum utilization of resources, or the point at which resource expenditures are optimized. Point C indicates minimum development time regardless of resource level. Arcs A and B, plus C and D exist due to the concept of diminishing returns. The arc BC represents the efficient portion of the development possibility curve in that time decreases as resources are increased. The concept illustrated appears primarily at the planning stage of the program. After this

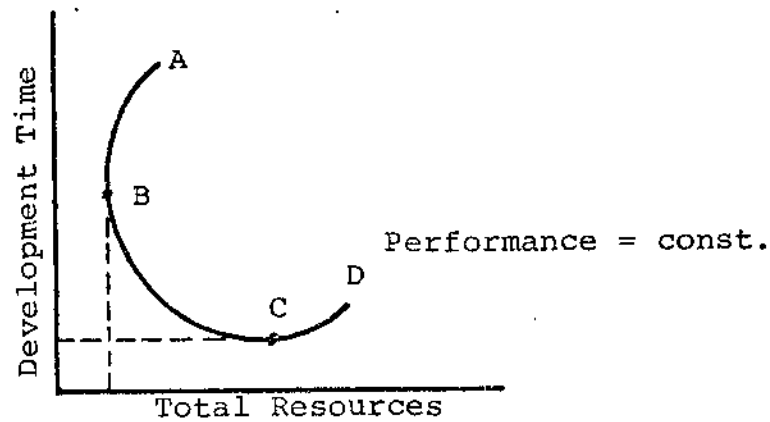

Fig. 10--Development possibility curve (Source: Peck and Scherer, I, 493).

stage, other factors seem to dictate the outcome. The optimal conduct of a weapons system program must be viewed as a complex management problem in which some of the variables must be suboptimized to achieve the overriding objectives. Unless the significant variable is chosen in advance, the entire management process may be suboptimized due to conflicting objectives. The trade-off theory can be best illustrated by again returning to traditional theory. Additional units of quality, or performance as the case may be, can be achieved with increasing amounts of resources. This suggests that the development possibility curve shown previously in Figure 10 may actually be viewed as a family of development possibilities, each curve representing a pre-established performance level. If increasing curve values represent increasing quality levels, then the family of development possibilities would appear as indicated in

Figure 11. This figure may be interpreted as total costs required to achieve a given level of quality at some time interval. For example, the commitment of 0-X dollars will

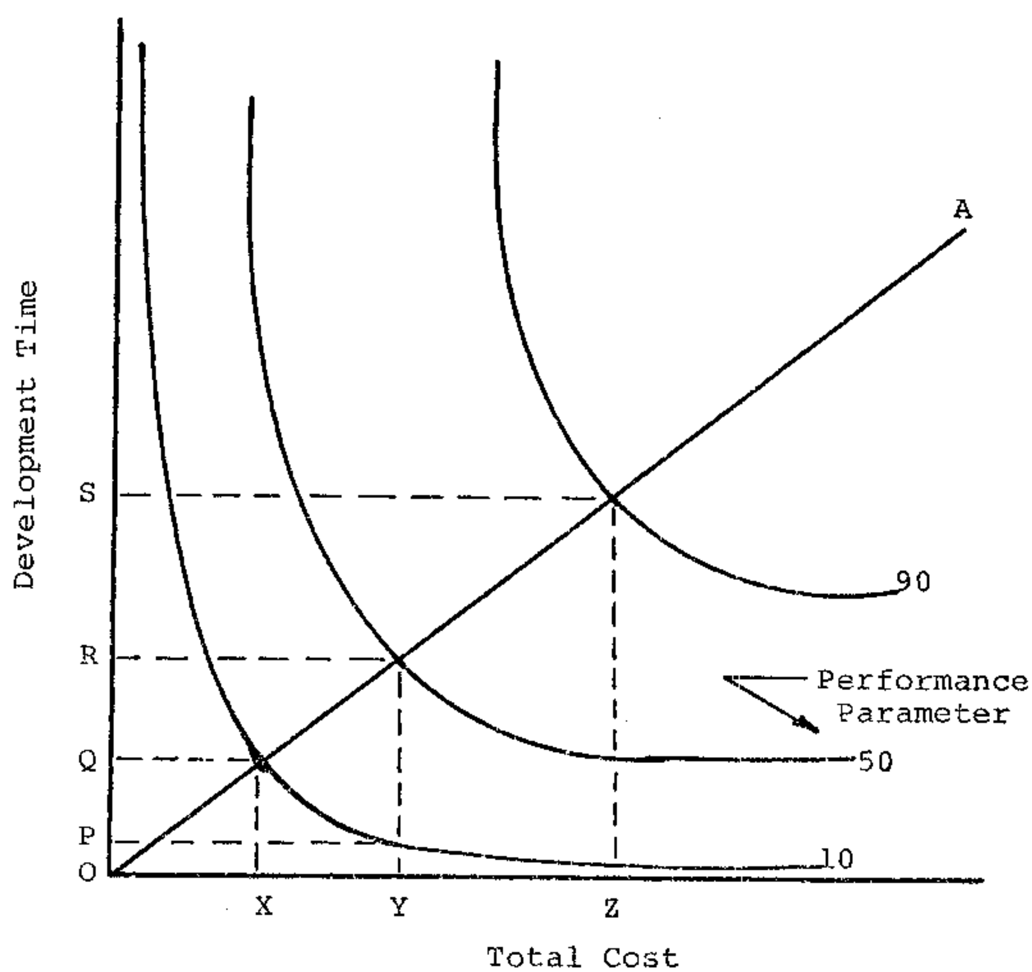

Fig. 11--Development possibility map with diminishing marginal returns. (Peck and Scherer, I, 469).

produce a system of performance parameter 10 in time period O-Q; also, the commitment of resources O-Y could produce a system of performance parameter 10 in time period O-P, or a system of performance 50 in time period O-R. This curve thus displays relative trade-offs between the variables of time, cost, and desired performance parameters. Since these are the same variables as those transmitted in the Cost/Schedule Control Systems Criteria, the concept and components of the development possibility curve are pertinent to this discussion.

There are many variables which collectively result in the development possibility curve. The significant variables are project manning, multiple technical approaches, overhead, and management.[46] Project manning refers to the quality and quantity of human resources available for the program. Within normal operating regions the time resource required to complete a project will be an inverse function of the resources available, although the concept of diminishing returns causes the relationship to become hyperbolic. Figure 12 illustrates this component of the development possibility curve. Just as with the development possibility curve, the region BC represents the efficient operating portion. This concept is difficult to apply due to the lack of qualitative measures for human resources. Salary will not suffice since one $20,000 engineer will probably be more productive qualitatively, due to advanced skills, than two $10,000 engineers. Even with this restriction, however, modern management techniques allow some flexibility in

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[46]For a more complete discussion of this subject see Peck and Scherer, I, 254-287.

planning resource expenditures versus completion times. For instance, several of the network planning tools allow dollar estimates to be used for discrete activities to show this very relationship.

The second major variable of the development possibility curve is that of multiple technical approaches. Much has

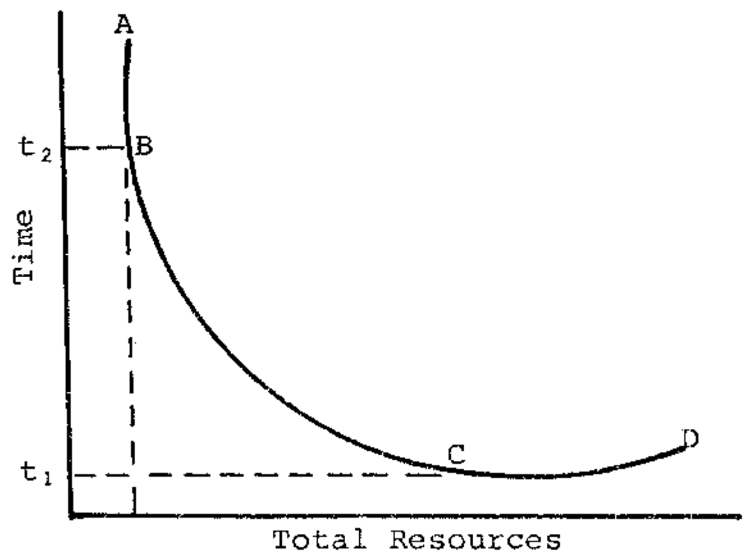

Fig. 12--Project manning (Peck and Scherer, I, 257-260)

been written of this concept in the past thirty years, both pro and con. As far as theory is concerned, however, there is no basic disagreement. In theory, if time is a constraint and the probability of success is low or highly uncertain, multiple approaches should be undertaken. The most notable scientific use of this method came from the development approach of the atomic bomb during the early forties. In an attempt to accomplish the desired task in globally minimal time, five completely separate techniques were pursued through 1943. Three were then carried through until the end of the war. Recently, the development of the operational intercontinental ballistic missile proceeded along multiple paths with the Atlas and Titan programs. Within each of these programs, further multiple efforts were attempted down to the smallest critical components. Apparently the typical weapons system development today attempts to avoid excess use of multiple technical approaches, although its use is prevalent enough to be recognized here. The effect of multiple approaches to a single design goal is illustrated in Figure 13. Time, t_1, represents the period of time required for a "crash" development program with all possible approaches to the solution explored. In recent years, many authors have strongly criticized the regimented military

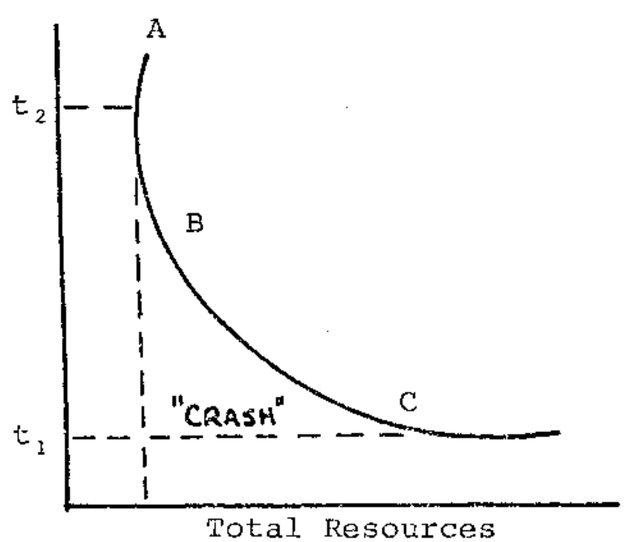

Fig. 13--Multiple approaches (Source: Peck and Scherer, I, 261-262).

approach to weapons procurement. These writers feel that the contractor should be given only general objectives and left to his innovative talents to create a device which will accomplish the desired result. Thus far, however, the trend has been towards more definition of final product specifications, and the Cost/Schedule Control Systems Criteria depends upon a significant level of definition in order to provide control parameters. The preplanning of specific design parameters and milestone accomplishment dates of these parameters appears to frighten many contractors involved in high technology development. This aspect of the procurement operation is becoming known in the industry as "technical tracking," or more formally as "technical performance measurement." The decisions necessary to attain some predetermined level of performance must accommodate the concept of multiple technical approaches in order to assure timely and adequate completion of the contract.

The third significant variable of the development possibility curve is that of overhead. Given a relatively fixed organizational structure, the level of overhead is found to be primarily a function of time. This would suggest that the expenditure of overhead funds is proportionate to the system development period. Attempts to decrease resource expenditures by extension of a program schedule are often foiled by the maintenance of high overhead. In most aerospace companies, the level of non-direct personnel is equal, at least, in magnitude to direct charging units. This would suggest that a time slippage due to technical problems in one area could often be severely compounded as a result of overhead charges. For example, a two month slip in engineering development of some major subsystem might result in excess direct charges in the vicinity of $10,000, but the overall budget overrun would be at least doubled due to the existence of continuing overhead and no other source to absorb the additional charges. In summary, the overhead function is critically linked to the direct charging units and is found to be a cost accelerator when programs begin to slip in time or occupy more resources than originally planned.

The fourth and final variable to be discussed as a component of the development possibility curve is that of management. The increasing complexity and size of weapons system development have created more than a linear increase in the level of management required. Obviously, a simple statement is not possible to define the effect that management expenditures have on the total development effort. Peck and Scherer concluded that the cost of management increased with development time.[47] Management is often hampered in the decision-making phases of the program by the lack of timely information and the coordinative aspects of the task. It would appear that these deficiencies can be minimized only

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[47] Ibid., p. 264.

by the expenditure of additional resources in the future for more sophisticated management planning and control systems. If this hypothesis is accepted, the management factor would generally agree with Peck and Scherer's, as illustrated in Figure 14.

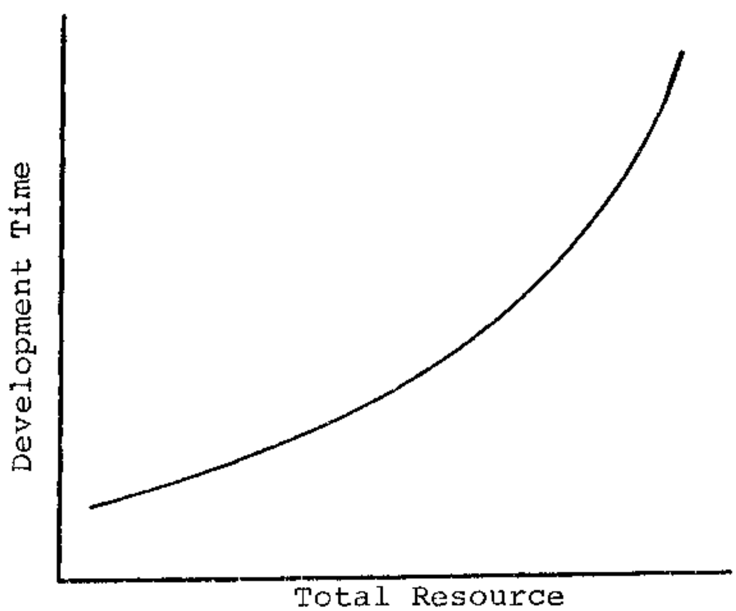

Fig. 14--The management factor (Source: Peck and Scherer, p. 263).

The factors discussed here will, when combined, produce a development possibilities curve as initially shown. Within the efficient operating portion of this curve, there appear to be significant trade-off possibilities between time, cost, and performance. This concept is difficult to apply since measurement units are difficult to establish for each of these three variables. As an example, time can be arbitrarily set as the period from some formal beginning date to operational date, but the actual choosing of operational date often becomes a matter of interpretation. Total resources expended are usually framed in dollar costs units and this would be adequate for many applications, yet the mix of resources required can be the true measure of a company's ability to perform. Thus, resources assume both quantitative and qualitative values. Technical performance becomes the most difficult variable to measure because performance is multi-dimensional to an even greater extent than the variables of cost and time.

Stubbing's Contemporary Thesis

Richard A. Stubbing, in his recent Princeton master's thesis, explored the performance of weapons systems over the past fifteen years.[48] Much of this information was gained as a result of his job as contract examiner for major weapons systems with the Bureau of the Budget. The quoted sources were publicized as being non-classified. The remarkable accomplishment credited to this source is the analysis of performance versus cost overrun and development time. Linear regression curves, with performance as the dependent variable and cost overrun or development time as independent variables, are shown in Figures 15 and 16, respectively. The regression equation of cost overrun versus

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[48] Richard A. Stubbing, "Improving the Acquisition Process for High Risk Electronics Systems," unpublished master's thesis, Princeton University, Princeton, New Jersey, 1968.

resulting performance violates traditional theory in that cost increases did not indicate improved performance, nor insure that the pre-established level would be reached.

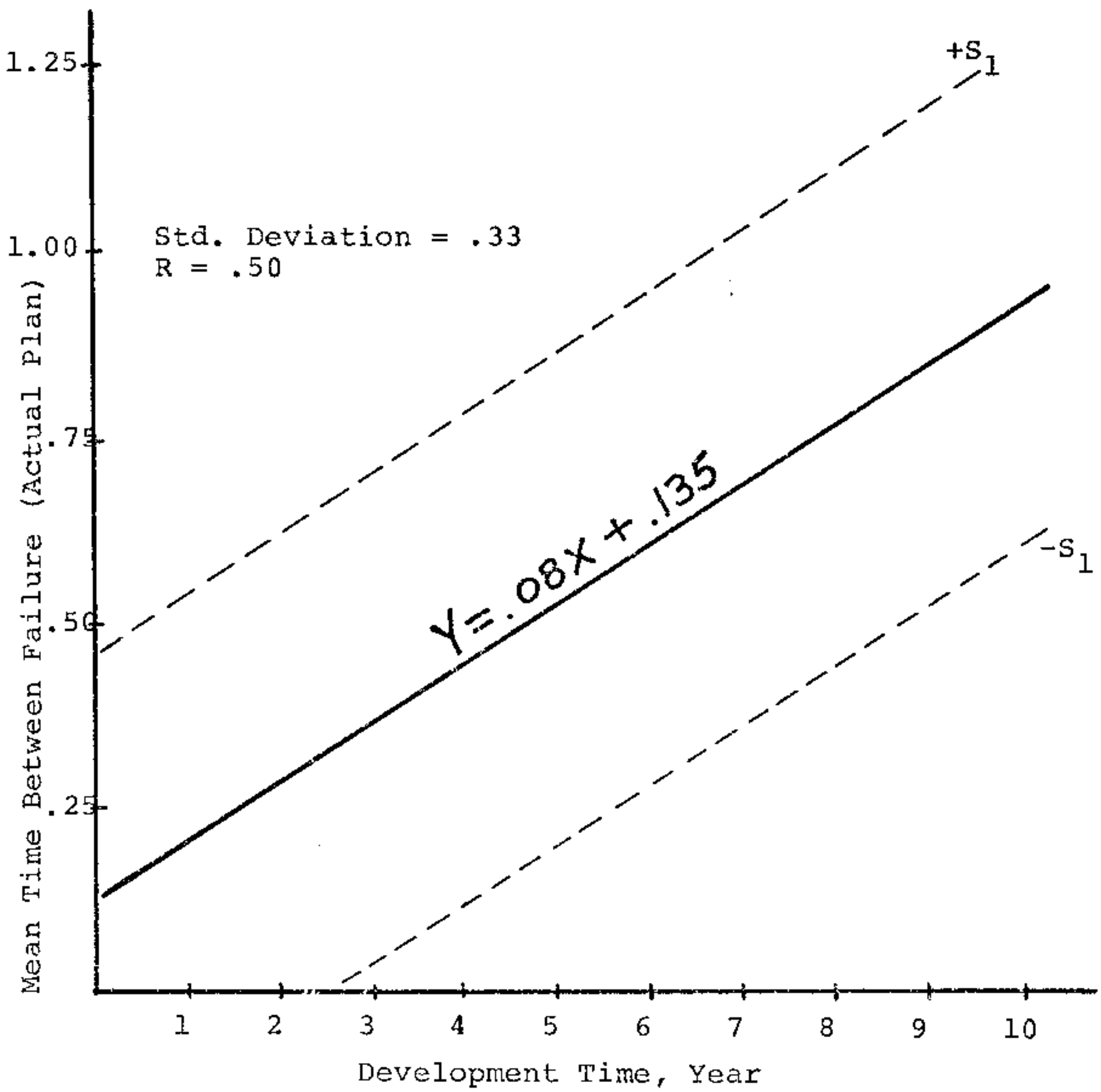

Fig. 15--Correlation of development time with system performance. (Source: Richard A. Stubbing, p. 19. Names of actual systems withheld from basic source due to security reasons.)

Stubbing's conclusion was that "crash" development programs caused severe overruns in both cost and time. He also noted that increase in resource expenditure was not justified since

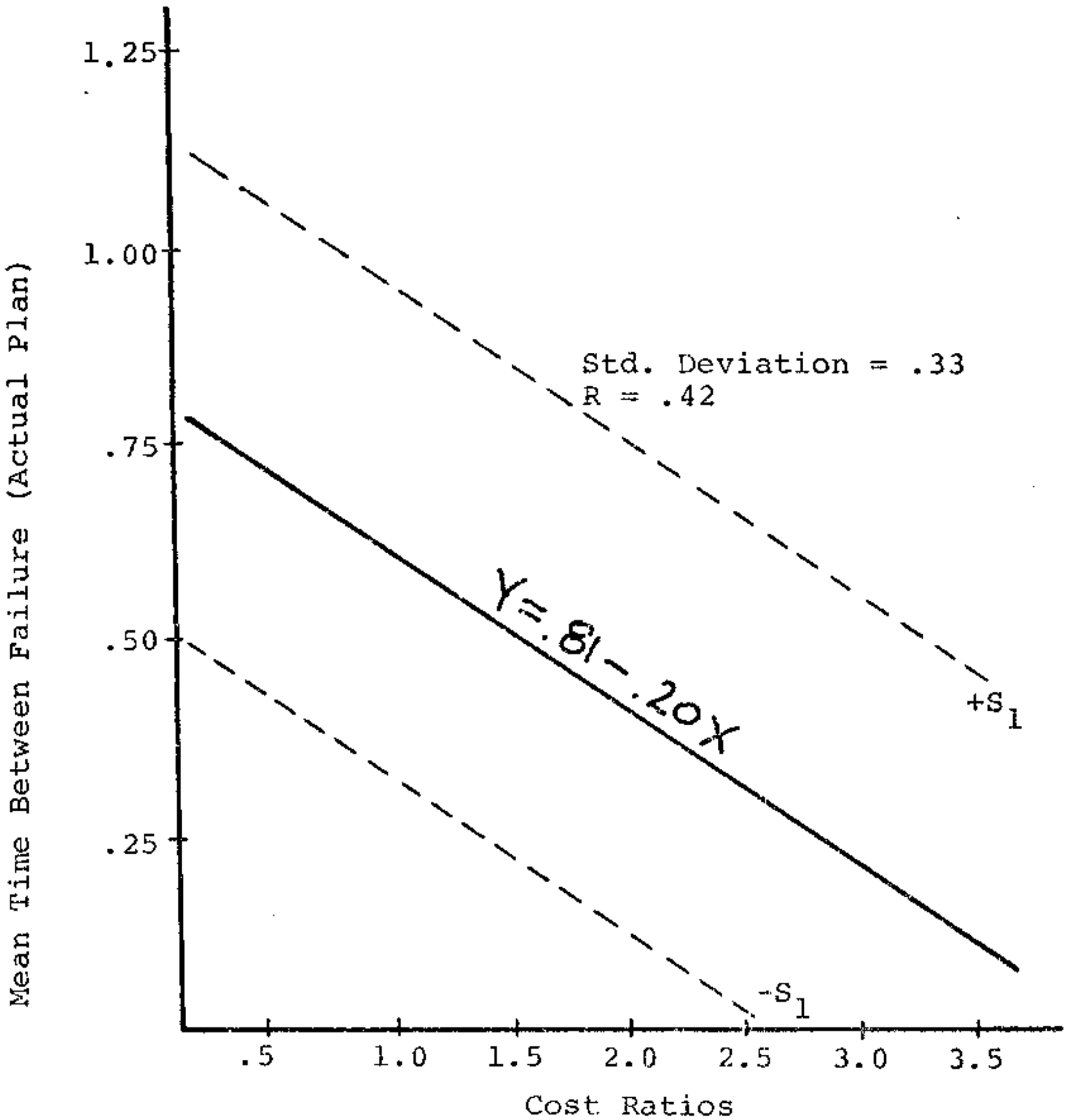

Fig. 16--Correlation of unit cost factor with system performance. (Source: Stubbing, p. 20. Names of actual systems withheld from basic source due to security reasons.)

performance also suffered.[49] In addition, it was concluded that contractors were not able to meet stringently established design goals and that more efficient program performance could be achieved if specifications could be flexible. Not only do these conclusions challenge the contemporary technique of military procurement, but they place in doubt the establishment of a system which dictates specific goals to a contractor. It would seem that the eventual success of the Cost/Schedule Control Systems Criteria would be strongly dependent upon pre-set design goals; otherwise, the technique would simply become a more sophisticated reporting system.

The regression line for development time versus system performance, Figure 15, indicates that an eight to ten-year period is needed for development if high performance goals are required for system success. The regression line for cost overrun versus system performance indicates that those systems which ran into cost problems were also accompanied by resulting low performance in terms of Mean Time Between Failure (MTBF). If the simplified performance variable chosen by Stubbing is accepted, it must be concluded that attempts to advance performance significantly, at the expense of both cost and time, have actually resulted in the defeat of all three objectives.

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[49] *Ibid.*, p. 38.

With the Stubbing thesis integrated into the classical concepts, one finds that the development possibility curve now becomes a three-dimensional hyperplane of another type. Figure 17 illustrates the trade-off that appears to occur in many cases. The resource trade-off that actually occurs in many cases is illustrated here by the delta increments on the figure. It should be noted that increasing cost overruns are accompanied by decreasing performance and increasing time ratios.

Although most of the significant variables have been discussed in this text, each program seems to have its own unique set of pertinent variables, constraints, and objectives. Therefore, general conclusions categorizing the weapons system development process can be drawn.

Contemporary Weapons Systems

This section will review present military procurement data and attempt to hypothesize future trends in order to establish the operating base on which the existing Cost/Schedule Control System will operate. In addition, the status of some major systems currently in development will be presented to demonstrate the ever-present problem of cost control. Finally, a listing of future systems and expected resource commitment will be summarized to introduce and illustrate the evolving trend in military weapons procurement.

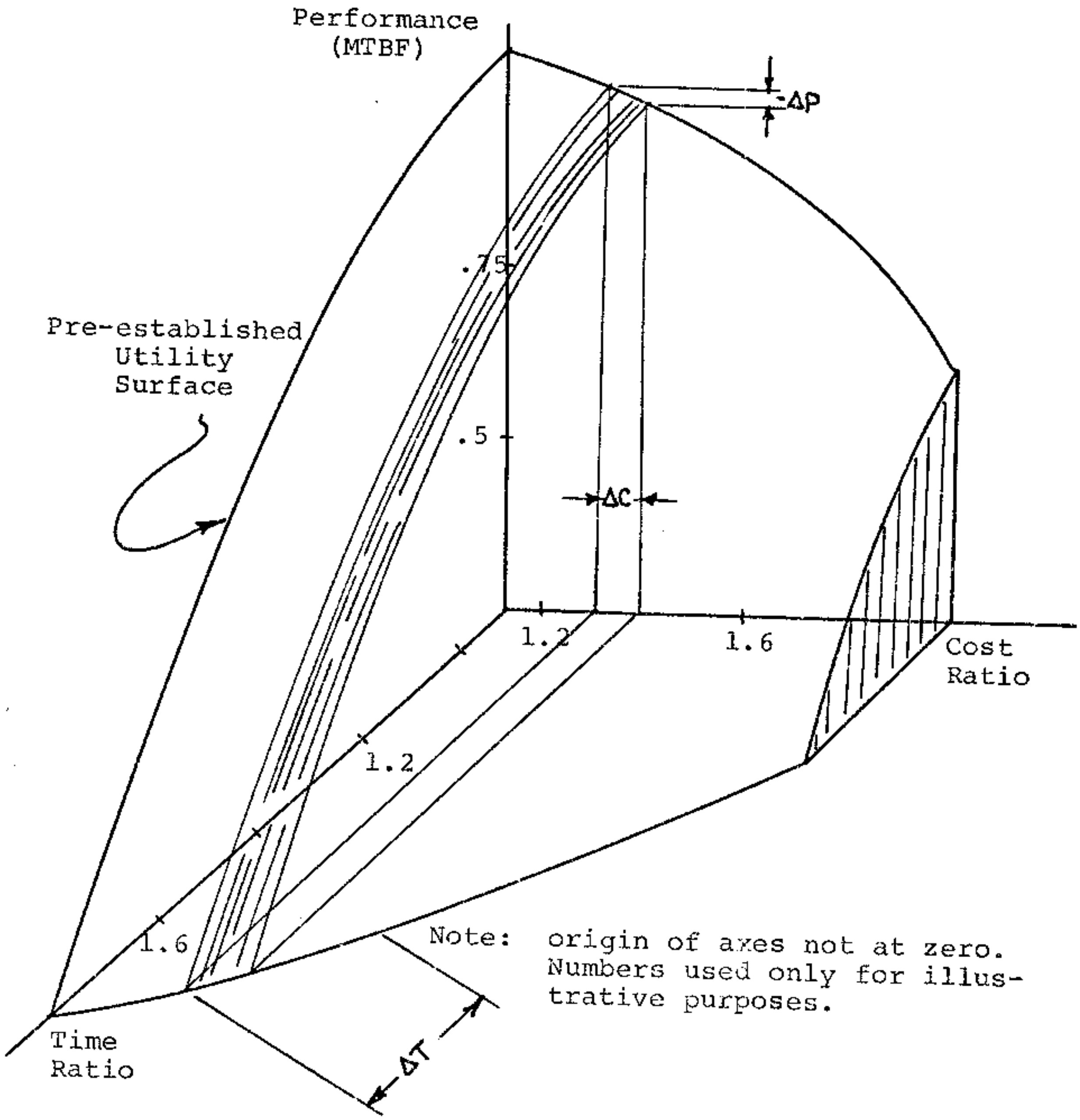

Fig. 17--Diagrammatic representation of typical weapons system production surface.

The latest budget estimate available indicates that the dollar commitment for fiscal 1970 will be approximately $21.5 billion for procurement and an additional $8.3 billion for development purposes.[50] Procurement for the next five years has been committed to a point where a cessation of fighting in Vietnam would have little effect on the major weapons now being produced,[51] according to Charles L. Schultze, former Director of the Budget, without consideration of the future commitment of funds for such tasks as the manned bomber, antiballistic missile, or the new Navy submarine detection systems.[52] The obvious conclusion to be drawn from these data is that military spending will continue to be quite significant over the next decade. With the strong opinions in Congress at present over military spending, it would also seem likely that continual pressure will be placed on the Department of Defense to justify fully major procurement decisions, especially in terms of cost and ultimate objective. Given this as a working hypothesis, it appears that the Cost/Schedule Control Systems Criteria, in some evolved form, will be necessary to supply these data to government bidders and contractors. The real question

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[50]Winston, p. 24.

[51]*The Dallas Morning News*, March 30, 1969, Sec. A, p. 21.

[52]*Ibid*.

appears to be what level of reporting is going to be required. It has been shown that sufficient resource expenditure will be made over the next five-year period to require continued emphasis on a cost, schedule, and performance control system. It is most likely that the existing efforts to implement the Cost/Schedule Control Systems Criteria will continue.

Data from six major programs currently in development have been chosen to reflect current cost performance of the industry for highly complex systems. Sketchy data published in unclassified sources indicate that each of these programs has experienced technical problems of varying degree, but individual contractors have generally solved these problems sufficiently for program maintenance. Time of system availability has also slipped, but considerably less than either cost or technical performance. This conclusion is consistent with case study results obtained for this research. Most managers feel that they can plan time best, then cost and technical performance to lesser accuracy. Table VIII summarizes current cost performance for six selected weapons programs. The fact that these cost overruns exist in the contemporary environment, where government involvement is pronounced, indicates that external control measures are not cost effective. Most of the weapons acquisition procurement programs listed in Table VIII have high technical advance probabilities for cost overrun. Many in the industry feel

TABLE VIII

COST OVERRUNS ON CURRENT PROGRAMS[a]

Program	Original Estimate	Current Estimate	Cost Ratio
Minuteman II (ICBM)[b]	$3.27 B	$ 7.0 B	2.14
Deep Submergible Rescue Vehicle (DSRV)[b]	$3.0 M/unit	$80 M/unit	27.0
C-5A Heavy Transport[b]	$3.4 B	$ 5.0 B	1.47
FB-111A Fighter-Bomber[c]	$0.9 B	$ 1.1 B[d]	1.24
Short Range Attack Missile (SRAM)[e]	$0.142	$ 0.20 B	1.45
Mark II Avionics[f]	$0.145	$ 0.30 B	2.07

[a]Data is consistent with latest available sources, but figures will most likely increase with time.

[b]The Tampa Tribune, June 12, 1969, Sec. A, p. 1.

[c]"This is the F-111 Story," p. 7.

[d]"The Price of Arms Control," Aviation Week and Space Technology, July 12, 1969, p. 65.

[e]"SRAM Cost Overruns Negotiated," Aviation Week and Space Technology, January 27, 1969, p. 16.

[f]Brownlow, p. 17.

that some of these contractors were attempting to "buy in" to lucrative production contracts and actually knew they were underbidding. The true cause is most probably some combination of these factors, as well as the changing desires of the government as a customer.

Throughout the history of military procurement, contractors have found themselves suddenly without funding as contracts were cancelled on short notice. During the forties and fifties the primary causes for contract cancellation, or abrupt changes in direction, were closely linked to the multiple path approach to weapons development. For instance, two or more contractors would be in competition for one production contract with only one award expected. The primary reason for not obtaining the contract was failure to perform in prototype competition. Since the early sixties, procurement agencies have become increasingly conscious of rising development cost and have tended toward paper design competition without the long established policy of actually creating the hardware. Further, with each service performing its own system selection, there were many instances of duplication, and often poor performance, due to early decision mistakes. As an additional factor, there were several examples of technical obsolescence within the missile industry, whereby the system was of no value even before the development phase was completed. This point is illustrated in Table IX by the use of selected examples of weapons system contract cancellations. It is the sunk costs factor represented by these and other similar programs that has stimulated the interest of the government in more sophisticated methods of determining an approach to weapons development which would optimize defense expenditures. This search for optimum combinations has tended to increase emphasis on the cost factor and accounts for more serious consideration of this variable in relation to the variables

TABLE IX

SELECTED CONTRACT CANCELLATIONS*

Year	Program	Stage	Primary Reasons**	Estimated Sunk Cost
1969	F-111B (Navy)	Dev.	C & T	$600 M
1969	AH-56A (Army)	Dev.	T & C	$200 M
1969	Manned Orbital Lab	Dev.	E	$600 M
1965	Mauler Missile	Dev.	T	$200 M
1964	Typhoon missile	Dev.	T	$200 M
1963	Nuclear plane	Dev.	S & C	$ 1.1 B
1963	Skybolt missile	Dev.	C	$800 M

*Sources: various unclassified periodicals.

**T = Technical performance of system; C = Cost of system; E = Budgetary move; S = Strategic factors which did not justify cost.

of time and performance. It should be noted that economic moves played a major part in each of the contract cancellations summarized in Table IX. In each of the more recent cases, it appeared that the cost of the individual system did not match its objective value; therefore, it was curtailed in lieu of some higher priority goal. In the future, it appears that the Cost/Schedule Control Systems Criteria will play a large role in contract decisions, since "cost-to-completion" analysis is a by-product of the system. Sensitive data of this nature are certainly a reason for the contractor's fear of such a system. From the government viewpoint, realistic cost forecasts, made early in a program life cycle, would significantly aid future procurement actions. These reasons, combined with the complicated logic of each party, would appear to summarize the struggle resulting over attempts to implement the planning and control system described in this research.

Current industry information indicates that the eight systems summarized in Table X are most likely to be the major

TABLE X

MAJOR WEAPONS SYSTEMS NOW IN DEVELOPMENT OR FORMULATION STAGES[a]

Name	Designator	Stage[b]	Approximate Cost[c]		
			R & D	Prod.	Total
Navy Fighter	F-14	D	.365	3.0	3.4
Minuteman III	ICBM	D	.4	2.6	3.0
Antiballistic Missile	ABM	D	.6	10 -20	10 -20
Antisubmarine Aircraft	EA-6B	D	.25	3.0	3.25
Poseidon Missile	--	D	1.2	4.4	5.6
Air Force Fighter[d]	F-15	F	1.0	4.0	5.0
Manned Bomber	B-1	F	1.3 -1.8	8 -10	9 -12

[a]Cost information was gathered from various sources and should be considered an order of magnitude only.

[b]Development stage = D; Formulation state = F.

[c]Approximate cost is in billions.

[d]This program is already reporting cost overruns of approximately $1.7 billion.

aircraft and missile defense expenditure items over the next several years, assuming each is successfully developed. The systems in this category represent a conservative procurement cost of over $35 billion within the next ten years.

In addition to the systems constituting the major impact group, there are many other systems which have high cost potential. By actual count there are two tactical aircraft and twelve tactical missiles in this supplementary group, plus two strategic aircraft and five strategic missiles.[53] Each of the supplementary group will exceed the $25 million research and development threshold normally requisite to establishing the Cost/Schedule Control Systems Criteria. That is, C/SCSC is not usually applied to smaller contracts. There are many more programs in the procurement stage which also qualify for inclusion under these Criteria. Certainly there is no shortage of large programs to which the Criteria can be applied if contractor acceptance can be established.

In conclusion, this section has illustrated that military procurement is, and continues to be, big business. Weapons systems unit cost in the future will be as large as the current expenditures, and probably even larger as complexity increases with advances in technology. The overall level of control will shift downward into the organization and outward to the subcontractor with the result being increased control responsibility placed on the prime contractor.

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[53]"Status of Major U.S., European Defense Aerospace Programs," Aviation Week and Space Technology (March 10, 1969), pp. 34-35.

This in turn should create a strong need for implementation and application of planning and control techniques which are far more sophisticated than those now available. If one concludes that pre-planning is possible and necessary for efficient utilization of the country's defense resources, then the traditional weapons procurement cycle will undergo significant changes involving slower development phases with multiple development activities, less state-of-the-art advance attempted, and increased emphasis on technical achievement within tight cost and time constraints. It is this second hypothesis that appears to reflect recent attitudes in the Department of Defense. Further development of this research is based on that hypothesis.

With the background discussion of the criteria now complete, an attempt will be made in Chapter IV to explore the evolution of government management control regulations since World War II. The interaction of the criteria environment with the operation of these indicated regulations should begin to emerge from this discussion. In addition to the integrative process described above, the next chapter will establish a descriptive framework from which to draw for further discussion of the impact of the Cost/Schedule Control Systems Criteria with relation to both government and contractor operational systems.

CHAPTER IV

THE DEPARTMENT OF DEFENSE MANAGEMENT CONTROL SYSTEMS EVOLUTION

The Cost/Schedule Control Systems Criteria, a performance measurement technique, was born in the mid-sixties within an environment of rapid growth in information technology on the one hand and strong pressure to prohibit further management systems proliferation at the other extreme. The Criteria thus exhibits a very modern look, but closer examination reveals that it is merely an evolution of older management control techniques.

Historical Evolution of Government Management Control Regulations Prior to 1960

Most of the history relating to government control regulations has been confined to the period after 1940. Before the forties, general management control efforts were expended in such areas as cost accounting, inventory control, work measurement, and other similar industrial management areas. Emphasis during this period was primarily in the functional areas of manufacturing and assembly. High quantity production runs were becoming more common by the thirties and, in 1936, T. P. Curtiss of the Curtiss Wright Corporation published an article titled, "Factors Affecting the Cost of

Airplanes."[2] This article summarized some fourteen years of cost improvement efforts during the continuous production of a two-place aircraft. It was this document, and the related multitude of others following, that established the conceptual background of planning and control for the aerospace and electronics industries. Fundamental to planning and control was the concept of the learning curve. Basically, the learning curve derived its validity from a worker learning by repetitive tasks and as a result taking a predictably smaller increment of time to accomplish the task during subsequent periods. During this period the cost of production was very small compared with development costs, and in addition, the government usually funded development on a cost-plus basis. Cost control systems up to the mid-forties were oriented around the production learning curve and seemed to satisfy all concerned.

During World War II emphasis was still placed on production output and cost was relegated to relatively low status. In 1942 the War Production Board was established to allocate critical resources among the various needy users.[3] This resource allocation concept actually became the antecedent to the Cost/Schedule Control Systems Criteria, which was not

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[2] T. P. Curtiss, "Factors Affecting the Cost of Airplanes," in _How to Use the Learning Curve_, edited by Raymond Jordan (Boston, 1945), p. 2.

[3] David Novick, editor, _Program Budgeting_ (New York, 1969), p. xxi.

to appear for some twenty-five years. Other than this one direct historical link, most of the government-instigated control systems during this period were geared to production and logistics activities.

By the mid-fifties three distinct trends in government procurement could be recognized as having significant impact on the contractor's method of doing business. First, the rapid expansion of technology during this period in jet aircraft systems and missile development, each in turn creating needs for complex electronic systems, had completely transformed the industries' way of doing business. Second, the threat of "spasm" nuclear war and cold war strategic maneuvering made time the most critical resource, since the period of action-reaction had essentially been reduced to zero. Third, the emphasis upon management competition in the late 1950's placed great reliance on planning and written information. Associated with this trend, and probably a primary causal factor, was the rapid development of the computer and its tremendous ability to generate data that was previously uneconomical to obtain. By 1958 contractor management began to find practical applications for their computer tool. The accounting system, inventory records and limited fabrication tracking programs were first developed to monitor certain programable areas of the production function.

The real contribution made in this time period with regard to management planning and control was the Program Evaluation and Review Technique, better known by the acronym PERT. This network management technique was developed in 1958 by representatives of the Navy Bureau of Ordnance and the consulting firm of Booz, Allen and Hamilton.[4] The original application of this time-oriented network technique was designed to assist in planning and controlling the development and installation of the Fleet Ballistic Missile program, or Polaris as it is more commonly known.[5] This technique is in essence the historical progenitor of the Cost/Schedule Control Systems Criteria. An important point to consider at this juncture is the emphasis that the network approach places on the total system and its major parts, where before each element had been considered to exist in its own sterile microcosm. Second, the control emphasis was broadened from a production orientation to the non-repetitive development portion where past history might have little or no bearing on current programs. By this it can be seen that learning curves and other related industrial phenomena were displaced and emphasis was being shifted to managerial fore-cast parameters. The PERT method was credited with saving

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[4] "PERT/Cost, Department of Defense Joint Course," compiled by the United States Army Management Engineering Training Agency (Rock Island, Illinois, 1967), p. 2.

[5] Peter P. Schoderbek, Management Systems (New York, 1968), p. 379.

two years in development of the Polaris missile and soon became the rage of the management world. By 1963, there were over fifty variations of PERT; man realized that he now had a way of making the computer do managerial-type work for him. PERT has been generally accepted as a valid concept for time control on large, complex, costly, and non-repetitive activities such as weapons system development.

The early PERT concept was a time-oriented tool, with little implicit regard for program costs. By 1962, information technology and computer capabilities had increased to a point where additional use could be made of the network technique. It was now possible to add budget costs to the network and generate reports on budget and manpower requirements versus time period, as well as to obtain the traditional PERT time-oriented reports. Paralleling this development contractors were expanding their expertise in internal computer systems and the Department of Defense became increasingly oriented towards systems information. Government requirements during this period were usually taken from contractor operating systems, reorganized into the necessary formats and then re-programmed into the government reporting system. Contractor-furnished data were often found to be lacking and quite subjective in interpretation. The end result of this was the proliferation of useless information throughout the acquisition and budgeting agencies. In an attempt to provide more usable information, the government imposed on its contractors the requirement of systematic reporting according to a standard format so that more intelligent decisions could be made at the agency level. It is little wonder that by the latter sixties some 3500 separate control systems were in existence within the Department of Defense.[6] The clamoring of contractors and the efficiency orientation of the Department of Defense eventually led to the issuance of the Cost/Schedule Control Systems Criteria.

Historically, then, one can view the Cost/Schedule Control Systems Criteria as the end product of an evolutionary process which can be directly traced to the development of PERT in 1958, with less visible roots in basic control techniques which originated during the scientific management era of the 1920's. Issuance of the Criteria represented a desire to improve reporting systems and decrease the proliferation of redundant management information systems that had become so evident by the 1960's.

Evolution of Government Management Control Techniques Since 1960

President Eisenhower reorganized the Department of Defense in 1958 to clearly establish the authority of the

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[6]Schmalz, p. 11.

Secretary of Defense.[7] The result of this action was essentially to centralize major decisions within the department, but the full realization of this potential awaited the appointment of Robert McNamara as Secretary of Defense in January, 1961. McNamara brought a Harvard flair for theory and a strong business background into his job, along with many staff assistants who had similar backgrounds. Before long, policies of the Defense sector began to reflect basic philosophies exhibited by Harvard and The Rand Corporation. The most significant contribution to be credited to the new establishment was the Planning, Programming, and Budgeting System of Charles J. Hitch, then Defense Comptroller. Basically, this system involved a complex approach to determining national objectives, establishing means to accomplish these objectives and budgeting the resources necessary to achieve these ends. Unfortunately, the operating level of the Department of Defense was not prepared for this new approach to management. Basic deficiencies were noted in the following areas:

1. Cost data was inadequate in both quantity and quality.

2. Operational planning and reporting was done for only one year at a time, with little regard for future costs.

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[7] Novick, <u>Program Budgeting</u>, p. 82.

3. Weapons system data was incomplete in that the full costs were not available (*i.e.*, real estate, training, development, associated equipment, *etc*.).

4. Budget categories were not related to mission requirements.

The requirements for implementing a program-budgeting system dominated many of the changes noted in the defense establishment through much of the early sixties and even beyond. One of the most ambitious undertakings which was to result from this marked change in defense management philosophy was to be the Cost/Schedule Control Systems Criteria, but before the Criteria itself evolved, a great deal of development effort would be expended in search of the one best way of planning and controlling the weapons system acquisition process.

Traditional budget allocation within the Department of Defense, before 1961, operated by simply dividing the total resource package among the three service departments. The departments were then left alone, for the most part, to allocate this fund in any way they saw fit. Each department sought to guarantee larger shares of the future budget by concentrating on dramatic new weapons.[8] By 1961 a general trend was underway to reorient reporting systems around basic missions and systems cost. The new system had two primary

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[8] *Ibid*.

aims: first, to permit analysis of total mission cost in light of national objectives; second, to protect and plan resource impact of proposed force structures over an extended period of time.[9] It was initially felt that such an ambitious program would take many years to implement effectively within the bureaucratic structure of the Department of Defense, but McNamara ordered its initiation with the 1963 fiscal year budget.[10] In order to accomplish this task the following five items were needed:[11]

1. Establishment of a program structure in terms of missions, forces, and weapons systems.

2. An analytical comparison of alternatives.

3. A continually updated five-year force structure and financial program.

4. Coordinated year-round decision making on new programs and changes.

5. Progress reporting to test the validity and administration of the plan.

In theory, the operation of the Department of Defense follows this pattern for all major decisions, although one might still question the validity of the resulting decisions. As a final link in this decision framework, the Cost/Schedule Control Systems Criteria is envisioned as supplying valid,

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[9] Ibid., p. 87.

[10] Ibid., p. 89.

[11] Ibid.

timely, and auditable data to the military data bank. At present the full implementation of this system has not been achieved due to contractor opposition.

Early experience with the Programming Planning and Budgeting system led the Assistant Secretary of Defense to seek a technique to evaluate the necessary parameters so that accurate and timely weapons systems decisions could be made. Military agencies had traditionally structured the necessary reporting requirements to fit each specific effort with the result that contractors coordinated their own management control system outputs, making the required prorations and allocations, then submitted the report to the responsible agency. It was found that reports generated in this manner were ineffective for the following major reasons:

1. Reporting base was different within the contractor's organization from that which the agencies needed for systems decisions.

2. Judgment factors made the resulting reports biased in favor of the optimistic contractor.

3. The time cycle for report generation was often excessive for proper control.

4. Proliferation of reporting formats and elements required and stressed by the various agencies did not allow contractors to establish a consistent working information system from one contract to the next.

5. Lack of specific definition often gave data which were not comparable from one time period to the next.

6. Estimates of work to complete were often in gross error.

By the mid-sixties the general state of events described above was widely recognized within the Department of Defense. In 1965, Robert Anthony, Department of Defense Comptroller, undertook the development of a system which would establish overall defense department requirements with regard to data. This system was to be primarily oriented towards selected, high-cost development systems because the greatest immediate cost savings were felt to be offered in this segment of the procurement cycle. In December, 1965, a policy guidance statement regarding establishment of this system was issued. The system was titled, "Selected Acquisitions Information and Management System," but better known as the acronym, SAIMS. This approach was to provide the conceptual framework for all government management control systems to be issued in subsequent time periods. The operational part of SAIMS was to become the Cost/Schedule Control Systems Criteria issued in the summer of 1966.[12] The evolution of government management control systems is directly linked to the evolution of SAIMS; thus, a more complete discussion of this system is necessary

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[12] Letter sent to Hon. Barry J. Shillito, Assistant Secretary of Defense, July 1, 1969, from the Council of Defense and Space Industries Associations, p. 6.

so that its relationship to the Cost/Schedule Control Systems Criteria can be understood.

Evolution of the Selected Acquisitions Information and Management System

The basic intent of the SAIMS approach is to obtain information related to the development of selected weapons directly through the contractor's "accounting" system. The major purpose of this system was to define, integrate, and standardize the task to be performed, while improving interparty communication and eliminating much of the confusion which results from effusive data.[13] With this approach, agency administrators have essentially the same data available to contractor management without the need for redundant reporting systems that prevailed in the mid-sixties. Through a set of guidelines, to be discussed later, contractors were envisioned as being able to structure their individual information systems so as to provide auditable and traceable data from internal basic records.

Four alternative criteria were established for inclusion in the SAIMS approach to a contractor:[14] (1) $25 million in research and development, (2) $100 million commitment in production, (3) high price uncertainty of the venture, and (4) special attention projects. Major weapons systems are

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[13] Office of the Secretary of Defense, Selected Acquisitions Information and Management System (Washington, D.C., 1968), p. 7.

[14] Ibid., p. 12.

defined by the first two items above. Also, as indicated by the latter two items, other programs which the procuring agency feels important can be included. The basic control variables in the SAIMS approach are cost, schedule, and technical performance. The justification for the earlier discussion of these variables now becomes evident. The second element of SAIMS is Economic Information Reports which are designed to assist the Department of Defense in measuring the impact of military procurement programs on industries and geographic areas. A third element of SAIMS is the requirement to generate reports of various contract cost categories. These reports consist of the following:

> 1. Contract cost data summary--identifies contract cost by Work Breakdown Structure on a recurring and not-recurring basis, plus estimates to completion (reference DD form 1558).
> 2. Functional cost-hour report--a semi-annual report sorted by basic functional categories such as engineering, quality control, manufacturing, etc. (reference DD form 1559-1).
> 3. Progress curve report--this report may be required quarterly and indicates learning curve type data for major items (reference DD form 1558-3).
> 4. Fiscal year summary--this report is the same format as the contract cost summary above, except data are submitted by fiscal years. This report may also be used for new or proposed programs (reference DD form 1558-3).
> 5. Fiscal year functional cost-hour report--this report is similar in format to the functional cost-hour report above, except data are categorized by fiscal year (reference DD form 1558-5).[15]

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[15] *Ibid.*, p. 21.

The three elements of the SAIMS approach thus include an orderly generation of significant data. The key to successful implementation of a system as described here is directly linked to the establishment of a valid performance measurement system within the contractor organization. It is this key element which is being explored in this paper. Figure 18, which follows, illustrates and summarizes the SAIMS framework as described above.

Department of Defense Resource Management Framework

By early 1966 there was an apparent merging of the systems development concepts and philosophy within the Department of Defense. Department of Defense Instruction 7000.1, titled "Resource Management Systems," was issued on August 22, 1966. In this document, an overall department management framework was envisioned with the Programming and Budgeting System described earlier constituting the basic planning component and a broad scale Assets Management System providing overall control capability for operations, inventory, and acquisitions. At this point a contractor reporting system began to play a vital role in the overall management scheme of the Department of Defense.

A reporting system would still function as a contract cost data generation mechanism, but, in addition, required basic inputs to the department's Asset Management System as well as to the Programming and Budgeting System. Figure 19

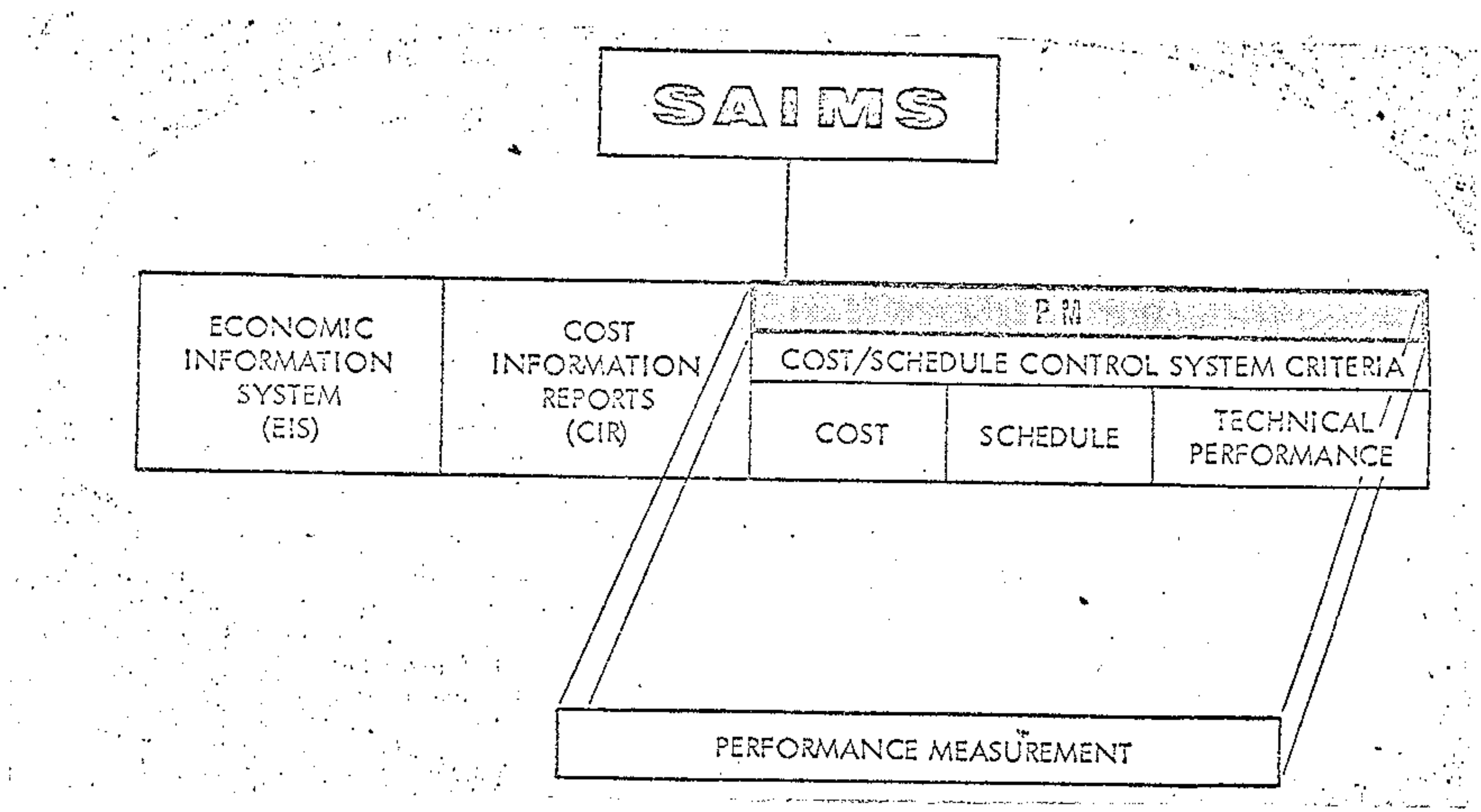

Fig. 17--Selected Acquisition Information Management System (Source: Office of the Secretary of Defense, <u>Selected Acquisitions Information and Management System</u> (Washington, D.C., 1968), p. 22).

interrelates the Performance Measurement, or Cost/Schedule Control System, to the overall government planning and control framework. It is stressed here that none of the indicated peripheral systems and related objectives can be fully completed until a Performance Measurement System is implemented. The investment in hardware, software, and training would seem to imply that the government fully intends to carry through implementation of its various system components, especially the implementation of a Performance Measurement System operating at the contractor level.

Reviewing the evolution of the Department of Defense Resource Management System, one notes that the basic concept apparently originated with a report prepared by David Novick of the Rand Corporation in 1954; however, it was not until the early sixties that the combination of improved information technology and political pressures caused such a system to be developed in practice.[16] It should also be emphasized that the drafting of a department-wide plan for data submission does not suffice for true implementation. Contractors have shown positive signs of rejecting this idea due to apparent imposition on classical management prerogatives, in addition to other reasons which are more difficult to categorize. Implementation of the Performance Measurement

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[16] Novick, Program Budgeting, p. 86.

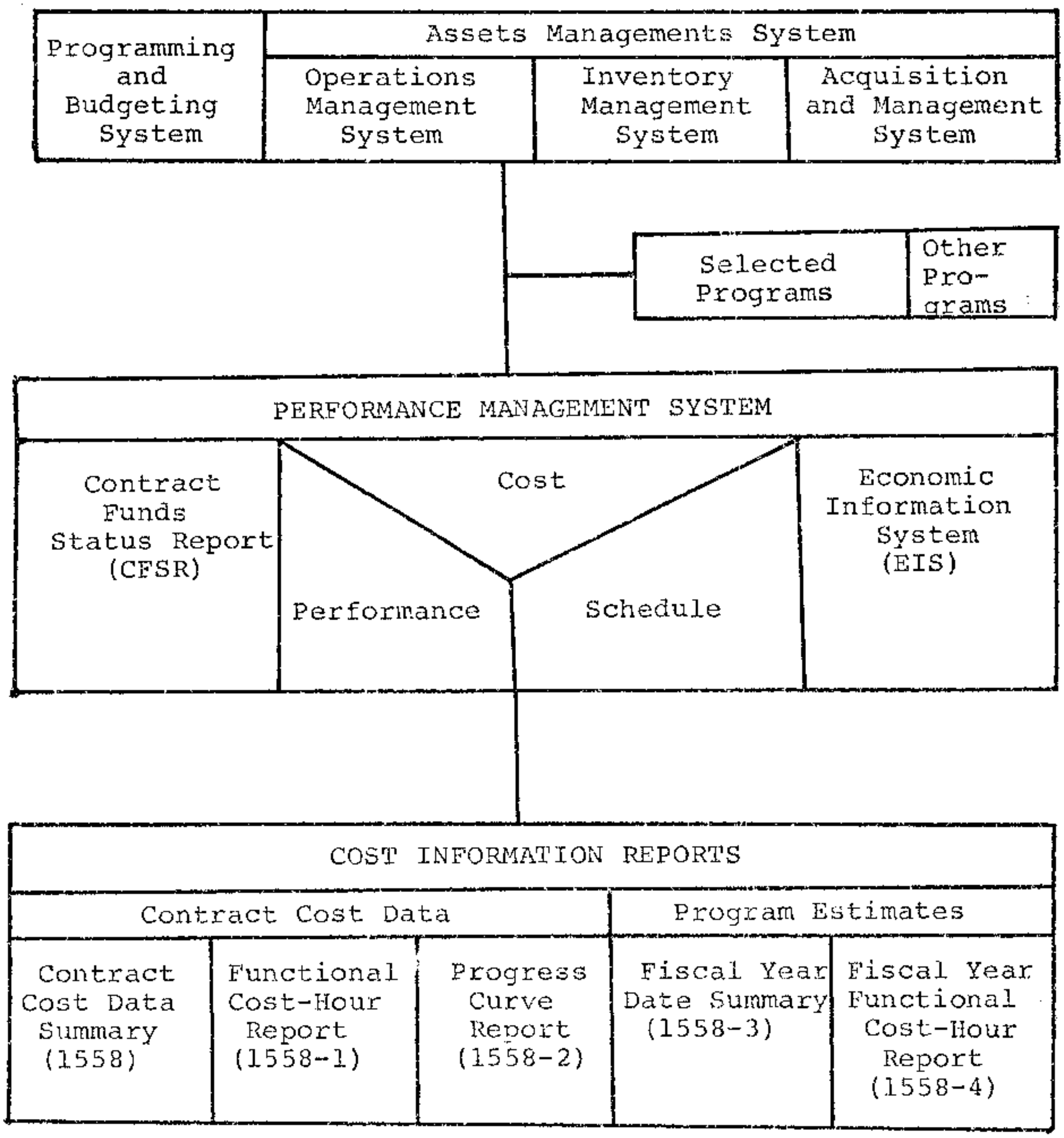

Fig. 19--Performance measurement as a part of the resource management system. (See Charles W. Kullman, "Resource Management Depends Upon Reliable Reports," *Defense Industry Bulletin*, IV (January, 1968), 26-31.)

System is currently being attempted in a much more complex way than past reporting requirements have been. The basic document was originally issued in 1966 as a relatively broad criteria in contrast to the more traditional rigid specification approach used on past requirements. To assist in evolving a workable document, an interindustry group was chartered in November, 1966 for two years, after which time a final approved document was to be ready for implementation throughout the acquisition network. This committee, titled "Council of Defense and Space Industry Associations," was headed by a government chairman and consisted of both industry and government personnel. Although much of this committee's time was spent in developing a Resource Management System, the basic charge was to

> . . . attempt to find ways of reducing the number, complexity, duplication, and hence cost, of management control systems that defense project managers and procurement agencies employ for planning, controlling, and getting information about work that contractors do for the Department of Defense.[17]

Within this charter the committee was and is now attempting to create a constrained list of applicable control systems which may be used by the various agencies, but if chosen, must be used in some specified standard way. From the second quarter of 1968 through the third quarter of 1970, an authorized list is scheduled to be made of applicable control

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[17] DoD-CODSIA Advisory Committee for Management Systems Control, Fund Report, Volume 1--Summary (Washington, D.C., 1968), p. 1.

systems, and the necessary corresponding revision of military standards will be accomplished soon after this period. A potential future impact of this work could be the widespread application of sophisticated control systems such that contractors would, for the first time, be expected to provide and maintain data systems to such requirements. It has been suggested that those contractors who do not have suitable systems may not be acceptable as vendors in the future.

As mentioned previously, the new approach to contractor requirements is advertised as being a flexible criteria, rather than the traditional requirement and procedure orientation. This implies that the contractor is challenged to find his most efficient way of providing data to fit established requirements, while taking into account the idiosyncracies found within individual organizations. The current problem in establishing a universal management control system is (1) to decide where the vagueness of criteria approaches is tolerable to the overall system and, (2) to determine under what circumstances the specificity of the regulation approach becomes intolerable to the individual contractor. Thus far this balance does not appear to have been found. The committee reported to the government recently that there was a serious question in many contractors' minds as to whether their individual systems were acceptable.[18] Thus far,

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[18]Letter to George W. Berquist, Deputy Assistant Secretary of Defense, from CODSIA, dated August 14, 1968.

answers to specific questions have been incomplete and contractors are holding up on new systems implementation awaiting final word from authoritative government sources. Regardless of the final implementation decision, there is little doubt that the Cost/Schedule Control Systems Criteria is having significant influence on the style and format of management control systems being designed and implemented throughout the military procurement industries. To this point, the Cost/Schedule Control Systems Criteria has been discussed in very broad terms. The next section describes the historical evolution of the specification and notes its planning and control usefulness in the weapons system environment.

Evolution of the Cost/Schedule Control Systems Criteria

The evolution of the Cost/Schedule Control Systems Criteria will be traced from two points of view. First, a historical recording of the basic industry techniques relating to the Criteria itself will be outlined. Second, the conceptual background for the Criteria will be traced and some explanation will be made to show why this method was chosen to structure future management planning and control systems. This Criteria represents a logical evolutionary trend of classical and contemporary management tools, not a revolutionary concept as many managers in industry seem to think.

In historical perspective there were three direct predecessor techniques from which the Cost/Schedule Control Systems Criteria evolved. These can be summarized as follows: (1) PERT Time--1957, (2) PERT Cost--1962, and (3) Cost/Schedule Planning and Control System (USAF)--1966. Each of these techniques evolved from the earlier one, which in turn resulted from more classicial notions.

The 1962 PERT/Cost Model extended the network management model to include time, cost, and manpower resource requirements for a large project, plus the option of resource allocation by optimization techniques.[19] Actually the PERT/Cost technique is still being used on some large system contracts, but interviews within the aerospace and electronics industries indicate that this requirement is being fulfilled as a redundant system outside the contractor's actual operating control model. A second problem category existing in this required system was that it was often not compatible with planning and control systems prevalent within the contractor's organization. In theory, PERT/Cost provides the manager or decision maker with data of unprecedented validity and speed. However, the technique has been found lacking in numerous areas. Peter Schoderbek, a recognized authority in network management applications, summarizes the challenge of PERT/Cost as follows:

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[19] Russell D. Archibald and Richard L. Villoria, Network-Based Management Systems (New York, 1968), p. 120.

1. Many companies do not have adequate ability in cost analysis to provide a proper control framework.
2. A lack of historical information in making project cost estimates makes future control less effective.
3. There is difficulty in making project costs compatible with organization fiscal practices.
4. Budgets generated by this technique are often taken as operating budgets without realizing the uncertain nature of the estimates.[20]

For these and a multitude of related reasons the early history of PERT/Cost is difficult to evaluate objectively. Poor data often led to poor decisions, or excess data generation often discouraged use of model capabilities. At any rate, an improvement in overall system management did occur in conjunction with the development of improved systems planning and control models such as PERT/Cost. Through this period many applications of networking were found and the basic concepts became well ingrained in the aerospace and electronics industries.

On July 29, 1966, an advance copy of a requirement known as a Cost/Schedule Planning and Control System (C/SPCS), Air Force Systems Command Manual 70-5, was issued to Air Force contractors. The major purpose of the document was to define an operating, planning, and control system which was able to insure meeting systems objectives with minimum resource

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[20]Peter P. Schoderbek, Management Systems (New York, 1968), pp. 396-403.

expenditures.[21] This document was the first attempt at issuing broad systems specifications which contractors must satisfy. Concurrent with the Air Force system introduction, both the Army and Navy issued similar documents to their respective contractors. The Army system was titled "Contractor Cost and Schedule Control System Criteria (CCSCSC)," while the navy system became known as "Cost Schedule and Technical Control System (CSTCS)." All of these documents became a part of the individual service management systems and, in time, began to develop their own unique characteristics. Contractor shortcomings were evident in most areas of weapons acquisition soon after the introduction of these requirements. Of the first sixteen Air Force contractors evaluated, using the Cost/Schedule Planning and Control Specifications, only two were approved.[22] It was not long before contractor criticism rose to such a level that full scale implementation was delayed pending an authoritative statement from the Department of Defense. By late 1969 the Army had shown little intention of implementing their system on a service-wide basis, while the actual Navy implementation moderated some of the initial requirements such as technical tracking. Only the Air Force still seems strongly oriented

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[21] C/SPCS, The Specification Approach to Performance Measurement, prepared by Director of Cost Analysis, Headquarters Air Force Systems Command, May, 1968, pp. 3-6.

[22] Harold C. Teubner, "USAF Management Specification Challenges Industry," Armed Forces Management (March, 1969), pp. 40-44.

towards full scale implementation of the system, as they have been assigned the responsibility for implementing the eventual department criteria.

From a historical point of view it has now been shown how the criteria evolved from earlier requirements and how each service has established its own philosophy with regard to degree of implementation. Contractor attitudes during this early period were anything but positive, as management felt that government was taking away the traditional right of management to control resource expenditures. The government, on the other hand, had valid cause for concern due to the increasing recognition of time and cost overruns, plus deficiencies in desired performance. Since July 29, 1966, conflict among the various contracting parties has precipitated a further redefinition of intent of the criteria in the procurement environment.

A part of the evolution noted in the development of the Cost/Schedule Systems Criteria is that related to academic disciplines. At least four major disciplines are represented in this document, although others are implicit in its operation. Direct conceptual links can be found in economics, industrial engineering, general engineering, and management. First, the criteria is economic-rooted due to its relationship with the Programming and Budgeting System, and the resource trade-off theory. Second, the design of network management techniques can be traced to an industrial engineering tool, Gantt charts, which were invented by Henry Gantt around 1900. Third, various other subcategories of engineering are indigenous to the development task itself, as well as computer technology, which is so much a part of the operating system operation. Fourth, management has contributed greatly in the development of this criteria through the search for better planning and control tools to be used on large and complex projects. Also, it is the force of strong management which must establish the necessary reporting and motivation so that the system may accomplish its original intent. Actually it is fallacious to isolate four disciplines for discussion, as the system is much broader than this. The operation of the system cuts across all functional lines of the enterprise during data collection and monitoring activities. Implementation of the system described in the criteria implies a computer oriented, multi-faceted, and sophisticated information network which is beyond the existing capabilities of most firms in operation today. In summary, the information system which is required to comply with the criteria represents a multi-disciplinary approach to information technology and will significantly push existing frontiers in contractor capability if successfully implemented.

The network approach was chosen as the most appropriate universal planning and control system available. Actually there are several reasons behind the selection of this approach as the base of a universal planning and control system. Certainly previous industry experience with the concept had a favorable influence on its selection. Also the desire to manage the weapons system rather than just an individual organization led to the network concept with its innate ability to view the overall project and interrelationships therein. The basic objective of this information system was provision for a consistent and timely data base from which program progress could be observed and evaluated. With the technology and contractor experience available it was felt that a PERT/Cost oriented system would best provide the fundamental framework for the new criteria. In an attempt to broaden traditional PERT applications, a third variable, technical performance, was included in the early draft. Successful implementations of this system would mean that contractors must operate a dynamic planning and control system capable of reporting actual time, cost, and performance status versus preplanned objectives.

The development of the Cost/Schedule Control Systems Criteria is currently in a dynamic state. The government seems to be finding the cost of implementation high, if not excessive, in some cases. Contractors on the other hand, fearful of not meeting customer requirements, have expended large sums of money in system design and development to promote a more progressive image. Unfortunately, specific examples of accurate and isolated development costs are extremely difficult to collect. Regardless, the criteria concept has stimulated the imagination of government agencies and frightened many contractors who view such devices as an invasion of managerial privacy. Actual implementation of the Cost/Schedule Control System is thought to be of secondary importance to this analysis. More significant is the pressure placed on contractors to improve operating management systems and techniques. This impact will probably outlast the Criteria itself.

Evolution of Management Control Systems Technology Within the Firm

The discussion in this chapter thus far has treated the evolution of government control systems independently; that is, as not related to or having a real impact on contractors' management information control systems. Such, of course, is not the case since the Cost/Schedule Control Systems Criteria specifies that government data *must* be obtained *within* the operating framework of the contractor's management information network. In this respect, C/SCSC is also unique. For this reason, it is, therefore, necessary to examine the existing control systems techology within the aerospace and electronics industries.

This section will show that the Criteria significantly strains the ability of most contractors. Indeed, none of the large aerospace contractors have yet been able to pass the validation test associated with this Criteria, although at least two are now in the process of being examined.

The development of management information and control systems within the aerospace and electronics industries has been rapid in relation to other commercially-oriented industries. This trend has probably been stimulated by government procurement practices, such as cost-plus financing and associated reporting requirements. The installation of third generation computers around 1966 seems to have stimulated broad increases in the application of automated information and control systems. In a recent interview the Grumman Corporation provided information relating to evolution of their "resource planning and control systems."[23] Table XI summarizes this large aerospace company's evolution of management information systems during the period 1958 to the present.

The systems evolution outlined in Table XI is generally compatible with the systems technology and implementation schedules of the other large aerospace companies. Two trends are significant in evaluating the systems evolution. First, there has been a tremendous proliferation of corporate subsystems since the mid-sixties, each with a unique set of operating criteria. Second, trends observed in at least half of the large aerospace companies indicate major effort being expended to tie various subsystems together in order to provide an integrated planning and control capability

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[23] Walter Wood, Grumman Corporation, interview, September 23, 1969.

TABLE XI

EVOLUTION OF AUTOMATED RESOURCE MANAGEMENT SYSTEMS AT GRUMMAN AEROSPACE CORPORATION

Year	System Title
1958	Fabrication tracking
1961	Spare parts ordering and tracking Min-max. inventory notices Master parts request file PERT networks for A-6 and E-2A
1963	Master inventory
1964	Tool design tracking Invitation to quote Automated purchase orders
1965	Production stock room control Configuration control and traceability
1966	Engineering drawing release Wire lists Real time receiving Machine shop scheduling and loading
1967	Shipping Maintenance (preventive) Manufacturing operations sheets Engineering master file
1968	Tool inventory Production data flow Economic order quantity Automated parts list Receiving inspection Seller evaluation Major assembly tracking Detailed parts tracking
1969	Integrated planning and control system (validation of criteria oriented)

without excessive interface. Efforts of this type were specifically noted at Boeing, North American-Rockwell, McDonnell-Douglas, and Grumman. In addition, almost all of these companies could be characterized as having progressive programs of management systems development. Much of this effort is stimulated by government pressures to design sophisticated planning and control information systems.

J. F. Brandejs of the University of Saskatchewan explains the current state of management information systems development as network-based and using "3.5 generation computers."[24] He states further that there is a "myth" concerning the existence of real-time management systems which will be stifled by the lack of creative educators and managers. Real-time management systems are still developmental. The programs require extraordinary imagination and familiarity with computer capability. The ordinary educator and manager lack the technological background necessary to meet the challenge of developing real-time systems. These statements certainly seem to summarize the existing state of management information systems in the aerospace and electronics industries. Management information systems over the near term appear to be moving toward more practical applications, increased complexity, improved presentation of output

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[24]Letter from Dr. J. F. Brandejs, Assistant Professor at the University of Saskatchewan, Saskatoon, Canada, October 3, 1969.

and significant problems of data privacy.[25] An operating Cost/Schedule Control System should present a similar array of problems to the contractor.

Implementation of management systems has often proven to be a much more difficult job than management originally planned. The system axioms of accuracy, completeness, timeliness, and simplicity frequently create significant problems for the systems designer. Input rigor and lack of ability to recall relevant data often turn theoretically useful systems into obsolete piles of machinery. One of the electronics industry firms, included in the case study, reported spending over $100,000 on the design and implementation of a relatively simple assembly tracking system only to find that lack of worker input discipline invalidated the potential system value.[26] The last two years have been spent attempting to motivate workers to provide relevant input data, but as of this writing, little progress had been made in restructuring the traditional thinking of most programmers. In essence, an attempt is being made to emphasize that the design and operation of successful management information systems requires more than improved hardware and qualified systems designers. Management motivation and worker input discipline seem to be equally significant variables in this

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[25] Ibid.

[26] Texas Instruments, case study research, August, 1968.

problem. Enlightened operation of a well-designed system, rather than its complexity *per se*, accounts for its value. Thus, within its many organizations the basic problem of management systems development becomes one of hardware operating capabilities outstripping managerial ability.[27]

Another factor which may cause some concern for contractor management, were implementation to be forced on it, is the problem of start-up costs. In an attempt to explore implementation problems, the question of systems development cost was asked on the questionnaire survey and pursued in the various interviews. Attempts to answer this question accurately were hampered by many factors. First, several of the large companies were expending large sums of money on a general upgrading of corporate planning and control systems. This meant that much of the cost reflected here could not be attributed entirely to the Criteria itself. The result of this quandry was often a cost estimation with explanatory comments. Second, exposure to the Criteria and plans for development of management information systems were quite varied within even the larger companies of the industry. Third, although some companies had done a great deal of work

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[27]The comment was made repeatedly on both questionnaire and interview sampling that upper management really did not want sophisticated systems such as the type being analyzed in this paper. Unfortunately the research methodology was not sufficient to evaluate this statement, but the comment was made too often to be attributed to dissatisfied staff employees.

in the area of interest, they felt that cost data of this type was proprietary and refused comment. In spite of these problems, information was obtained from seven of eight large system contractors. A summary is presented in Table XII. Although there is marked diversity of the findings shown in Table XII, the relative order of magnitude should be some measure of the financial impact of this system. It should be re-emphasized that the dollar expenditures noted in the table do not include the actual implementation cycle; therefore, the eventual cost will probably be greatly increased over that indicated. A sizeable portion of the ultimate cost will come in training expenses which will be incurred at various functional and corporate branches. Company E has relatively high implementation costs due to its early association with the Air Force version of this Criteria, plus an ambitious internal systems development program. It was noted that there is a direct relationship of implementation cost with new large system contracts which would lead one to conclude that implementation figures will increase as new systems contracts are granted to other large contractors.[28]

It was mentioned earlier that many contractors are now attempting to tie various subsystems together in order to accomplish integrated planning and control. A definite interrelationship of key systems seems to be necessary before

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[28] These data supplied by Mr. A (anonymity requested), April, 1969.

TABLE XII

ESTIMATES OF IMPLEMENTING THE COST/SCHEDULE CONTROL SYSTEMS CRITERIA IN LARGE AEROSPACE COMPANIES[a]

Company	Approx. Period	Estimated Amount
A	67-68	$ 450,000[b]
B	68	$ 35,000[c]
C		N.A.
D	66-68	$ 475,000
E	66-68	$20,000,000[d]
F	67-69	$ 1,500,000[e]
G	68-69	$ 1,000,000
H	67-68	$ 100,000[c]

[a]Data synthesized from questionnaire survey, and personal interviews within respective companies. All companies requested anonymity in reporting data. McDonnell and Douglas corporations reported separately.

[b]Includes only one division of a large company. Data on other divisions not available.

[c]Questionnaire response indicated a high level of expenditures to implement desirable internal control systems which would also function as compatible government reporting devices. The amount indicated is thus only one identifiable portion of the total expenditure.

[d]This figure quite probably reflects the total corporate expenditure for management control systems. An interview source stated that the "true" Criteria implementation costs were in the $1-2 million range.

[e]Total corporate expenditures for implementation of management control systems during the period 1967-1969 was $15-22 million.

a contractor can hope to validate his overall management system. By making manual entries from one system to another, the proper data could be generated, but for a large weapons system this would not appear practical. A schematic of this hypothetical system is shown in Figure 20.

The Work Breakdown Structure concept seems to be the device which is most often used to provide common identification nomenclature to the various systems and, eventually, to the operating Cost/Schedule Control Systems Criteria. It should be noted that each of the systems identified in this framework is hardware oriented, yet much of the labor resource expenditure takes place in a non-hardware environment. The planning and control of research and development efforts will be accomplished primarily through the operation of the accounting system in conjunction with the Work Breakdown Structure.

In operation the Criteria requires that the user establish budgets for fixed increments of work, establish time schedules for completion, and measure output versus the original plan. However, from the operating systems viewpoint, two factors seem to impede achievement of such goals. First, the planning discipline required to adequately define work increments and establish cost budgets is apparently lacking in many companies. Second, tracking systems which measure actual status of work performed have not proved adequate to satisfy the reporting accuracy demanded in the

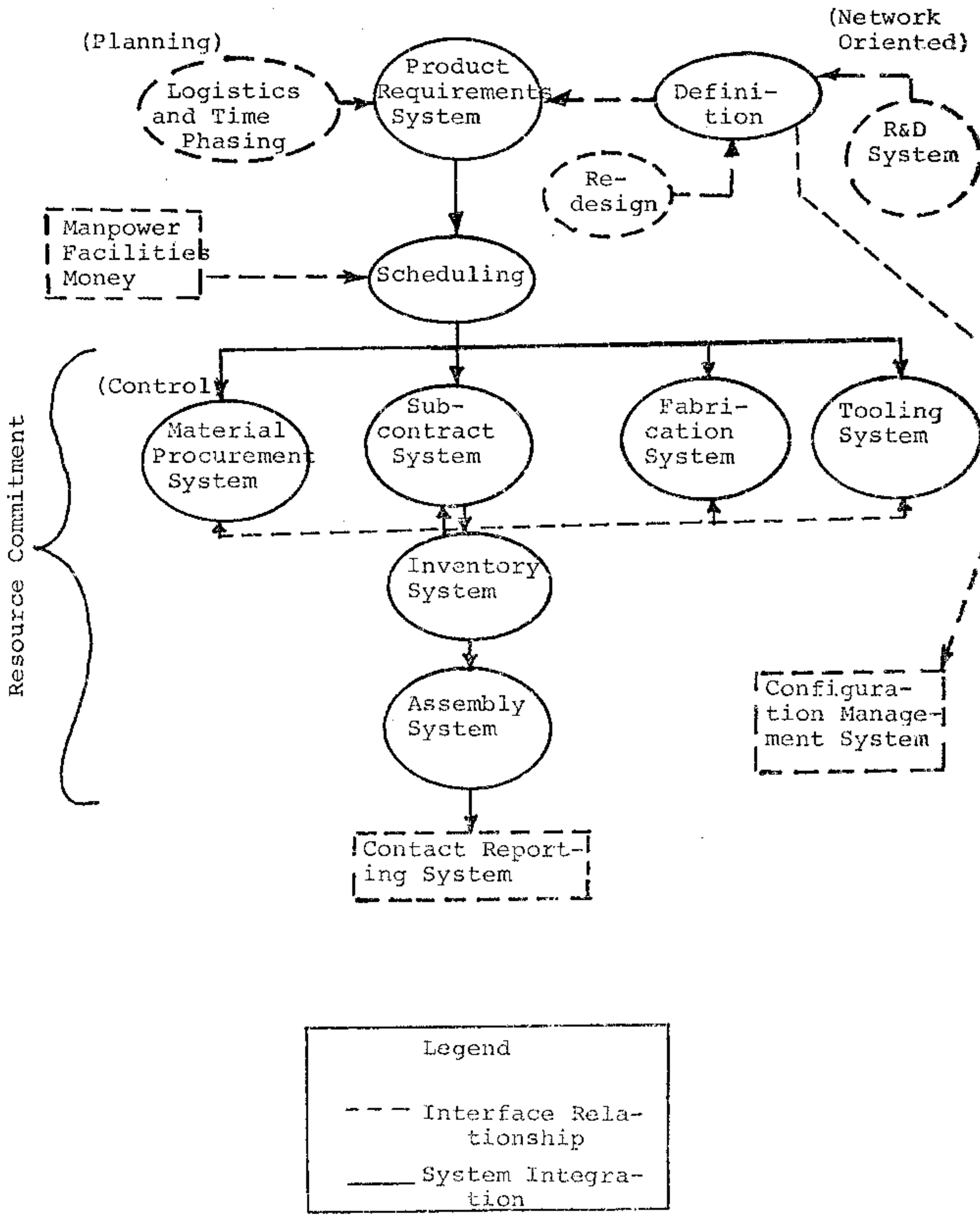

Fig. 20--Theoretical management information systems design using C/SCSC.

Criteria. For these two reasons most of the contractors who will eventually come under aspects of the Criteria now must expend resources in finding ways to bridge these gaps in their internal systems operation. The basic problem seems to be more a deficiency of input discipline than of procedural theory. The immediate solution to the classic problem of research and development management is elusive as all control system operations depend upon a level of definiteness which is never present in early developmental planning.

Review

In summary, this chapter analyzed the evolutionary cycle of the Criteria. Government control systems were shown to be production-oriented through the fifties, but changing somewhat to a combined production and development orientation by the mid-sixties. The increasing cost of development appears to be the primary stimulant for this transition. Development of network management techniques, such as PERT, in the early sixties provided the theoretical mechanism through which more sophisticated Cost/Schedule Control Systems were to evolve by the mid-sixties. From this base, government-management control techniques were integrated through the Department of Defense Selected Acquisition Information Management System (SAIMS); it was in this broad framework that the Criteria itself was born in 1967. In conjunction with increasing efforts by the government to maintain visibility into contractor operations, significant strides have been made in the development of management information systems within both the aerospace and electronics industries. Current efforts are being made to implement internal systems which will, it is hoped, perform internal control as well as satisfy government data requirements. This is being done through the Work Breakdown Structure (WBS) which is designed to integrate the contractor PERT network with the government SAIMS concepts.

Chapter V will now describe the actual evolution of specific Criteria documents, as well as the basic content of each of these sources. In this discussion, a shift will be made away from the conceptual viewpoint used in the present chapter towards the more mechanistic requirements of the Criteria. A transition from the environmental aspects to an overview of the Criteria will then be complete and the necessary background established whereby the Criteria impact can be analyzed.

CHAPTER V

DESCRIPTION OF THE COST/SCHEDULE CONTROL SYSTEMS CRITERIA

The primary purpose of this chapter will be to review the basic documents which constitute the Department of Defense's efforts to implement the Cost/Schedule Control Systems Criteria. As in the previous chapter, much of the material will be viewed as an evolutionary pattern in that the documents will be placed in chronological perspective. Also, the time span discussed here is very short and dates cited reflect only formal publication of data. An important secondary objective of this chapter is the discussion of the semantics of certain key terms and essential elements of the Criteria.

First, then, this chapter will present specific documents and relatively well-defined elements. Although an attempt is made to be as specific as possible in describing these documents, the volume of directives allows only a summary of key points. Primary emphasis in the discussion will be given to segments which have been identified as creating significant compliance problems for the contractor. Second, in a concluding section, the initial impact of the

Criteria upon the contractor's method of operation will be explored with the objective of providing a smoother transition into the following chapters. This chapter is therefore a pivotal chapter in the transition from descriptive material to actual contractor impact.

Introduction

One of the major problems in discussing a concept such as the Cost/Schedule Control Systems Criteria is the rapidly changing list of acronyms and titles assigned to describe its varying characteristics. The first order of business here will be to establish one name which will be used to indicate the total accumulation of documents pertaining to this concept. For simplicity, then, the word "Criteria" used from this point on will indicate the broad set of documents constituting all attempts made by the Department of Defense and its counterparts to define and implement cost, schedule, and technical performance management systems within their contractors' organizations, the subcontractors' organizations, and the subcontractor network. The analysis of this activity is the major objective of this paper. Discussed previously were the key variables in the design and development of major weapons systems. The Criteria approach uses the variables cost, time, and technical performance as control parameters through which performance of the contractor is to be reported and evaluated. An attempt should now be made by the reader to recall the earlier discussions of resource trade-off and related economic discussion as the Criteria documentation is outlined.

Comparisons of planned versus actual data indicate that the control philosophy implicit in the Criteria is classical in origin. From an operational viewpoint, the control process is considered to be only as effective as the planning data input. Such an approach must be questioned due to the uncertainty prevailing in much of the development task. As an auditing tool this system will serve to report actual resource expenditures versus planned values so that accurate comparisons may be made. Although the Criteria itself does not include a reporting requirement, it certainly establishes a concrete data base from which subsequent reporting specifications will evolve in conjunction with the overall Department of Defense Resource Management System.

Evolution of Cost/Schedule Control Systems Criteria Documentation

Seven separate documents constitute the current state of the Department of Defense documentation efforts. Collectively, these documents constitute the Criteria. Each of the source documents described below approaches the concept of planning and control systems either from the viewpoint of the overall department, or from that of the Air Force. It appears that the department plan will stress implementation first in the Air Force, then attempt to broaden the working criteria to procurement activities within all service branches. In response to this objective almost all of the formal Criteria documentation issued thus far stems either from the Department of Defense in the form of a general instruction, or from the Air Force as a more narrowly defined document. With these thoughts in mind, the following documents are discussed as constituting the formal definition of the Criteria. The basic intent and objectives of each of the documents will be described in the following seven subsections and illustrated in Table XIII.

AFSCM 70-5.--This early document, issued by the Air Force Systems Command, was the original attempt at structuring contractors' internal planning and control systems. Under this requirement the contractor was obligated to furnish to the Air Force reports derived from a unified structure operating within the contractor's own internal planning and control system. The establishment of formal Work Breakdown Structures, firm budgets for negotiated work, formalized accounting procedures and scheduling techniques, as well as defining a new set of reporting parameters, is designed to provide the customer increased "visibility" into the development operation. It should be noted that this early document essentially avoided the problem of technical performance reporting and focused primarily on the cost and schedule

TABLE XIII

BASIC SOURCE DOCUMENTS

Document	Name	Date
AFSCM 70-5	Cost/Schedule Planning and Control System	July 29, 1966
DODI 7000.2	Performance Measurement for Selected Acquisitions	December 22, 1967
DODD 5010.20	Work Breakdown for Defense Material Items	July 31, 1968
Mil-Std-881	Work Breakdown Structures for Defense Material Items	November 1, 1968
DODI 7000.2 (revised)	Performance Measurement for Selected Acquisitions	January, 1969
Mil-Std-XXX*	System Engineering Management for Defense Material Items	February 3, 1969
AFR 375-7	Performance Measurement for Selected Acquisitions	June 27, 1969
AFSCP-173-3	Cost/Schedule Control Systems Criteria (Implementation Guide)	July 7, 1969

*Will be issued as Mil-Std-499 (USAF) as indicated in a letter from George W. Berquist, Deputy Assistant Secretary of Defense, dated October 23, 1969.

variables.[1] Contractors using this requirement who were surveyed seemed to view it as a requirement to implement, fundamentally, a PERT/Cost System. Thus, many of the larger contractors set about fulfilling WBS requirements with a PERT/Cost approach.

[1]This is the consensus of many persons interviewed within the aerospace industry, not necessarily the intent of the issuing agency.

AFSCM 70-5 is not only prescriptive in that contractors must attempt to implement its regulations, but it also introduces the system evaluation concept whereby the customer validates the contractor management system three months after contract award. In the three and one-half years since this document was first issued much has evolved in both concept and experience. Some of the original ideas have proven to be quite acceptable and desirable, while others have been shown to be unfeasible. Segments of this document were subsequently revised and then issued under new titles. Certainly one major effect of this gyration has been to leave the contractor in a state of limbo concerning the adequacy of his internal management system. Actual success of this document is questionable, although its value in testing the early concept was very likely quite valuable to the Department of Defense as a conceptual sounding board. Many contractors after attempting to implement the requirements found them to be excessively rigorous and costly. Using the feedback generated during the evaluation cycle, efforts have since been expended in search of a more universally acceptable approach. Each of the documents described below represent the fruits of this effort.

DODI 7000.2.--This document will be most remembered of all the Criteria sources since it represents the first formal attempt by the Department of Defense to implement a department-wide system which would fit into the broader Resource

Management System. In this source the subject system was identified as the Cost/Schedule Control Systems Criteria, or better known by the abbreviation C/SCSC. Just as in all of the documents related to the criteria, contractor application was keyed to so-called "selected acquisitions" which were defined in the previous chapter. Much of the descriptive material from this source was very similar to that in the Air Force version above, but generally speaking, the requirements outlined here were less rigorous since they were to apply to a much larger population of contractors. Five specific operational areas of the contractor system were isolated for criteria statements as to "systems engineering" ability. These areas can be summarized as follows:

1. Organizing--this section outlines some of the definitive tasks necessary for the contractor to perform. Basically, the requirement states that all work must be defined by a formal Work Breakdown Structure and necessary resources identified.

2. Planning and Budgeting--this section broadly outlines requirements to plan, set output objectives, maintain firm budgets, identify management reserves, and establish formal overhead accounting documents.

3. Accounting--this first Criteria document for the broad segments of the Department of Defense set only very general requirements for cost reporting. Reporting rationale and traceability were stressed in this section.

4. Reporting--five key report-type criteria are outlined in this section. These elements are summarized below.

a. Report applied direct costs for work performed and the budgeted costs for the same work.

b. Indicate actual indirect costs and budgeted indirect costs.

c. Show budgeted costs for work performed and budgeted costs for work scheduled.

d. Note significant variances in each of the categories listed above in terms of labor, material, overhead, or any other significant element.

e. Identify, monthly or more often at the discretion of the contractor, differences between planned and actual parameters of schedule and technical performance.

f. Identify managerial actions that are being taken as a result of deviations observed above.

5. Revising--continual reevaluation of authorized or replanning changes on technical performance, schedule, and cost provisions of the contract. Develop estimates of cost at completion and funds requirements based on latest contractual developments.

In essence, the Criteria approach summarized here impinges upon all functional areas of the contractor's organization. Primary emphasis is noted in the requirement for formalized documentation and planning of work to be performed, plus resultant revisions to the contractual scope of this work. From an implementation point of view, the various services have used their own individual interpretations of this Criteria, but all of the subsequent development efforts have placed formal requirements in the five areas outlined above.[2]

This document was ultimately revised and reissued in January of 1969. Basically, the new document consisted of the same content as its predecessor, but many terms were more clearly defined. Also attempts were made to make basic requirements even more general in nature than in the earlier version. For purposes here, both of these sources will be considered identical in concept.

DODD 5010.20.--The basic purpose of this document was to formally establish Work Breakdown Structure formats for seven categories of defense items: aircraft, missiles, space systems, surface vehicles, electronics, and ordnance. Given a particular type of defense item, reporting or management categories were established which would be controlled throughout the total acquisition process. Since the major thrust of this paper is concerned with aerospace contracts, the present discussion will focus on that area.

The Work Breakdown Structure for aircraft systems first divides the total task into ten major subcategories. Items

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[2]Letter, George W. Berquist, Deputy Assistant Secretary of Defense, October 23, 1969.

which were chosen for cost and reporting categories are as follows: (1) airframe, (2) peculiar support equipment, (3) common support equipment, (4) systems test and evaluation, (5) system/project management, (6) training, (7) data, (8) operational/site activation, (9) industrial facilities, and (10) spares and repair parts. The observant reader will notice that this breakdown represents actual reporting of life cycle cost for the item. Beyond the level illustrated above there is a third level of the structure which is more specifically defined for control purposes and problem analysis by the procuring agency. A representative example of structure elements of level three for the aircraft segment is airframe, power plant, and communications. Subordinate functions of the standardized structure shall be maintained by the contractor and used in the following six basic areas:

1. Project management,
2. Establishment of management control systems,
3. Provision of framework for configuration management,
4. Creation of framework for Resource Management System reporting,
5. Logistic planning will be keyed to framework,
6. Programming and budgeting will be performed for all elements of the structure.

In essence this document became the broad conceptual framework upon which the subsequent Military Standard 881 would evolve. Issuance of this document was little more than formal recognition of a concept which was conceived during the early days of PERT, around 1959, and became an integral part of the early Criteria documentation.

Mil-Std-881.--This document seems to represent a formal splintering of the original concept in that early Air Force attempts to implement the Criteria used the Work Breakdown Structure as an essential element of the overall system upon which basic operating validity would depend. After more complex documents ran into contractor opposition, the Department of Defense seemed determined to push actively forward some of the more acceptable concepts of the Criteria. The most universally acceptable concept was that of dividing work up into manageable packages which were structured in such a way that valuable information for planning and control could be extracted. This formalized Military Standard is thus viewed as a first step in the long-range goal of full Criteria implementation, but also represents an acceptable or usable package to be used for smaller programs which did not fall into the "selected acquisition" category. The Work Breakdown Structure thus was designed to provide a consistent and viable framework to facilitate

> a. A more effective management and technical base for planning and assigning management and technical responsibilities by operations within those governmental offices responsible for the acquisition of defense material items and among those contractors furnishing the items.

b. More consistent control over and reporting of the progress and status of engineering and other contractor efforts, resource allocations, cost estimates, expenditures, and procurement actions throughout the development and production of defense material items.[3]

In concept, this document is quite similar to other documents which had been in use within the defense industry since the early sixties. In fact, it represents a standard regimented approach to data collection and management control throughout the weapons system or, as the document is written, life cycle. Not only does the document fit integrally into the Criteria concept, but also focuses attention on cost reporting for systems analysis within the Department of Defense. From a long-range viewpoint this document will probably make a greater operational impact on the contractor's way of doing business than any other single source document. Rationale for this statement is based on the idea that once the data are collected in some standard format, the other requirements represented by the total Criteria become somewhat mechanical. The Department of Defense's logic for introducing this concept first in sequence was to implement slowly a key element of the Criteria into the contractor's internal logic system. Thereafter, introduction of the mechanical requirements would be more readily palatable.

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[3] Mil-Std-881, p. iii.

Mil-Std-XXX[4].--This document has had such a brief history that no experience with implementation is available for illustration. Several subtle changes appear to be contained within this source which distinguish it from earlier sources. First, procuring agencies have the formal authority to select and choose parts of the specification for application to given contracts. This represents added flexibility over almost all of the previous military oriented specifications. Second, and much less well defined, is the problem of managing the allocation variables of time, cost, and technical performance. Time and cost appear to have been combined into one definitive category titled "Cost/Schedule Performance Measurement (C/SPM)," while technical performance is separated into a second definitive category titled "Technical Performance Measurement (TPM)." It appears that this division alleviated one of the larger existing implementation problems of previous techniques, that being the necessity of managing cost, time, and technical performance with equal rigor through the development cycle. Such a division thus allows varying emphasis to be placed on each of the two categories, or essentially neglected if the procuring agency so desires.

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[4]This document will eventually be issued in revised form after Air Force evaluation as Mil-Std-499 (USAF) according to a letter from George W. Berquist, Deputy Assistant Secretary of Defense, dated October 23, 1969. The ultimate product is hoped to be a department-wide systems engineering approach to acquisition management.

A third change from previous systems is the emphasis on integrated systems. Evidence of this trend is reflected in statements regarding such factors as

1. Identification of System elements in accordance with Mil-Std-881 (described above),

2. Configuration control items identified within the overall plan,

3. Performance systems effectiveness studies to ascertain such facts as life cycle costs of various proposals and reliability,

4. Consistency of decision making throughout the Work Breakdown Structure,

5. Traceability of changes throughout the Work Breakdown Structure,

6. Visibility of technical progress and timely reporting of problem areas.

In addition to the traits described above, the contractor must submit a system engineering management plan (SEMP) which sets forth his proposed efforts for the conduct of the contract. During performance of the contract, this plan will be used for surveillance of the contractor to affirm the extent to which program objectives are being accomplished. It is further stated that engineering decisions made during this process shall be optimized, taking into consideration the resource and schedule constraints, plus the incentives stipulated in the contract. Cost estimates will be established for these decisions in view of the overall life cycle cost. Optimization is further defined as the exclusion of undue engineering sophistication for any single element. Certainly these objectives represent conceptual and technical advances over existing patterns noted in the typical acquisition cycle.

Each of the points discussed in relation to this document appears to indicate that the government is continually expanding its requirements into increasingly broader terms which, in theory, approach total system integration, yet in operation this approach leaves sufficient flexibility so that procuring agencies are not forced to accept the total package constraints. Once again the Criteria concept is invoked here, although many will argue that some of the requirements approach such strict definition that the document assumes the characteristics of a traditional specification. Requirements for validation are believed to be spelled out in DODI 7000.2, but firm confirmation of this must await issuance of the final draft. So far as complexity is concerned, this source document attempts to define the entire environmental structure. This suggests that future versions will have to either become more specific, or omit some of the more controversial issues such as configuration control. Whatever may be the case, military contractors are looking at a systems engineering document of this type as the key to future requirements.

AFR 375.7.--This regulation represents the Air Force's attempt to begin full scale implementation of a performance measurement system for "selected acquisitions." Two points are pertinent to this summary. First, this document is merely a continuation or service implementation of Mil-Std-XXX described above; therefore, the essential elements are identical. Second, as indicated above, the history of this document is so short that little more than a content description can be made at this time. Future impact of such a document appears to be linked to Air Force procurement objectives and philosophies of the various user contractors and government procurement agencies. George W. Berquist recently reported in a letter pertaining to this research effort that the Air Force was being chosen to attempt actual implementation of the Criteria first.[5] Once the problems were resolved within this contractor sphere, then Mil-Std-XXX would be appropriately revised and issued for application throughout the various services. In this assignment the Air Force has been charged with the task of finding a workable performance measurement technique. It appears that sufficient progress has been made through the government-industry council that specific points have been issued for use as

[5] Letter from George W. Berquist, October 23, 1969.

validation checklists. The validation aspect of the regulation will be discussed in the following subsection.

In comparison with most government documents, AFR 375-7 is very brief, being only seven pages in length. Items covered are congruent with the original Criteria document, DODI 7000.2, previously issued by the Department of Defense and discussed earlier. The actual impact of this document will be felt by the contractor through the validation requirement outlined in section four of the source and more specifically defined in the Implementation Guide, AFSCP 173-3. So far as the contractor is concerned, it will be difficult to separate AFR 375-7 from any of the source documents described in this section, plus several others which are peripheral to the Criteria.

Words used to describe Criteria objectives are

> . . . efficient and effective management of cost, schedule, and technical performance. The system will produce valid, auditable, and timely performance data that can be summarized for use by each successive level of management and by the Government.[6]

This short quoted statement from the regulation seems to be consistently voiced throughout the spectrum of systems management documents now being issued by the various agencies involved in military procurement. It may be questionable just how much of this philosophy the contractors are taking

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[6]Performance Measurement for Selected Acquisitions, AFR 375-7, pp. 1-5.

seriously, but there seems little doubt that the Criteria concept is becoming well ingrained within the military segments of the acquisition picture.

AFSCP 173-3.--This document is the Implementation Guide for the Cost/Schedule Control Systems Criteria as contained in AFR 375-7. There are four major objectives stated as the purpose of AFSCP 173-3:

1. Explain and amplify AFR 375-7, "Performance Measurement for Selected Acquisitions."

2. Assist Air Force managers who must assess the acceptability of contractors' systems in response to C/SCSC requirements.

3. Assist contractors who must understand and respond to C/SCSC.

4. Avoid duplication of contractor internal systems for government reporting requirements.

Chapter two of this source document outlines the various standard procedures for application of the Criteria. Once a contract is identified for surveillance by the criteria, then it is considered incumbent upon the contractor to submit a proposal for his desired system which will meet the outlined requirements of the Criteria. Chapter three of AFSCP 173-3 outlines the demonstration procedure for the criteria. Such elements as team composition, report formats and contractor responsibilities are specified.

Chapter four, "Guidance for Evaluation and Demonstration Reviews," is actually the requirements portion of the Criteria as it exists currently. In this section specific checklists and tests of compliance are outlined for the various parts of the Criteria. The validation requirements are considered vitally important for full understanding of the Criteria; therefore, they have been inserted in total as Appendix D of this paper. Basically, the chapter describes the implementation process as a two-step operation, first evaluation and then demonstration. The evaluation process is merely an appraisal of the overall systems design which has been submitted by the contractor in response to a contractual proposal. Demonstration, on the other hand, involves a detailed on-site examination of the contractor's operating systems. During both of these phases, system documentation becomes a necessary condition for approval. The following four steps are required:

1. Responsibilities of operating personnel
2. Limitations on action
3. Internal authorization required
4. Step-by-step instructions.[7]

To avoid duplicating previous descriptions, let it suffice to say that the implementation summary evaluates five basic operating areas of the contractor's organization:

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[7] Cost/Schedule Control Systems Criteria (Implementation Guide), AFSCP 173-3, pp. 4-3 to 4-10.

organization, planning and budgeting, accounting, analysis, and revisions. These same five areas were discussed in some detail under the DODI 7000.2 document section above. Certainly at this juncture it is not difficult to see the integrated philosophical scheme of the entire set of documents being discussed here. Various contractors are now in the process of being validated using this guide, or other similar documents issued by their respective procurement agency. This aspect of the Criteria was explored in the questionnaire survey performed in conjunction with this paper and will be discussed at some length in the next chapter so that the reader can focus his attention on certain key problem areas associated with the Criteria and its implementation. The information contained in Appendix D and the summary section of source documents will be helpful for analyzing some of these individual problems.

Chapter five of AFSCP 173-3 briefly discusses the basic problem of surveillance. In essence, surveillance is considered to be a Department of Defense responsibility which will be carried out at each contractor facility where performance measurement requirements are in effect. This simply means that once validated, a contractor must carefully maintain the operational integrity of his internal control systems, lest he be faced with additional costs of demonstration. Chapter six outlines the potential existence of data requirements associated with the Criteria. Although the

Criteria itself does not specify data requirements or formats, the contractor should expect to supply some sort of data in association with the performance of the contract. These data, regardless of format, must be derived from the contractor's internal system, using the Criteria as a guide for data collection and content.

In summary, the Implementation Guide represents the most concrete contractor guidance of all primary source documents. It would certainly seem that the intention of the Air Force and the Department of Defense is to push full scale implementation of the Criteria-oriented system, as described by this set of documents. As problems become better defined, it is quite possible that there will be additional conceptual changes in the Criteria documentation, but certain points seem to be well established in the literature and there are positive signs of these becoming part of most contractor internal control systems. Indication of this consistency was mentioned throughout the discussion of the various documents, but it will be the primary purpose of the next section to demonstrate the calculation and application of various "essential elements of the criteria." Successful accomplishment of this task, linked to a basic understanding of the spectrum of various source documents discussed here, will allow the reader some appreciation of the Criteria scope and its eventual impact on the contractor's way of doing business within the military sphere. Each of the larger contractors in the aerospace and electronics industries seems quite aware of this Criteria and the resource expenditure required, but little outward recognition has been made of the broad impact that such a requirement will have on the total acquisition cycle consisting of major procurement agencies, large prime contractors and the vast network of subcontractors.

A very difficult to describe change from previous systems is the increasing emphasis on integrated systems. Physical indications of this trend are reflected by statements regarding such factors as

1. Identification of system elements in accordance with Mil-Std-881 (described above),

2. Congruence of configuration items within the overall plan,

3. Performance of systems effectiveness studies to ascertain such facts as life cycle costs of various proposals, reliability, etc.,

4. Assurance of consistency of decision making throughout the Work Breakdown Structure,

5. Traceability of changes throughout the Work Breakdown Structure, and

6. Visibility of technical progress and timely reporting of problem areas.

In addition to the requirements described above, the contractor must submit a systems engineering plan which attempts to define parameters regarding the achievement of cost, schedule, and performance objectives. The increase in emphasis reflected here appears to be oriented towards a more balanced management of the cost, schedule and performance variables.

Essential Elements of the Criteria

The central theme of the Criteria is an attempted integration of time, cost, and performance parameters. Prerequisite to integration are two essential concepts, earned value and Work Breakdown Structure relationships. This section wil discuss these two parameters both in theory and application, since accurate understanding of each is necessary before looking at the contractor's potential problem areas. None of the existing government documents adequately demonstrate the concept of technical tracking; therefore, implementation examples relating to this subject will be illustrated later as a contractor innovation. Primary variable emphasis here, then, will be on cost and schedule parameters.

Earned Value

The earned value technique provides the means for an integrated measurement of cost and schedule performance against plan. This approach differs from more classical techniques in that it compares performance by combining cost and time into a common framework. In the Criteria application, the common framework is, of course, a Work Breakdown Structure as will be discussed in a later section. A relatively abstract example of earned value will be given simply to establish a starting point for the remainder of this discussion. The following example has been chosen to illustrate this point:

Assume that the scheduled production rate of an item is one unit per month and the established budget for this item is $10 per unit. At the end of six months, five units have been completed at a cost of $55.

Classical performance measurement would state that the program is $5 under plan and one month behind schedule. This approach is adequate for simple programs, but hopelessly inadequate for complex weapons system development programs. Using the same data the earned value approach can be illustrated as follows, using the variables defined below:

(ACWA) Actual Cost of Work Accomplished = Reported costs

(PVWA) Planned Value of Work Accomplished = units completed times budgeted cost per unit

(PVWS) Planned Value of Work Scheduled = units scheduled times budgeted cost per unit

then; ACWA = $55

PVWA = $50

PVWS = $60.

Using the variables above, cost and schedule variances can be defined as

Cost Variance = PVWA - ACWA = 50 - 55 = (5)

Schedule Variance = PVWA - PVWS = 50 - 60 = (10)

Since both variances are negative, the program is not only behind schedule, but spending money at a faster rate than expected. It is this integrative analysis capability that makes the earned value concept so useful for planning and evaluation purposes.

In actual application these variables often become quite difficult to calculate due to the scale and complex nature of the development process. As a broad rule, potential problem categories can be divided into one of the three following areas:

1. Time-phasing of resources in conjunction with overall program schedules such that variances truly indicate potential problems.

2. Established budgeting for each element of the total task.

3. Measurement of task accomplishment, or discrete portions of task accomplishment. Alternatively, each package can be of such length so as to be negligible when compared with the entire program. Under this approach work package accomplishment can be measured simply as affirmative or negative.

At this point it is difficult to comment on which of the above areas constitutes the greatest problem source, but each of the earned value parameters represents a challenge for the implementing contractor.

Work Breakdown Structure

The Work Breakdown Structure is defined in Military Standard 881 as

> . . . a product oriented family tree composed of hardware, software, services, and other work tasks which result from project engineering efforts during the development and production of a defense materiel item, and which completely defines the project/program. A work breakdown structure displays and defines and the product(s) to be developed or produced and relates the elements of work to be accomplished to each other and to the end product.

When viewed as a total entity, the work breakdown structure bridges government specified elements, the contractor's internal extension of the structure, and potential extensions into various subcontractor organizations. This structure is illustrated in Figure 21. The lower levels of the contractor's extended Work Breakdown Structure are further divided into work packages which are normally associated by specific operational sheets or work orders.[8] As a general rule, all work packages will be organizationally oriented, then have established budgets which cover the duration of the work package. Thus, the work package concept is the link between the Work Breakdown Structure and the earned value concept. Vertical continuity through the Work Breakdown

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[8]"C/SPCS, The Specification Approach to Performance Measurement," p. 22.

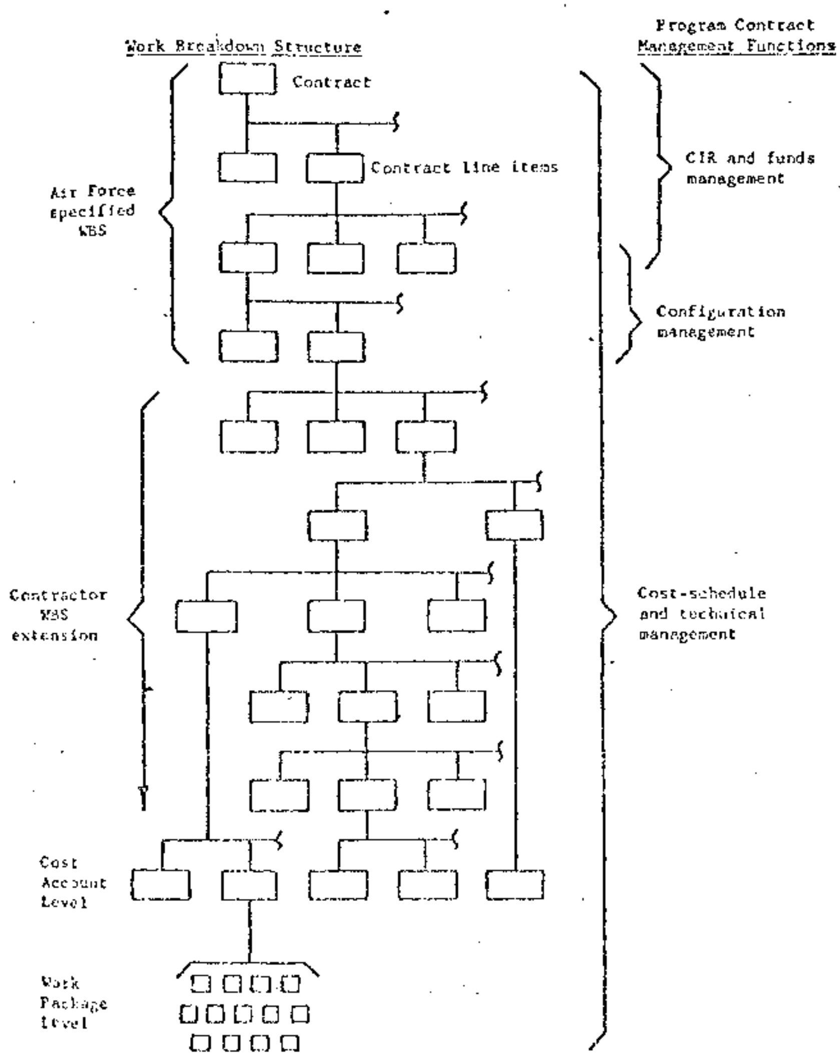

Fig. 21--Work Breakdown Structure (Source: C/SPCS, _The Specification Approach to Performance Measurement_, p.22).

structure is achieved by the integration of work packages through cost accounts and on up to higher reporting elements. Given the degree of uncertainty present in most development programs, it is often necessary to establish work package planning by the "rolling wave" approach. In effect, this involves continual downward evolution of the Work Breakdown Structure as the program becomes progressively better defined. The Criteria requires the following three objectives be met by the structure:

> 1. All authorized work must be defined and identified.
> 2. The structure must extend to the level at which cost accounts and work packages are established.
> 3. The contractor's ultimate extension of the structure must reflect the way work is actually being performed.[9]

If these requirements are met, it is then possible to use the earned value approach as defined earlier to evaluate cost and schedule performance of the contract.

Integration of Earned Value with the Work Breakdown Structure

An attempt will now be made to give an elementary application of the earned value concept for more realistic program parameters. Table XIV illustrates the basic format for a development work package plan, given only a few milestone, or major, work elements. It should be noted that budget

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[9] *Ibid.*

TABLE XIV

DEVELOPMENT WORK PACKAGE PLAN
(000'S DOLLARS)

Work Package No.	Title	Budget	1 2 3 4 5 6 7
1	Design Reviews	$ 100	SXXXXXXXXXC*
2	Release Drawings	500	SXXXXXXXX
3	Material Lists	20	SXXXX
4	Mechanical Drawings	70	SXXXXXX
5	Test Specifications	30	XXX
6	Assembly Drawings	400	XXXXXXX
7	Support Manufacturing	50	XXXXXXXXX
	Total	$1,170	Report Date

*S = work package effort started; C = work package effort complete.

relationships must be established for each work package, then distributed over the proper time frame. Two assumptions seem quite implicit in this technique, yet each may be open for considerable debate in actual practice. First, cost expenditures are assumed linear over the chosen time frame, although this assumption would certainly not fit all cases in practice. Second, it is assumed that accomplishment can be measured, or reasonably estimated, for all incomplete work packages. Also, technical progress through the work package life cycle is assumed linear in the calculation of planned value of work accomplished (PVWA). Both of these assumptions would be limiting factors were the size of any one work package a significant portion of the overall project. Most military documents recommend that the size and span of a single work package be less than $100,000 and eight weeks. Within this constraint, the limiting factors described above generally become negligible.

The challenge to the operating manager in the Criteria approach is to find meaningful control parameters upon which to monitor time, cost, and schedule performance. If the proper parameters are defined and integrated into the system, problem identification becomes a relatively mechanical task for the operating system. In Table XV two major points are pertinent to this discussion. First, the overall status calculations are demonstrated and, second, isolation of the specific problem element is achieved. Calculation of the

TABLE XV

DEVELOPMENT WORK PACKAGE STATUS REPORT

Work Package No.	(B) Planned Accomp. (%)	(C) Actual Accomp. (%)	(D) ACWA* ($)	(E) PVWA** (A) (B) ($)	(F) PVWS*** (A) (B) ($)	(G) Cost. Var. (E)-(D) ($)	(H) Sch. Var. (E)-(F) ($)
1	100	100	120	100	100	(20)	0
2	75	50	460	250	375	(210)	(125)
3	100	50	10	10	20	0	(10)
4	100	80	50	56	70	6	(14)
5	100	0	0	0	30	0	(30)
6	20	0	0	0	80	0	(80)
7	0	0	0	0	0	0	0

*ACWA = Actual cost of work accomplished.

**PVWA = Planned value of work accomplished.

***PVWS = Planned value of work schedule.

Quantitative estimates for completion: Cost = ACWA/PVWA X Budget = 640/416 X 1170 = $1,540. Schedule = PVWS/PVWA X Budget = 675/416 X 7 = 11.4 months.

various earned value statistics follows the definition previously given and is sufficiently labeled in the example for the reader to follow. It should be noted that both the cost and schedule variances, columns G and H respectively of Table XV, indicate negative totals. As in the earlier example, this reveals the project to be spending more money than planned for the average work package and, further, the overall program is running significantly behind schedule. The most likely source of this problem can often be identified by closer examination of work package variances. In this example, the large cost and time overruns of work package two, release drawings, are identified as the key contributor to overall program shortcomings. Further problem identification must be made by use of basic Work Breakdown Structure documents and a network management plan which indicates the interrelationships between various work packages. For instance, it is possible that problems in work package two may be created by severe problems in some other pacing element which would be identified by the systems engineering plan. Many companies often use supplementary reports to indicate critical problem areas. These reports can be simply qualitative evaluations, or more sophisticated probabilistically based evaluations of program performance. One particular technique being stressed by many military procurement agencies is that of the milestone chart. A milestone chart outlines a sequential list of various tasks to be completed in the program and their corresponding time schedules.[10] In this manner a check can be made on certain key control points throughout the program life cycle. Regardless of the method actually used, it becomes a significant challenge for the average contractor to structure his information collection and planning systems to meet all of the requirements of the Criteria and still remain reasonable in cost. Other definition and implementation problems will be discussed briefly in the following paragraphs.

Miscellaneous Elements

Several miscellaneous terms and concepts are important to a fuller understanding of the Criteria approach. It will be the purpose of this section to discuss some of the more critical periphery requirements associated with this technique. The rationale for each of the parameters discussed is primarily to maintain the integrity of the resulting earned value calculations. Also, many of the requirements focus attention on key elements throughout the development cycle.

Work Breakdown Structure reporting nomenclature.--In order to establish a reconciliation trail, certain reporting requirements have been established for work packages. Three major categories of performance and budget reporting have

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[10] Archibald and Villoria, p. 11.

been established: direct resource expenditure, apportioned effort from other sources, and level of effort charges which occur regardless of output. Additionally, section 3.1e of the validation checklist outlines the requirements for cost collection on a recurring or nonrecurring basis. This second category applies primarily to direct and apportioned efforts; thus there are essentially five ways in which costs have to be collected. This scheme is illustrated in Figure 21. In many instances, the cost evaluation techniques described above are foreign to the contractor's operating system. This would appear to indicate that improved reporting discipline will be necessary in order to collect cost and budget data on this basis. Discussions with Air Force validation team members indicate that effort will be made to constrict use of the apportioned category. In addition, most of the managers surveyed during interviews expressed apprehension regarding their ability to structure budget data in the manner described here. One of the most frequent comments made regarding this phase of the Criteria was that it would significantly hamper a manager's ability to manipulate cost data within a work package as had been the previously accepted practice in many firms. In essence, it seems that future managerial practices will require an evaluation to be made of five potential types of resource commitment as illustrated in Figure 21. Not only will performance

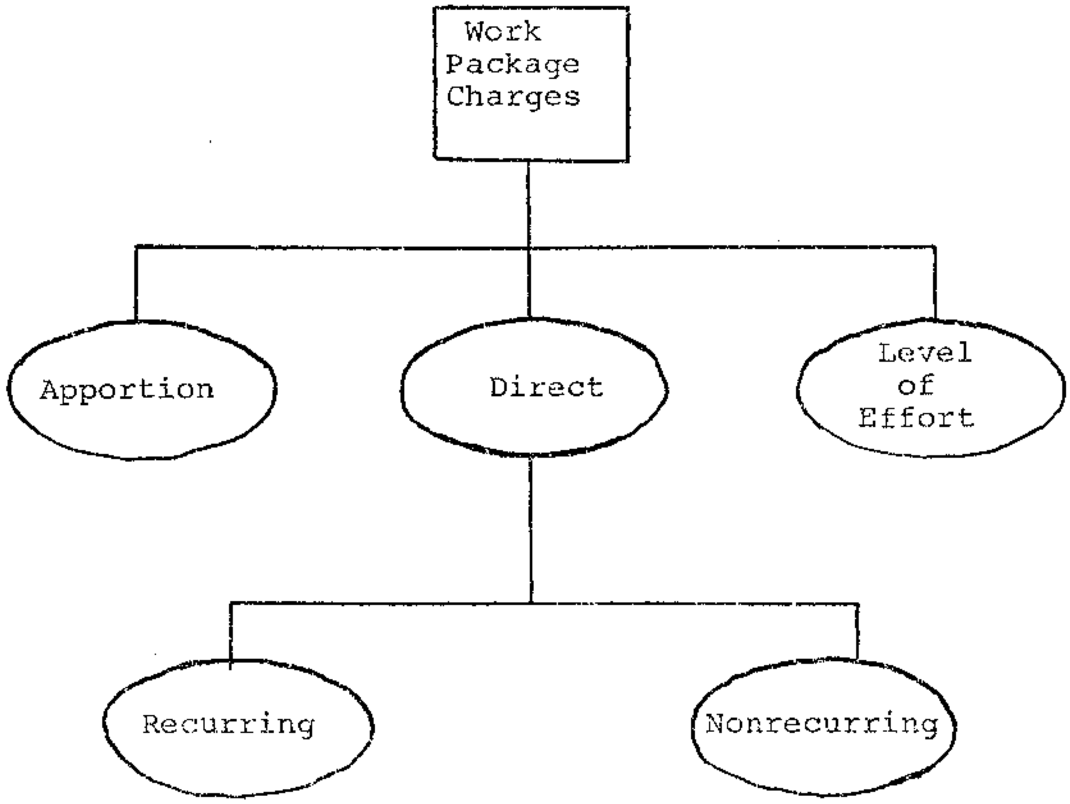

Fig. 21--Work package cost categories (Source: Military Standard 881).

comparison be possible by work package, but also by each of these categories.

Rigid baseline.--This element arose due to past problems with "rubber budgets," or budgets which changed with time and often reflected little more than a contractor's whim. Cost overrun calculations could previously be expressed in a multitude of ways with whatever bias suited the situation. Classical cost problems have often arisen over such questions as whether the cost quoted reflects amortized development cost, whether the cost reflects training, and so forth. One of the basic objectives of a modern planning and control document is the establishment of well defined objectives and maintenance of these throughout the product life cycle. Unfortunately this task is nearly impossible to accomplish in real world development programs due in large part to changing desires of the customer, or to lack of original definition. For these basic reasons, the customer is forced to make contractual changes after the original document has been agreed upon. It was noted earlier that the government as a customer apparently is becoming more conscious of this problem and is placing greater pressure upon contractors to specifically define a system and then to hold to its development on a nearly fixed price contractual relationship. As this objective is achieved, the concept of a rigid budget baseline will tend to operate in fact as it is presumed to in theory.

In operation there are several significant ramifications to the fixed budget concept. From the reporting viewpoint, cost overruns will be almost impossible to conceal from the procuring agency, Congress, or the reading public. This objective will probably focus continuing emphasis on weapons systems cost performance. Within the contractor organization, however, the benefits are less certain. First, it is possible that operating budgets will reflect and emphasize original budgets which may be obsolete for present control and planning purposes. Second, contractors are forced by this requirement to show whether a reserve exists. Sections

3.8 and 3.9 of the implementation guide outline the requirement for the total budget to equal the sum of all cost accounts plus management reserve accounts. Although not obvious, this set of requirements makes cost increases resulting from design changes much more difficult to justify. The contractor is required to show impact of such changes on the Work Breakdown Structure, which in turn has been shown earlier to have a highly regimented set of cost categories. Padded estimates will be easier to spot and cost account manipulation will be more difficult.

Basically, the ultimate result of a fixed budget application will be an increased pressure on the contractor to accurately forecast work package costs and generally spend additional initial planning time establishing an overall systems engineering plan. There is already strong evidence, manifested in such contracts as the C-5A aircraft at Lockheed, that the government is becoming a more prudent buyer. No longer can the contractual relationship with the customer be viewed as governmental benevolence.

Configuration management.--Since 1964 the control of complex weapons systems configuration has been the object of great interest in the Air Force as well as in the other service branches. Although the operating mechanism of this process generally falls outside the cost and schedule control system, technical performance systems must interface closely with the configuration control process. The Work Breakdown Structure provides, once again, the common denominator upon which configuration elements are identified and monitored. Certain items are identified in the structure for inclusion into the configuration management system. In 1964 the Logistics Management Institute reported that engineering change proposals accounted for 20 per cent of the typical weapons system cost appreciation during development.[11] In the pre-production stage, configuration items are only those specification items that are referenced directly in a contract.[12] A configuration element is thus identified for technical performance monitoring as well as configuration management control.

Material accounting.--Implementation of the Criteria may cause considerable problems in the area of material accounting. Traditional systems generally charged material expenditures on an as-committed basis. The Criteria specifies that the contractor's system record resource expenditures only when they are actually incurred, or can be uniquely identified with a specific serialized item. Some of the larger aerospace contractors view this requirement

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[11] Edward J. Engoron and Albert L. Jackson, "Configuration Management," Defense Industry Bulletin, IV (April, 1968), 22.

[12] Military Standard 881 (Washington, D.C., 1968), p. 3.

as a necessity for improved work in process control systems. Actually, the requirement as stated involves an accrual accounting approach for all of the resource categories such as labor and overhead. It happens that most production and design oriented enterprises already use such a system, thus the impact of the requirement is primarily in the area of material accountability.

In summary, this section introduced selected items of nomenclature, or concepts, which were felt necessary for an improved understanding of the Criteria requirements. Work Breakdown Structure nomenclature, rigid baseline budgets, configuration management, and material accounting requirements have been illustrated briefly above. At this point the reader should be aware that the broad objectives of the Criteria are to instill a planning and control discipline into contractors' management systems, thereby providing the mechanism for obtaining accurate performance measurement information regarding the progress of the weapons system acquisition program. This process has been characterized throughout this paper as a highly uncertain and costly investment requiring scarce resources. Moreover, the acquisition activity is becoming increasingly expensive in development cost where many of the activities are not amenable to exact forecasting and industrial engineering approaches to work measurement. The Criteria approach has been conceived in this environment and is now entering a critical period of implementation in many contractor organizations.

Implementation of the Criteria

Before reviewing the statistical results of the research study, it is useful to describe how a contractor validates his management control system and to suggest a few of the more sophisticated approaches taken by contractors to meet Criteria requirements. This section is transitional between strict description of the Criteria itself and the operating problems of the contractor. In practice it was found that there was no fine line of distinction between these two points. The material relegated to this last subsection is categorized as being broad in nature, similar to the Criteria, yet relatively narrow in application. In other words, much of the material discussed here represents an interface between the theory of the Criteria and the implementation attempts of the contractor.

The validation process.--Since an attempt has been made by the government to create a specification which is general enough to allow contractor individualism, the validation process becomes a quite critical part of the overall system. Under present guidelines the total validation cycle requires approximately nine months to complete.[13] In addition to

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[13] Teubner, p. 44.

this, recent extensions to the Truth in Negotiations Act place added burden on the contractor by requiring that the prime contractor vouch for the validity of data submitted by each of his subcontractors. It would seem that this would require subsequent validation cycles throughout the subcontractor network. During this validation period, the contractor must expend a great deal of effort in documenting and demonstrating his existing planning and control system. Formal presentation of the proposed system must undergo a four-step process in accomplishing accreditation: evaluation, demonstration, on-site demonstration review report, and systems surveillance.

The evaluation cycle generally occurs when a contractor is being considered for a selected acquisition contract. Part of the formal proposal information includes documentation as to management and control systems capabilities. In the current environment this portion of the proposal response weighs heavily in future source selection decisions. Therefore, the contractor must keep in mind the final performance evaluation. The system evaluation process is basically an examination of the contractor's ability to control the complex task of managing a weapons system development program. Once this preliminary effort is complete, the validation process moves into an on-site demonstration review. The checklist, presented in Appendix D of this report, illustrates the depth required in this sycle. Actual testing, auditing and performance evaluation of the contractor's system normally requires from two weeks to six weeks depending upon particular circumstances.[14] Not only is the contractor required to have a system which accomplishes the intent of the Criteria, but it is necessary to have current written documentation available which describes his internal control system. In theory, the demonstration team goes into the contractor organization, reviews the system documentation for compliance, then uses actual documents generated internally to evaluate the system's congruence with the Criteria. The contractor must be able to transpose data from his internal operating system to the government data system. Also, the Work Breakdown Structure must be used internally to budget, define, and measure work as it is actually being performed. If these two basic requirements are not being met, the contractor will not pass the initial portion of the review.

After the contractor has satisfied the demonstration team of his system control philosophy, the Criteria validation process proceeds to a demonstration review report made by the team. In this document the team outlines specific areas of deficiency and recommends acceptance or rejection of the system as it was examined. Approximately thirty days after this point the contractor is shown the review document

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[14] Ibid., p. 44.

and a "fix-it" conference is scheduled for resolution of the indicated problem areas. Assuming these differences can be resolved, the system is then approved to operate in its demonstrated configuration. During the contractual life cycle, surveillance of the system will be maintained by the local government representative in order to insure that the system has not been changed without prior approval. In this general fashion the contractor's management system can be validated at the discretion of the reviewing agency for all future contracts, selected service contracts, or for only a specific contract. It is the second alternative, selected service contracts, that has been predominant throughout the short history of the Criteria. One major reason, of course, is that the Criteria documents have been in such a state of flux that broader approval has been impossible.

Demonstration results have been anything but smooth for the typical weapons system contractor. Of the first sixteen contractors who attempted to pass the early Air Force version of the Criteria, as of October 1969, only two have successfully cleared all of the hurdles and this was not without changing the original system to correct "discrepancies."[15] More recent attempts at contractor validation offer similar success statistics. Only the Radio Corporation of America, Defense Electronic Products Division, has completed

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[15] *Ibid.*, p. 45.

validation of the department-wide criteria at this writing. Interviews with the Boeing Company and Grumman Aerospace Corporation revealed that these control group members are currently in the demonstration cycle and each felt confident of passing the validation tests, at least under the option of single contract validation. Many companies have expended considerable resources in preparation for this requirement and various innovations have been attempted to accomplish performance measurement as specified by the Criteria. No amount of time and documentation could adequately describe all of these efforts, but a few brief examples will be given later in this section to show the impact which the Criteria is already beginning to have on the industry's way of doing business.

The early power struggle for Criteria interpretation.--Six Criteria elements are frequent reasons for a contractor's system's failing its validation test. These elements may be summarized as follows:[16]

1. Contractor had redundant operating systems, one for internal purposes and the second for government reporting.

2. Often resources were expended beyond the funding limit established through the Work Breakdown Structure.

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[16] This list cannot be credited to any single source; rather it represents a consensus of comments gleaned from many industry and government sources.

3. Periodic changes to schedules and cost estimates made variance analysis of little use.

4. Work packages were too long and task descriptions too general.

5. Contractor's systems lacked overall integrity. In some cases cost and schedule control were non-existent, while others had major deficiencies in certain broad requirement areas of the Criteria.

6. Unspecified but necessary functions must be rigorously controlled in order to fit into the Work Breakdown Structure. Items of work which are authorized but for which a contractual price has not yet been agreed upon, constitute the major portion of this problem.

By 1968, industry elements, consisting primarily of aerospace, electronic, shipbuilding, scientific apparatus, and automobile representatives operating under the umbrella of the Council of Defense and Space Industry Association, began to collect and disseminate information to the Department of Defense regarding the Criteria. Through this mechanism, contractors had a way to voice opinions regarding the Criteria without becoming personally involved in the controversy themselves. As a consequence the implementation and resulting interpretation problems seemed to become a power struggle between the government and its broad collection of suppliers. It is difficult to identify a victor in this battle, but each side appears to have found some measure of satisfaction.

In essence, the subject industries felt that the Criteria regimentation was an infringement upon classical management prerogatives in that it could report small element costs, restrict managers from manipulating resources and generally delve into the contractor's internal workings more than any previous system had attempted to do. On the other hand, a large resource commitment was being brought to bear by the Defense Department in implementing its department-wide resource management system, of which a working system within the contractor organization was an integral part. The industry approach has thus been to influence the Criteria structure rather than simply to fight the concept itself. Political factors and public awareness of cost performance within the defense acquisition environment also added impetus for such a system to evolve.

The industry associations attacked early Criteria documentation by stating that many of the requirements were too vague, too expensive for the resulting benefit, beyond the existing capability of contractors; or pushed for more general statements of Criteria intent and more specific definition of terms. Certainly the efforts of the various industry associations has resulted in a change of the Criteria from what it would have been without resistance. Some of these evolutionary changes have been touched on earlier, but should be briefly mentioned again here to focus attention on the areas affected. The major area noted in which original objectives have been most altered is that of technical performance measurement. None of the government documents discuss this subject sufficiently for a contractor to implement in detail. Generally, this means that the problem is handled by the contractor in a relatively informal way as compared with other Criteria elements. Most industry members feel that the original objectives of time, cost, and technical performance have been essentially restricted to include only time and cost. Meager attempts are now being made to control technical performance through the use of elementary techniques such as milestone charts. Most of the contractors interviewed felt that this method was quite ineffective for the task. A second major Criteria area which has changed somewhat from the original approach has been the reporting detail implicit in the Work Breakdown Structure. It is now generally accepted that data will be reported only through the third level of the structure, which would still give the manager some measure of freedom in carrying out his duties without the customer being so intimately involved.

Summarizing the results of the power struggle hypothesized, it seems as though the government has succeeded in getting its contractors to become increasingly conscious of internal planning and control concepts. This awareness is manifested in large expenditures for management control systems development and the apparent acceptance of the Work Breakdown Structure concept as a valid tool upon which to structure the various configuration and performance measurement systems. Industry, on the other hand, has seemingly dominated in the struggle for a broader interpretation of the Criteria elements and the insistence that technical performance requirements, while reading well, are generally beyond the existing state of the art for most types of weapons system acquisition efforts. Certainly the struggle is not over and other changes will occur as a result of such factors as management technology, political elements, or other broad changes in defense philosophies.

Initial Impact Upon the Contractor's Method of Operation

Due to the unexpected mandates of the Criteria, several forces are currently in motion dictating change in the methods which the contractor uses for planning and control. Although it is premature to catalog the entire impact of the Criteria, three distinct elements have become well enough established to describe here as key changes which were brought on by the Criteria and its surrounding structure. First, and most obvious of the trends, is the acceptance by most contractors of the Work Breakdown Structure concept. Second, contractor innovations in pursuit of an acceptable technical performance measurement system have resulted in significant progress being made towards the solution of this difficult problem area. Third, the structure and format of many contractor and subcontractor internal management information control systems is being shaped by the overall requirements of the Criteria. The logic and rationale for each of these trends will be developed in the following subsections.

Work Breakdown Structure.--Much has already been said in behalf of this technique. Certainly a contractor, mindful of this concept, will have to plan system development tasks much more carefully than was done previously. Examination of some initial subcontractor proposals regarding various subsystems designed for next generation aircraft, such as the F-15, reveals that the Work Breakdown Structure concept now pervades much of the prime and subcontractor network. Contractor jargon is being further expanded to include "work packages" and "rolling wave concepts" which are implicit to the operation of a predesignated structure.

Several operating managers interviewed felt that the actual implementation of the Criteria and its associated system structure would force the lower level manager to take a much harder look at the development task before committing himself to a work package plan with which he must live for the life of the contract. Reframing this into the nomenclature of the Criteria, it seems feasible to say that managers are becoming more conscious of integrating time, cost, and performance parameters with the realization that these will be used for future control purposes. With improving reporting capabilities, some companies are using the Work Breakdown Structure as an external reporting mechanism, as well as the basic tool for internal control. From the government viewpoint, then, this concept seems to add integrity to external data reports and reduce the likelihood of redundant data reporting systems within the contractor's organization. One of the case study companies is attempting to capitalize upon the Work Breakdown Structure's logical composition by designing a cost collection system which uses the numbering logic of the structure to sum up costs. For example, historical cost data can be generated for selected items in the structure simply by specifying an identifier number to the computer program. Previously, this same data had to be extracted manually from the cost accounting system. The effort required two or more weeks of time and one equivalent month of human effort.

In summary, the Work Breakdown Structure concept is being widely accepted by most of the contractors interviewed or surveyed. A significant short term benefit of this technique is the ease with which historical costs can be extracted and control activities can be launched. The general level of cost, time, and performance planning is being improved due to increased attention focused on lower levels in the organization. The government is vitally interested in complete and successful implementation of this concept as it, in essence, provides the foundation upon which the Criteria must be formed.

Technical performance measurement.--DODI 7000.2 defines this portion of the Criteria as "the regular demonstration and prediction of the degree of actual or anticipated achievement of selected technical goals or objectives of a system or part thereof, together with a causal analysis of the difference between the achievement and the objective."[17] This brief statement sums up the substance of government guidance regarding this portion of the Criteria. In the two years since this policy statement was issued, contractors have hastily searched for techniques which would satisfy the requirement in the customer's eyes. It was quickly noted that systems designed to measure cost and time parameters were infinitely simpler than measuring whether the weapons system being developed was going to exhibit the desired set of performance characteristics at some future time. Because of this basic quandry, the subject of technical performance has existed to date primarily in name only. The government meanwhile has continued to push Work Breakdown Structure and systems engineering concepts which stress cost and time parameters, while all parties search for a workable system which would measure technical performance progress. If one were attempting to show the impact of the Criteria on the

[17] DODI 7000.2, p. 3.

subject of technical performance, specific items of accomplishment would be difficult to illustrate. However, the real impact appears to be more conceptual than tangible. Said another way, contractors are being forced to think about the problem, but no hard and fast rule has yet evolved from this search.

Radio Corporation of America, Defense Electronics Products Division, was the first contractor to be validated under the Criteria guidelines and as a result of this precedent-setting move may well have established a conceptual format for others to emulate. For sake of discussion this contractor's system can be broken into two major parts, a performance control subsystem and a technical achievement subsystem.[18] Most of this internal planning and control system follows the traditional lines that have been described throughout previous portions of this paper. For instance, the performance control subsystem relies on a well-defined Work Breakdown Structure and an integrated network plan. Through this arrangement, most of the requirements relating to the Criteria can be met here as in many other companies. The unique point of this system is found in the orderly definition and arrangement of a technical performance measurement system. This system represents a workable approach

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[18] Paul W. Coben, RCA Defense Electronic Products, Camden, New Jersey, interview conducted at the National Contract Management Association seminar, Washington, D.C., August 8, 1969.

to the task of planning and controlling technical parameters for a complex weapons system component.

Technical performance measurement as envisioned by RCA takes on both qualitative and quantitative dimensions. The qualitative portion, titled "Technical Achievement Summary," simply evaluates each key parameter as either progressing satisfactorily, or presenting problems. Items identified as problems are explained in writing and corrective action is indicated. An example of the Technical Achievement Summary chart is illustrated in Figure 23. The RCA quantitative technical reporting system is titled "Technical Performance Index" and is illustrated in Figure 24. From the Criteria point of view, it is the quantitative method that is of particular interest. A technique such as the one indicated here is badly needed in order to integrate the reporting methods for cost, time, and technical performance parameters. It therefore appears that future techniques to define performance development progress will rely heavily on the concepts described herein. Seven steps are outlined in implementing the planning, measurement and control stages of this technique. These steps are summarized as follows:

1. Determination of organizational authority and assignment of a direct responsibility for progress to an individual.

2. Definition of key technical parameters.

C/SCS Project

EQUIPMENT DESCRIPTION:	ANTENNA - ELECTRICAL		REPORT MONTH:	August 1968
WBS KEY:	05-060/015	RESPONSIBLE ENGINEER: E. Krome	DATA AS OF:	June 16, 1968

ITEM	KEY PARAMETER	SPECIFICATION VALUE	10/67 CONCEPT REVIEW	11/67 PDR	1/68 B.B. TESTS	6/68 CDR	8/69 LAG REL	10/69 CHASSIS TESTS	11/69 CAR TESTS	11/69 S.S. TESTS	2/70 SYS TESTS	4/70 SELL OFF	SCHEDULE DATES / PERFORMANCE ACHIEVEMENT EVENTS / REMARKS
1	Gain over Isotropic	30±0.5db	30 ✓	30 ✓	28 X	28 X							Requires ground plane enhancement via heavier mesh
2	Elevation Beamwidth	1° to 20°	1-20 ✓	1-20 ✓	1-20 ✓	1-20 ✓							
3	Azimuth Coverage	150°	150 ✓	150 ✓	150 ✓	150 ✓							
4	Azimuth Beamwidth	5°± 1°	5±1 ✓	5±1 ✓	5±1 ✓	5±1 ✓							
5	Side Lobes & Grating Lobes	1st 16db 2nd 22db Other 24db	16 18 20 X	16 18 20 X	16 18 20 X	16 18 20 X							Tighter phase control Re-design in process
6	Cross Polarization	20 db	18 X	18 X	20 ✓	20 ✓							
7	Maximum VSWR of Sub-Array	1.8:1	1.8:1 ✓	1.8:1 ✓	1.8:1 ✓	1.8:1 ✓							
8	Power Handling Capability	5MW-Pk. 100KW-Av.	5 100 ✓	5 100 ✓	5 100 ✓	5 100 ✓							
9	Elevation Coverage	30°	30 ✓	30 ✓	30 ✓	30 ✓							
10													
	MILESTONE NUMBER →		0040	0230	1005	1340	2380	4700	5900	6950	7270	8300	
			10/67	11/67	1/68	6/68							← COMPLETION DATES

✓ - PERFORMANCE ACCEPTABLE
X - PERFORMANCE PROBLEM

FOOTNOTES:

Fig. 23--Technical Achievement Summary (Source: Paul W. Coben).

3. Establishment of acceptable performance values from contractual document.

4. Assignment of various weighting factors assigned to rank relative importance of variables chosen within the spectrum of system performance (sum of factors equals 100).

5. Periodical re-evaluation of predetermined probabilistic confidence achievement factors.

C/SCS Project

EQUIPMENT DESCRIPTION: ANTENNA - ELECTRICAL		REPORT MONTH: August 1968	
WBS KEY: 05-060/015	RESPONSIBLE ENGINEER: E. Krome	TPI: 82.0	

ITEM	KEY PARAMETER	SPECIFICATION VALUE	SPECIFICATION WEIGHT FACTOR (SWF)	CURRENT CONFIDENCE FACTOR (CCF)	OCT CON-CEPT REVIEW	NOV PDR	DEC	JAN TRADE OFF STUDY	FEB	MAR	APR B.B. TESTS	MAY	JUN CDR	JUL	AUG DWG REL.	SEP
1	Gain over Isotropic	30±0.5db	20	.8	16	16	16	16	16	16	12	12	12	12	16	
2	Elevation Beamwidth	1° to 20°	10	.8	8	8	8	8	8	8	8	8	6	8	8	
3	Azimuth Beamwidth	5° ± 1/2°	10	.9	9	9	9	9	9	9	9	9	9	9	9	
4	Azimuth Coverage	150°	10	.9	9	9	9	9	9	9	9	9	9	9	9	
5	Side Lobes & Grating Lobes	1st 16db 2nd 22db Otr. 24db	10	.6	7	7	3	3	3	3	3	3	3	4	6	
6	Cross Polarization	20 db	5	.9	5	5	5	5	5	5	2.5	2.5	2.5	2.5	4.5	
7	Maximum VSWR of Sub-Array	1.8:1	10	.8	9	9	8	8	8	8	8	8	8	8	8	
8	Power Handling Capability	5%-Pk. 100%-Avg	15	.9	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	
9	Elevation Coverage	30°	10	.8	9	9	8	8	8	8	6	6	6	8	8	
10																
	TECHNICAL PERFORMANCE INDEX= $\sum_{1}^{n}$ [(SWF)(CCF)]				85.0	85.0	79.5	79.5	79.5	79.5	71.0	71.0	71.0	74.0	82.0	

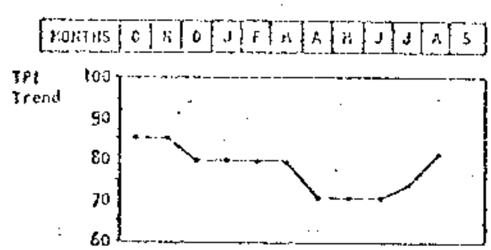

Fig. 24--Technical Performance Index (Source: Paul W. Coben).

6. Monthly calculations throughout the development cycle of performance indices computed by multiplying the weighting factor times the confidence factor, then summing for all parameters.

7. Plotting of trend lines to show evolving state of program performance expectations.[19]

Each of these steps is illustrated in the sample data in Figure 24. Other companies interviewed were approaching the problem of technical performance measurement in much the manner outlined above, although none appeared to have progressed quite to the stage illustrated for RCA. Specific companies which seem to be following this general path in search of an acceptable Criteria method are Boeing, Grumman Aircraft, and Texas Instruments. Conceivably, other corporations are also proceeding in this direction, and if technical performance is ever stressed in a purely quantitative manner, the method described here will probably capture the essence of the concept.

The subject of technical performance measurement is difficult to elaborate without getting lost in a forest of perplexing problems and vague terms. Assuming a general scheme for calculating technical performance can be agreed upon and then required of weapons system contractors, reliance upon this system is going to be more difficult since human judgment occupies a key role in the calculation of results. In many cases, actual discovery of bias error must await several months of development before one can say for sure that the system is invalid. This is certainly not an

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[19] Ibid.

acceptable situation from the control viewpoint. Even if one were to neglect the problem of input bias, there is the additional problem of parameter forecasting. Unless the device being developed does not represent a significant state-of-the-art advance, then the ability of aerospace and electronics managers to predict performance outcomes must certainly be questioned. The current impact of the Criteria approach on the functional area of technical performance measurement has been more to focus managerial attention on the problem rather than simply to compel compliance with this segment of the Criteria requirements. Thus far the government as a customer appears to have recognized the complexity of this problem and has not pressed contractors into unworkable systems which emit paperwork simply for the sake of another report. With proper guidance and continued recognition of the problem complexity, it is likely that the seeds already planted will germinate into a viable approach to this problem.

Internal control systems changes.--There is strong evidence within both the aerospace and electronics industries to support the hypothesis that the Criteria is already beginning to shape the structure and format of many contractors' internal planning and control systems. Since this was one of the basic objectives, it is not terribly surprising; however, the degree of conformity is remarkable when one considers the broad spectrum of activity involved in developing and producing a modern weapons system. Without attempting to prove a cause and effect relationship, it is possible to show that the evolution of the Criteria and its ensuing implementation has a similar evolution of management information control systems within many large and medium-sized contractors. This evolutionary cycle began with improving cost control systems and then progressed through various iterations of systems management techniques, followed more recently by attempts to implement combined technical performance and configuration management systems. The most recent stage in the evolutionary cycle has been discussed conceptually in the subsection immediately above and little more can be added here.

Too few companies have reported their efforts in these complex areas to allow inference to be made as to broad industry patterns. On the other hand, cost and time control systems are beginning to take on "typical" characteristics. The next section will briefly illustrate the Criteria impact in these two key areas.

Cost control systems.--Development and structure of cost systems has followed a very traditional pattern which originated back in the scientific management era some sixty years ago. The major change has been the speed, detail, and size of the reporting system, as well as the technology implicit in the system. All of the cost reporting systems observed during the visitation and interview stage of this research were computerized. In addition, many of the companies have improvised system techniques of close to real time for inventory, assembly, and fabrication status reporting. The structure illustrated in Figure 25 summarizes the basic format being developed by most of the contractors in compliance with Criteria requirements. Two very distinct changes are noted in the evolution of this structure. First, the rigor and maintenance of fixed budgets is quite different from the traditional practices of most contractors. Second, the degree of sophistication involved in measuring of actual work accomplished is much greater than previously, especially in the manufacturing areas. In non-hardware output areas, accomplishment is much more difficult to define, and it is quite possible that the impact will not be so great here. Organizationally, this type of system will probably change the concept of accounting within industry. Either the accounting function will become larger to handle the increased information load, or the function will dwindle and some staff group will emerge to monitor the enlarged information system. At present there is no well-defined trend from which one can draw conclusions. Regardless of the future of the Criteria concept, it seems reasonable to say that contractors have been given considerable motivation to improve their internal cost control systems.

<u>Systems management techniques</u>.--Much of the historical evolution relating to the PERT concept has been previously discussed and is relevant to this section. Once again it is difficult to say that the Criteria has led to improved systems management techniques, but it seems reasonable to

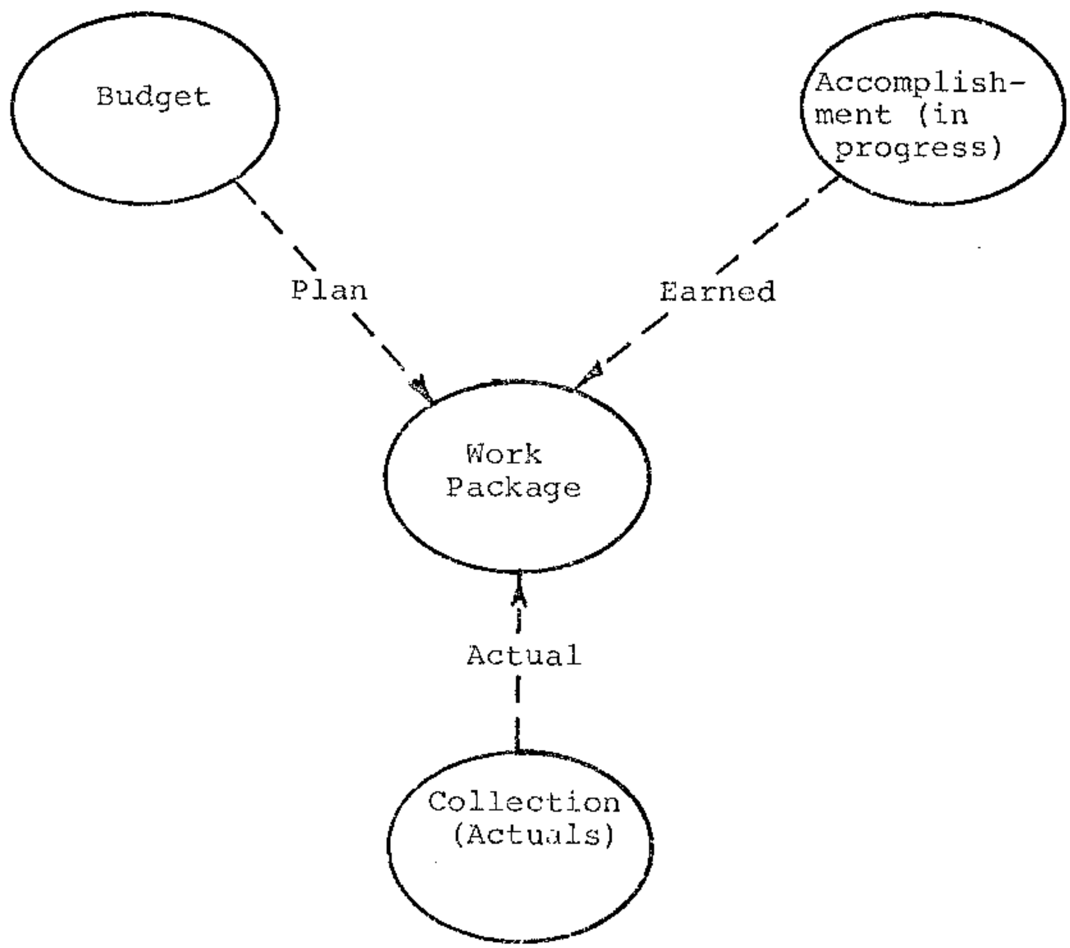

Fig. 25--Cost control structure

say that both of these events matured together in an environment where increased emphasis was being placed on the overall system rather than on a single functional area of a contractor's organization. If the definition of the Criteria can be slightly broadened for a moment, then it is possible to say that the basic Criteria objectives were to improve the system's emphasis throughout the acquisition framework. For contractors who are now attempting to implement the Criteria concept it appears that this is indeed happening and would have been much slower in coming without the emphasis created by the Criteria.

Implementation of the Criteria forces the contractor to perform a great deal more planning in preparation for proposals and development work on a weapons system. Not only must existing systems and techniques be better defined, but the recurring task of planning and control is also being increased in size and scope.

When one looks at the increased level of program visibility regarding cost, time, and performance, it is easy to see that the potential for increased centralization of decision making is possible. On the other hand, a few of the managers interviewed believed this improved level of visibility to be an incentive for higher management to remove themselves essentially from many of the decisions that they now make and simply perform a surveillance function while decentralizing the overall decision-making process. Thus the potential impact for such a system can be viewed in two ways--increased decentralization or more centralized decision making.

In order for the modern contractor to satisfy requirements regarding the Criteria, it will be necessary for him to have a very sophisticated network management system in which time and cost constraints are closely monitored. Many contractors are attempting to modify older PERT/Cost programs in order to meet this requirement, while others are using "canned" programs from the major computer manufacturers. Most frequently noted in the second category is the systems program written by International Business Machines for the IBM-360 Program Management System. Within this broad system are operating modules which can be used to satisfy general Criteria requirements. A small segment of the larger contractors have embarked upon various programs for total new system development, but this type of effort is cost prohibitive for most contractors.

The typical contractor is being pressed to improve existing cost and earned value type reporting systems, while at the same time network management techniques are being used to focus attention on the overall task of weapons system development. These changes represent tangible impact of the Criteria concept, but are not given to imply that all problems regarding cost and time control have been solved. Such systems are simply man-made information devices, not generators of weapons systems. The mere existence of modern information devices thus does not *per se* connote sophisticated management. It will be years before the true impact is known regarding these systems' ability to control the resulting performance of a weapons system and its ultimate cost and time utility. An operating information system as described in the Criteria is viewed as a highly complex man-machine management system from which there is great potential benefit, but the inanimate system by itself is valueless.

Chapter VI will attempt to document the recent past in regard to such areas as performance measurement, Work Breakdown Structure format and usefulness of selected management tools within the contractor organization. Second, using the previously described theoretical discussion as a framework, the primary research results will be synthesized into conclusions regarding the present impact of the Criteria on military contractors.

CHAPTER VI

ANALYSIS OF PRIMARY RESEARCH DATA

Introduction

This chapter summarizes and outlines the results of the primary research conducted at eleven aerospace and electronics corporations, plus the results of three questionnaire surveys from various segments of the industry. The industry, as used in this description, consists of a combination of aerospace and electronics contractors typically involved in weapons systems development and production activities at either the prime or lower tier contractor level.

A complete summary of the industry questionnaire and data are presented in Appendix C. Interview sources were used to further develop analyses in selected problem areas. Reviewing the development of the research efforts related to the project, it is easiest to summarize these efforts by stating that the early interviews led to questionnaire formats whose results ultimately led to further interviews. Through this cycle, every feasible effort has been made to explore the depth and scope of the Criteria, as well as its effect upon contractors within the aerospace and electronics industries.

Primary Case Study Data

Texas Instruments, used for the pilot study, has long had the reputation of being a progressive management company and a reliable producer of complex military electronic equipment. In an effort to better manage their military business, top management created, in 1965, a group known as "project management systems." One of the primary functions of this staff group was to develop new and effective management control techniques for operating managers, then assist in implementing these systems in project operations. An important point in the development of this research should be inserted here. The management systems organization was a creation of top management and was essentially forced into being from above. Project managers often looked at the "project management systems" groups as excess overhead and cooperated with them only to the degree necessary to satisfy top management reporting requirements. Looking back on this situation, it is interesting to make a comparison with the government as a customer requiring certain reporting data and corporate management essentially acting in the same role. Reactions of operating managers are observed to be quite similar in both of these instances.

Much of the research effort at Texas Instruments was directed toward an analysis of the Criteria effect on operating levels of a contractor's organization. Such an environment provided an excellent opportunity to study the Criteria and much of the questionnaire format was derived after this study. Exposure to the problem while an employee of the company provided this researcher with several preconceived notions about the study and some of these early biases have weathered eighteen months of research and analysis. During the two-month study at Texas Instrument, approximately fifty managers with varying functional backgrounds were interviewed and problem areas were explored. These activities resulted in a listing of the most frequent problems envisioned by the managerial group and some understanding of the systems requirements necessary for proper control of a weapons system program.

The early approach to program management at Texas Instruments relied on PERT networks generated by the project management systems staff group. Associated with this network was a regular program status report submitted to top management. The internal status document basically viewed the control problem qualitatively and attempted to analyze key functional areas of the organization. Also, technical performance, schedule, and cost parameters were collected from various sources and presented in this same report document. Many managers felt that these reports represented an infringement upon their prerogatives and the data submitted were often highly filtered, thus valueless as control tools. A brief check of this reporting technique indicated that the system was often highly subjective and the resulting reports were not auditable, except possibly in the area of cost reporting.

Needless to say, the Criteria approach demanded more than traditional management information systems could provide, and the company had to struggle with the problem of implementing more sophisticated methods of control. Two of the more noticeable efforts were a PERT/Cost system for project analysis and a purchasing system designed to automate much of the internal procurement process, as well as to give a more detailed reporting capability. With successful implementation of these systems, the company began to approach the degree of formal systems sophistication required by the Criteria.

It was discovered during subsequent stages of the research program that this quest for acceptable planning and control systems was going on in many contractor's organizations throughout the electronics industry, as well as in all of the large prime contractors in the aerospace industry. Preliminary checking indicated that much of this effort was being expended in reaction to the increasing government requirement for more sophisticated management control systems. Also, during 1968, the Air Force was pressing for widespread implementation of the Cost/Schedule Control Systems specification. Most of the contractors envisioned this requirement as a renewal of the previous attempts to implement PERT/Cost and several contractors began to experiment with this network method in order to further test the C/SCSC in the operating environment.

Efforts at Texas Instruments seemed to follow the general industry pattern, and the IBM version of PERT/Cost, called "PMS 360," was initially used as the basic internal computerized control system. Attempts were also made to use the "PMS 360" program for production projects, although the classical application for network techniques had been for non-recurring development programs. Since it was felt that the Criteria would possibly be applied to large production programs as well as development programs, a management control system had to be able to function in both roles equally well. This process was occurring within the organization in conjunction with development of more sophisticated management planning and control techniques such as the PERT/Cost effort described above.

Interviews

The interview cycle occurred in conjunction with other phases of the research effort. Specifically, the time period involved spanned from July, 1968 to December, 1969. Many individuals were contacted and numerous opinions were collected during this period, but, in retrospect, there were fourteen corporate sources which essentially provided the framework from which most of the resultant conclusions were drawn. These companies and their respective primary contact sources are indicated in Table XVI. Every effort has been made herein to treat the confidential data received in these interviews with proper respect. Although certain interviews were conducted in pursuit of specific objectives, the unstructured approach was found to be the best method for gathering large amounts of data in the shortest period of time. One major disadvantage of this method is that the resultant set of comments received from one individual were difficult to compare with others. As time progressed, interviewees were frequently chosen for specific areas of expertise, rather than for broad understanding of the overall Criteria implementation problem. In this manner, attention could be focused on one particular aspect of the Criteria.

In addition to the personal interview sources listed in Table XVI, several letters were written in search of particular information or opinions by experts in the field. Primary examples are letters of inquiry to the Department of Defense and the Air Force Systems Command. George W. Berquist and Admiral K. C. Childers gave most generously of their time in answering specific questions related to government intent, Criteria value, attitudes, and so forth. The interview process was very beneficial for reliable data collection, but less satisfactory from the standpoint of auditability and bias. Such interviews generally offered company exposure from a single corporate member; thus comments received from this source were often narrow in scope

TABLE XVI

INTERVIEW SOURCES

	Company	Primary Source(s)	Functional Title(s)
1.	Aerospace Industries Association Washington, D.C.	Richard Scharr*	Acting Director, Technical Council
2.	Collins Radio Dallas, Texas	Gordan Stieger	Engineering Manager
3.	Council of Defense & Space Industries Association	F. L. Thorne**	Electronics Industry Representative
4.	General Dynamics Fort Worth, Texas	Ralph Darling	Engineering Manager
5.	Grumman Aerospace Stuart, Florida	Edward Siebert	Operations, Planning & Scheduling
6.	Honeywell, Inc. St. Petersburg, Florida	H. R. Flatten	Dir. of Material
7.	International Business Machines Gaithersburg, Maryland	Robert Jutson**	Management Systems Development
8.	LTV Aerospace Grand Prairie, Texas	C. E. Stewart	Engineering Manager
9.	McDonnell-Douglas Aircraft Corp. St. Louis, Missouri	T. F. O'Connell	Systems Analysis
10.	North American Rockwell El Segundo, California	R. K. Harr**	Corporate Management Systems Group

TABLE XVI--Continued

Company	Primary Source(s)	Functional Title(s)
11. RCA, Defense Products Div. Camden, New Jersey	Paul Coben	Administrator, Management Information Systems Development
12. Sperry Rand, Micro-Electronics Division Clearwater, Florida	William Paul	Director of Material
13. Texas Instruments Inc., Apparatus Division Dallas, Texas	Jack Lawson Mike Sullivan Dale Boyett	Management Systems Development Management Systems Development Project Management
14. U.S. Army Management Engineering Training Agency Rock Island, Illinois	Lynn Bryant	Director

*Questions answered by letter.

**Interviews conducted by telephone.

and not necessarily representative of the overall company's posture. On the other hand, the questionnaire responses were often found to be idealistic and attempted to "whitewash" the company's approach to the problem.

Miscellaneous Primary Data Sources

Two unexpected, yet influential, primary data sources appeared by chance in the latter stages of the research effort. Each of these gave valuable insights into the Criteria or its working environment. First, the National Contract Management Association presented a seminar in Washington, D.C., on August 8, 1969, titled "Performance Measurement for Selected Acquisitions." This seminar attracted both government and industry personnel, and thus provided a broad personal exposure to both sides of the Criteria implementation problem at one time. Second, J. F. Brandejs of the University of Saskatchewan, writing on another subject, happened to enclose some of his thoughts and approaches to current management problems by the use of more advanced management control information systems.[2] These enclosures were found to be so pertinent to the question of the Criteria and its true value that permission was requested to use Brandejs' observations in this report.

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[2] Letter from Dr. J. F. Brandejs, Professor at the University of Saskatchewan, Saskatoon, Canada, October 3, 1969.

The seminar described above used a team approach in discussing the Cost/Schedule Control System, AFSCM 70-5, being implemented by the Air Force. In one session the government described why the document was necessary and how the Air Force intended to validate the contractor's internal system for compliance with the specification. A second session, using simulated functional project managers as participants, described individual sets of problems associated with the requirements of the Air Force system. Finally, the two teams met face to face and a formal debate ensued. Although the questions had been studied in advance, there were occasions when attitudes of the two parties became something less than cordial. Overall, however, the seminar was valuable and provided a broad exposure to companies working with the problem of the new Criteria interpretation and implementation. In addition, there was an opportunity to test some of the preliminary conclusions being drawn from the early questionnaire responses. In every case, the responses were verified and thus validity was added to the questionnaire survey. As a final note to the seminar, J. Ronald Fox, Assistant Secretary of the Army, presented the long-range governmental objectives for the Cost/Schedule Control System. Basically, his view was that the government was being forced to press for further application of sophisticated contractor reporting systems and the Criteria approach now appeared to be the best long range approach to such information.

Analysis of Questionnaire Data

This section describes the results obtained from the various questionnaire surveys and attempts to draw meaningful conclusions from the statistical data. Interpretation of the statistical data will be enhanced by specific information gained during the interview stage of the research effort. The broad objective of this section is a brief, yet documented, commentary on Criteria impact observed within the industry.

Population Analysis

Respondents to the industry questionnaire survey consisted of both large and medium size corporations from the "top 100" defense contractors of fiscal 1968. Twenty-one corporations responded with usable data. Additional effort was expended to find out if any of the non-responding companies were involved with the Criteria approach. If some positive indication was obtained from industry or other sources, this was also related to the sample response data summarized in Appendix C. Fourteen companies, 71 per cent of the usable responses, indicated an awareness of the Criteria and positive steps taken to implement the concept in the company's internal planning and control system. In addition to these fourteen, nine companies were identified as having expended an unknown amount of effort to implement the Criteria.[4] Combining these data, it appears that approximately twenty-three companies in the sample are now involved in varying stages of Criteria implementation. Ranking these positive responses by deciles within the "top 100" listing, and adjusting for companies not surveyed, the dispersion of Criteria involvement throughout the population can be observed. Figure 26 illustrates the distribution of favorable responses versus "top 100" decile rank. This figure indicates that the Criteria exposure to date is oriented to the larger corporation, with little involvement by corporations below the fourth decile. For example, all of the top eleven contractors surveyed were familiar with the concept, yet only three companies in the lower four deciles were cataloged as being aware of the Criteria existence. Actually, none of these latter companies gave firm indication of this involvement, but interview comments led to their being cataloged as positive. Data in the fourth and ninth deciles are not deemed representative since six companies within each of these groups were not within the defined study area. Figure 26 is quite significant to the study in that it documents the current level of Criteria involvement within the industry.

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[4]See Appendix C, response code E-1, for a list of these companies.

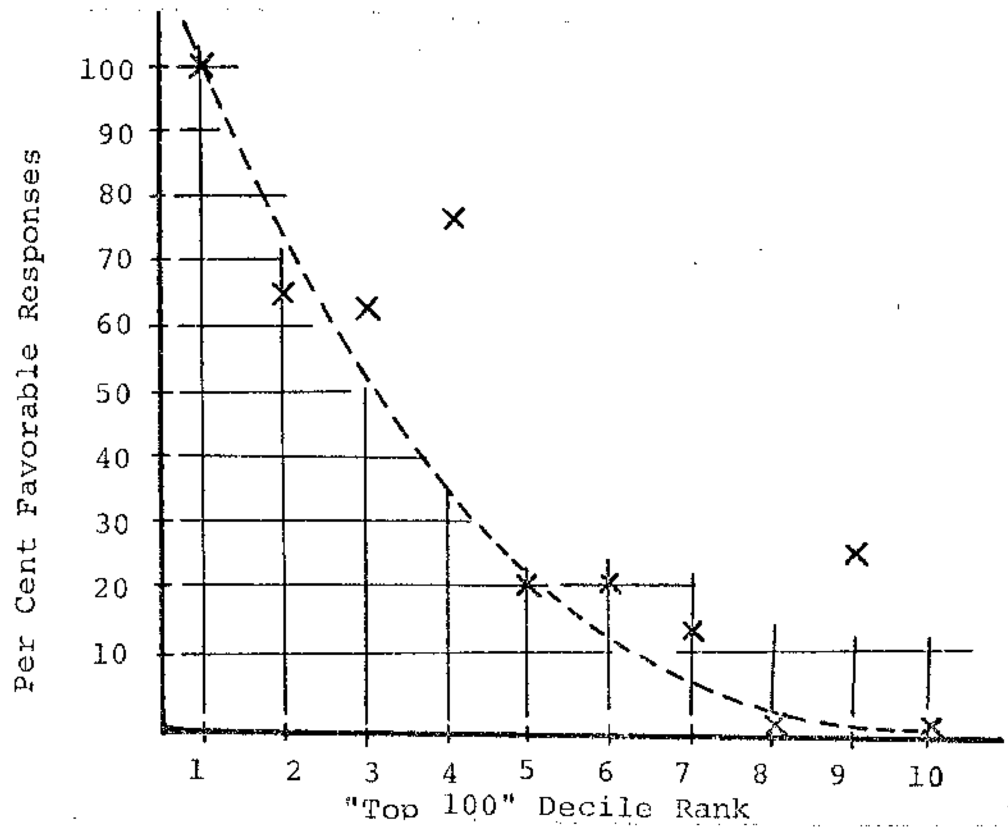

Fig. 26--Criteria exposure versus size (Source: "Top 100 U.S. Defense Department Contractors," _Aviation Week and Space Technology_ (January 1, 1968), pp. 72-73).

Contract Data

Each of the companies chosen in the control group was of extremely large size; thus its dollar volume of military contracts was similarly large. Average contract size in the control group was $1.4 billion, while the remainder of the population averaged $285 million. The largest contracts for individual systems were approximately $1.9 billion and $290 million, respectively. It should be noted that all of these values exceed the threshhold requirement for Criteria implementation, and, indeed, many of the respondents either indicated that the requirement was now being proposed, or actually required. The case study company, while operating as a subcontractor through the larger contractors in the aerospace industry, ranked thirty-ninth on the "top 100" list and was typified by systems whose life cycle contract values were near $20 million.

Typical time cycles for the research and development effort in the electronics industry case study company were approximately fifteen months, with extremes from three to thirty-six months. For the smaller companies within the industry sample, contract time cycles appear to be a direct function of dollar value and state-of-the-art advance. The total product life cycle within the case study company was 8.4 years for the total sample, but only 4.7 years if two very large system contracts were excluded from the sample. As expected, this value is considerably lower than the total cycle time observed for larger systems in the aerospace industry. In general, it does appear that contractors, at least through the top five deciles, qualify for Criteria surveillance as prime contractors and the majority of the entire list of contractors could qualify for surveillance as critical or major subcontractors. Threshold level for surveillance is typically $25 million for research and development, or $100 million in production.

The distribution of contract types differed significantly from the overall defense acquisition population. This distribution of data is presented in Table XVI below. One striking feature of these data is the strong diversity of the sample population from the overall Department of Defense

TABLE XVI

COMPARISON OF CONTRACTUAL TYPES

Type	Control Group*	Remainder of Population*	Total Defense**
Fixed Price	19.7%	41.3%	52.7%
Fixed Price Incentive	63.5	18.1	18.7
Cost Plus Incentive Fee	5.6	14.5	9.0
Cost Plus Fixed Fee	7.7	24.1	10.8
Miscellaneous	3.5	2.0	8.8

*Source: questionnaire survey of "DoD top 100" contractors.

**Military Prime Contract Awards, pp. 47-52.

averages, summarized as "total defense." The control group was characterized by the low incidence of fixed price contracts and the high percentage of fixed price incentive contracts. The remainder of the sample population more closely approximated the total defense averages. If the high level of fixed price contracts indicated in the remainder of the sample population can be considered stable, as evidence indicates it should, then there should always be a more restricted application of reporting requirements in this segment of the acquisition process. The policy-making segment of the Department of Defense indicated that the intent of the Criteria was not strictly to monitor fixed price.

However, such a relationship does not preclude data reporting very similar to the Criteria requirement.

Managers within the case study company felt that the type of contractual form used by its customer was primarily a function of the time urgency of the particular product more than any other single factor. Classical approaches to this problem have been to relax the tight monetary funding restraints implicit in fixed price contracting whenever the state-of-the-art is significant, yet many highly sophisticated products were being made by the case study company on fixed price, or very tight fixed price incentive contracts.

The implications of the contractual statistics and managerial attitudes are important to this study for four basic reasons. First, the government as a customer has essentially stated that it would be less interested or involved in contractor activities if the contract was fixed price in nature. Second, the resulting impact of the Criteria approach is apparently tied to the degree which the Department of Defense is able to negotiate fixed price relationships with its various contractors. The data indicate that this effort has not been very successful in the larger companies. On the other hand, the smaller companies have often been forced into accepting fixed price contracts in order to obtain new business. Further change in this area would tend to minimize the effect of the Criteria on smaller contractors. Third, major subcontractors who become involved building subsystems for large weapons system producers may have to assume many of the requirements imposed on prime contractors. In fact, the problem is somewhat compounded at the lower levels in that each prime contractor is essentially asking the smaller contractors to supply a significant amount of very specialized time, cost, and performance data to fit individualized Criteria systems. The small contractor often finds himself in somewhat of a dilemma in that management systems design funds are limited, yet he must have a system which will mesh with that of several prime contractors' systems. Fourth, although the government has stated that the intent of more sophisticated management information systems is to improve "visibility" in contractor operations, there is still a general level of confusion as to exactly what this means in any particular case. For instance, a fixed price contract does not significantly lower the government's desire to obtain information on time of availability, performance, and cost information which might be used for future negotiations. Therefore, this trend towards fixed price contracts does not mean that the Criteria concept will not have any consequences for smaller contractors. These four points offer potential divergent paths for the future trend of the Criteria.

The first two points seem to indicate that simple application of increased fixed price contracts will decrease the impact of the Criteria concept on the smaller contractor.

On the other hand, items three and four indicate an increasing involvement for the small contractor regardless of the contractual form. Most of the industry interviewees felt that the second set of conditions was most likely. The conclusion of this study is that the degree of impact is partially related to the contractual form, since there will be some required level of involvement by smaller contractors, through requirements imposed by the prime contractor, regardless of the contractual form.

Performance of the Contract

Three elements typify the weapons acquisition process within the industry: employee mix, percentage of profit on contract, and subcontract patterns. The control group once again is characterized by large size. The average number of employees involved in system development was nearly 50,000 per contractor for the control group. The remainder of the population averaged fewer than 12,000 employees per enterprise and the overall industry survey average was approximately 25,000. The relative size of these two segments of the survey is impressive and reinforces the point that the aerospace and electronics industry is unparalleled in the number of people working to accomplish a single common development and production objective for such sophisticated equipment. Within each of these categories, data were collected on three particular types of employees:

engineering, direct production, and clerical. In both sample segments the direct production category was the largest, claiming 41.9 per cent of the employees in the control group and 40.9 per cent of the employees in the remainder of the industry sample. Of these employees, 18.9 per cent and 24.8 per cent, respectively, were involved in contracts as either engineers or scientists. Approximately 25 per cent of the work force in both groups performed the clerical functions. Finally, the control group categorized 28.1 per cent of its employees in a miscellaneous category, while only 6.9 per cent of the remainder of the sample were cataloged in this area. Due to the large variance in the miscellaneous category, extra effort was spent in interviews examining skill mixes. Although it was impossible to be completely specific as to the composition of this segment, three items represent major constituents of this category. These are maintenance, technical staff, and managerial personnel that are not categorized in the engineering or production functions. It was then concluded that the major variance indicated probably resulted from differences in the technical staff size, since the maintenance function appeared relatively similar in both cases. Interviewees suggested that a possible causal factor which might precipitate this difference was the level of government involvement in the control group activities and the volume of paperwork, data, and reports which were submitted to the government. Although this opinion could not be proven, it offers interesting opportunity for conjecture on the future of an industry which may be headed towards increased government paperwork, data, and reporting.

The percentage of profit on military contracts has been a subject of long controversy and much of the data necessary to analyze accurately this problem are blocked by strict corporate security. The average profit on sales reported through the two segments of the questionnaire survey was 4.8 per cent, and there was little variance between the two segments of the population survey. This would seem to indicate that the extra complement of employees in the large firms is considered an inevitable part of the acquisition expenses of large weapons systems. This is suggested by the profit data which, otherwise, would have differed for each sample segment. It should be noted that this conclusion is somewhat of a generalization in that many large contractors are coming under profit pressures on large contracts, but this pressure appears to be created by poor cost estimates rather than high overhead resulting from excessive labor costs. Several of the large weapons systems contracts were reviewed earlier with the conclusion that many, if not all of them, were under increased cost pressure from the customer. Regardless of the historical profit data reported in the survey or other literature, it does appear that the government as a customer is going to demand greater justification for increased cost. The result of this will probably be an increasing number of technical staff personnel who will be required to generate the volume of operational data required by the government.

The control group subcontracted an average of 45.4 per cent of the weapons system effort, although many respondents indicated that this figure was highly variable, depending upon the type of program in question. It appeared with the small number involved in the control group that the most typical consideration dictating the level of subcontract was the state of the art implicit in the particular program. High technology programs would have subcontract percentages near twenty, while a production program with few technological demands might exceed 50 per cent. Obviously, there are numerous other critical factors, such as the level of activity within the prime contractors plant, but technology was the most often mentioned variable within the control group sample.

The response relating to subcontract operations from the smaller companies of the survey population was somewhat unexpected. The average level of subcontract operations here was 37.0 per cent, which was higher than initially thought. If one can assume that this is truly typical of the smaller companies of the industry, then an unforeseen problem begins to become evident. Control systems which operate only within one level of the acquisition system will be largely ineffective in controlling total systems cost. The data above suggest that the necessary level of control should involve not only the prime and major subcontractors, but also possibly the third level of subcontractor. An approach to such a control system would necessitate greatly improved compatibility between various levels of the subcontractor network. As a hypothetical example, the F-200 Aerospace Company might be involved with a large weapons system contract complete with full Criteria requirements; the ABC Electronics Company, a major subcontractor, might then be requested to supply certain cost, schedule, and technical performance data to the prime contractor. Finally, the XYZ Company, a subcontractor to ABC, might then be required to submit similar information to the required common reporting framework. Two alternatives are likely from such a situation. First, each company may simply transform its own internal information into the required format for submission to the next higher tier. Such an alternative suffers from the deficiencies of data auditability, timeliness, and accuracy. Second, future evolution of the companies involved in military procurement would indicate increasing similarity in internal management information systems and resulting reporting formats.

The cost of creating an industry-wide Criteria type planning and control system would probably be prohibitive in the foreseeable future, even if each individual company could eventually satisfy the Criteria. Given the flexibility now desired in the Criteria, there is certainly no assurance that one Criteria system is compatible with another, except for manual entries from one to the other. One of the significant challenges regarding the Criteria appears to be a means for integrating one corporate system to another. At present it does not appear that many subcontractors wish to have such data so readily available.

Three conclusions regarding contract performance have been drawn from the data surveyed. First, the average number of employees per company involved in weapons system development is large, approaching 25,000 for the industry. Second, it appears that the larger companies of the survey are characterized as having a greater number of technical staff personnel than smaller companies in the sample. Since there is no significant difference in profit between the two segments of the sample, it is theorized that the government considers this added cost necessary for supplying additional reports and data. It then follows that an increase in data requirements for smaller contractors will lead to increased numbers of technical staff personnel to generate the data. Finally, the subcontract patterns indicate that common contractor internal control systems characteristics will be necessary to generate the required data with proper auditability, timeliness, and accuracy.

Criteria Implementation

The distribution of Criteria exposure versus decile rank within the "Top 100" was previously illustrated in Figure 26. This section describes the implementation problems indicated by the questionnaire survey and interview sources.

Even though all seven of the control group corporations indicated an exposure to the Criteria, it is interesting to note that only four of them felt able to meet the formal demonstration test outlined in DODI 7000.2 and its related documents. Only 30 per cent of the smaller companies felt able to pass the validation test. Currently, none of the companies in the industry have formally satisfied the Criteria validation requirements. Many of the problem areas, indicated in the questionnaire survey and interviews, were found to be common throughout the sample. For companies not yet experienced with the Criteria, specific validation questions were asked and answers to these were used to evaluate the severity of implementation for the total industry population. Table XVIII summarizes the common compliance problems which would either necessitate a change in the formal internal control systems configuration, or some difficulty from a managerial viewpoint. An attempt was made to rank the variables in order of severity by validation area. This would indicate that the material accounting problem was most common; maintenance of rigid baseline, second, and so on.

TABLE XVIII

COMMON CRITERIA COMPLIANCE PROBLEMS*

Validation Area**	Comment
Accounting	Material accounting requirement necessitated changes to the internal system in order to collect material costs at the point of usage.
Planning and Budgeting	Maintenance of rigid baseline for either work package, cost account, or configuration item.
	Level of budget detail required in excess of that currently being done. Changes in this area would be done more for reporting purposes than for improved internal management.
	Inability to plan size and time span of criteria level. Typical industry level would be three months and 60,000 man hours (approximately $200,000) as compared with the suggested eight weeks and $100,000.
	Interpretation of level-of-effort activities varies.
	Engineering tasks difficult to break down into recurring and non-recurring categories.
Revisions	Operation of an "engineering change notice" system which would be compatible with the criteria would be extremely inefficient for "real world" resource management.
	Planned Value of Work Scheduled (PVWS) and Planned Value of Work Accomplished (PVWA) calculations with no retroactive changes would be inefficient.

TABLE XVIII--Continued

Validation Area**	Comment
Analysis	Criteria specifies lower level of cost comparison than necessary for proper control.
Organization	Reorganization would be required to accomplish "appropriate work authorization documents which subdivide the contractual effort and responsibilities within functional organizations."
Miscellaneous . . .	Air Force Demonstration Team members tend to emphasize "how" rather than "what" in evaluating a system.
	Interpretation of the criteria varies significantly with time among the Air Force Validation Teams.

*Source: Summarized from questionnaire survey, case studies, and interviews.

**Major portions of the validation procedure as indicated in AFSCP 173-3, Cost/Schedule Systems Criteria (Implementation Guide), pp. 4.3-4.9.

The sample results indicate general agreement among the various industry elements. Comments in Table XVIII summarize the industry attitude towards the Criteria within the contractor environment. It is interesting to note the disagreement among the seven members of the control group regarding the impact of the Criteria. Three of six usable control group responses indicated that the Criteria would cause no significant impact on the previous method of doing business, while the other three indicated either a "yes" or qualified "yes" to this question of impact. Most of the control group interviewees were more positive in their comments. There is considerable evidence indicating that the response to this portion of the questionnaire was dictated to some extent by the company's desire to appear progressive; therefore, such responses would tend to minimize problems which were being experienced. For those companies which indicated that the Criteria would have a significant effect on corporate operations, the following responses were obtained:

1. Internal planning and control is improved through the process of satisfying government requirements.

2. Overhead is increased due to the level of planning necessary to satisfy new requirements.

3. Cost of such a system is disproportionate to potential benefits.

4. Top management does not want such a system; therefore, it is just another government requirement which will be complied with in order to stay in business.

5. The Work Breakdown Structure requirement is "antipathetic" to the functional organization.[5]

The questionnaire asked if the Criteria and its associated resource management system would significantly improve the company's ability to spot problem areas in advance. Fifty per cent of the control group answered this question negatively and 70 per cent of the smaller companies in the survey did likewise. Overall, 61 per cent of the survey answered that the company's ability to spot problem areas in advance would not improve significantly.

The cost of implementing the Criteria approach is very pertinent to the ultimate decision of whether contractors persist in the power struggle now occurring. The control group felt that the cost of operating such a system would be approximately 1.8 per cent of a $100 million weapons system contract, while the remainder of the population estimated the system cost to be 4.2 per cent for the same size contract.[6] Independent study made during the case work phase of the research effort led to a systems cost estimate by the author of 3 per cent to 5 per cent. Data of this type are difficult to estimate because much of the existing

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[5]All respondents to this question requested anonymity.

[6]Each of the indicated responses brought with it a warning that such cost estimates are subject to much definition. In addition, the variability of responses leads one to the conclusion that such data are extremely subject to estimate error.

internal control operation would exist regardless of external requirements; thus it is hard to segregate what would be done anyway from what is required. Companies in the survey sample had spent an average of $2.8 million over the last three years on systems design and implementation to meet the Criteria. From this it can be seen that the resultant estimate will not be simple to attain.

The survey summary in Appendix C indicates that the above totals are once again heavily biased by the control sample. Smaller companies with less exposure to the Criteria have spent an average of only $475,000 thus far. In addition to this, several large computer companies are working on "canned" programs to generate cost and schedule data compatible with the Criteria, and this effort may save the smaller companies from exorbitant internal systems design work.

Work Breakdown Structure

Part C of the questionnaire surveyed broad attitudes concerning the application of Military Standard 881. The familiarity with this document is reflected in the resulting statistics. For example, 100 per cent of the total population were familiar with this document, and 68 per cent of the total population agreed that it was a valid approach to the control of research and development programs. Also, more than 80 per cent of the total population agreed that they would use the approach even if it were not mandatory.

Many of the companies now actively involved with the Work Breakdown Structure have established a staff group to assist the project or program manager with the accomplishment of a formalized structure. Approximately 75 per cent of the control group is in this category and over 40 per cent of the smaller companies have followed suit. These data seem to indicate that the concept is being applied broadly throughout the industry.

The final objective of section C of the questionnaire was to ascertain the usefulness of the Work Breakdown Structure. Three particular categories were chosen for analysis: internal planning and control, top management information, and customer reporting. The data in Table XIX indicate results of the total population survey, with

TABLE XIX

INDUSTRY OPINIONS OF CRITERIA VALUE IN SATISFYING THREE TASKS

Category	Per Cent Favorable
Internal planning and control	82
Management information device	55
Customer reporting	86

numerical values summarizing industry opinions of Criteria value in satisfying three vital tasks within the development process. That is, 82 per cent believe that the Criteria will improve internal planning and control. Many participants feel that the Work Breakdown Structure (WBS) document or its resulting data are not designed for top management reporting; there is some disagreement as to which of the other two categories is most useful. The members of the control group unanimously found the technique to be useful for customer reporting, probably because of the effects of Criteria reporting requirements. In addition to this, the control group generally responded more favorably in all categories as to the usefulness of the WBS technique.

The control group envisioned the document as most useful for customer reporting, while the remainder of the population indicated that internal planning and control would be its most useful function. No specific reason could be obtained to explain why managers in one segment of the population would find the technique most useful for internal purposes, while the other segment thought it to be most useful for customer reporting. One hypothesis, similar to that previously presented, is that the early exposure to the Criteria may have made the control group managers more conscious of customer requirements than corresponding managers in non-Criteria companies. Presumably, the Work Breakdown Structure should be quite useful both for internal control and customer reporting.

Planning and Budgeting Process

Since much of the validity of a resource management system depends upon the ability of a manager or individual to estimate probable outcomes for the project, a great deal of time was spent analyzing this general problem area. For example, if it is not possible to estimate accurately the future cost of a particular item, then it is not really possible to compare performance or take effective control of the operation. This section describes managerial attitudes toward pertinent facets of the planning and budgeting process, and attempts to identify which variables typically cause the greatest problems in achieving program success. Three sets of data will be used for comparison throughout this section: the control group (C), remainder of the "Top 100" population (R), and the Texas Instruments survey (T).

Six variables were chosen for ranking by the respondents in order to measure the most significant managerial priorities within the planning and budgeting process. Table XX summarizes these data for all three sets of responses. There

TABLE XX

PLANNING AND BUDGETING VARIABLES

Variable	Rank		
	C*	R*	T*
Performance (contract specifications)	1	2	3
Cost of effort	2	1	2
Time to first delivery	3	3	1
Production volume (qty.)	4	5	4
State-of-the-art advance	4	4	N.A.
Value engineering	5	6	6

*C = control group; R = remainder of population; T = Texas Instruments survey.

is a marked degree of disparity among the three sets of responses, particularly for the performance, cost, and time variables. One possible reason for this variance is that each of the three groups had different objectives. First, the control group (C) indicated the traditional development approach to high performance products and flexible cost contracts. Apparently, both the government and the prime contractor realize that long cycle times are involved before first delivery. On the other hand, the remainder of the population (R) is becoming characterized by firmer cost contracts with generally lower state-of-the-art approaches to subsystems development. This second point is a judgment, but it does agree with many comments received in this segment of the industry. Third, the ranking at Texas Instruments provides an in-depth look at one unique member of the total population which should, in theory, be congruent with the remainder of the population set (R). The apparent discrepancy of the Texas Instruments sample with its counterpart is explainable somewhat in that many of the product managers responding to the sample were involved in programs which were advancing technology, and development time was typically critical.

According to traditional theory, the performance variable should be the most pertinent variable, followed by time, and finally, by cost. The existence of the cost variable as either number one or two in rank, as shown in Table XX, indicates an increasing awareness of this variable in comparison with the performance and time variables. Many respondents indicated that the three variables could not be ranked as they were of equal importance, but this is not a realistic attitude in the operating environment since parameter trade-offs must be made.

The second part of the Work Breakdown Structure of the questionnaire focused on the ability of a company or individual to actually plan the future outcome of the cost, time, and performance variables. Unfortunately, the results were questionable as they did not conform to actual industry performance. These data appear to suffer from the perennial optimism of management. Regardless of the numbers themselves, the relative relationship of the variables is a rank measure of the respondents' ability to predict the future outcome of the variables. Table XXI summarizes the responses

TABLE XXI

PLANNING RATIOS*

Variable	Ratio		
	C**	R**	T**
Cost	1.2	1.1	1.3
Performance	1.1	1.0	1.06
Time	1.0	1.0	1.1

*Ratio value is defined as the actual parameter value divided by the originally planned value, i.e., a 1.5 cost ratio would indicate that the cost exceeded plan by 50 per cent.

**C = control group; R = remainder of population; T = Texas Instruments Survey.

from the three sets of questionnaires. One important conclusion can be drawn from these data. In all three sets of data, the ability to control the resultant cost variable was inferior to the ability indicated for control of performance and time ratios.

The data in no way reflect the actual ability to match resultant parameters with original objectives, but the ranking of these three ratios is felt to be significant since the order reflects managerial ability to control the various parameters.

During the early phases of the research program, before the questionnaire format had been decided upon, several comments were repeatedly made concerning the primary contributors to suboptimum performance of a particular development program. Using these observations as a basis, five specific elements were chosen for analysis during the questionnaire phase of the project. These elements, or causal variables, are shown in Table XXII along with the resultant response rankings for the three sets of questionnaires. This set of data is one of the most enlightening developments of the entire research project. Rank positions of the various elements, reinforced by a large number of interview inputs, indicate that most managers feel that suboptimum performance in their industry is created primarily by external factors. Specifically, pushing the state of the art to meet specifications and time restrictions were

TABLE XXII

ELEMENTS CAUSING SUBOPTIMAL PROGRAM PERFORMANCE

Element	C*	R*	T*
Customer's changing desires	1	2	4
Time restrictions	2	4	2
Pushing state-of-the-art to meet specifications	2	1	1
Cost restrictions	3	3	3
Production processes	4	5	6
Other	5	6	5

*C = control group; R = remainder of population; T = Texas Instruments survey.

indicated to be major factors. It is also interesting to note that the control group (C) indicated customer's changing desires to be their most significant factor. For the overall population, the following three causal elements were found to be the major factors in producing suboptimal program performance: (1) high state-of-the-art programs, (2) varying customer desires, and (3) time restrictions ("crash programs"). Each of these elements directly contradicts the basic control-oriented objectives of the Criteria and will have to be minimized within the contractor environment before satisfactory implementation of any planning and control system can be achieved. Stable programs must be given to qualified contractors with sufficient development time in order to achieve more satisfactory results. The work of Stubbings and others, previously described in Chapter III, indicated that the idealistic objectives so prevalent in the weapons acquisition process do not produce the most efficient device in terms of either the least cost, desired time, or planned performance constraints. The irony of this is that the cause of the "inferior" product is apparently the over-eager customer who simply wants the best product for his money.

This section of the questionnaire confirmed two very important hypotheses. First, the increasing importance of cost in relation to performance and time was indicated in all three sets of questionnaire data. Second, the short-comings of systems development were indicated by the questionnaires and interviews to be an external phenomenon in that the customers' changing desires, time restrictions and high state-of-the-art program objectives all decrease the effectiveness of a contractor in predicting the ultimate outcome of a program's cost, time, and performance parameters.

General Management Tools

Several basic management tools and techniques useful in program planning and control were selected to ascertain their applicability within the various segments of the population. Various network techniques and classical production control concepts were included in the questionnaire for sampling. In addition, due to the close association of a particular tool or technique to the Criteria itself, a qualitative check on internal response consistency could be made. This section will evaluate the usefulness of the Criteria components for various segments of the population. The network management techniques, implicit in the PERT approach, were generally found to be useful in the weapons development project. PERT/Time, the time-oriented network, is a widely accepted tool which the questionnaire revealed was used in 100 per cent of the control group corporations. On the other hand, only 61 per cent of the other members of the survey indicated that PERT/Time was used. Implementation of the Criteria will probably significantly increase the number of companies using this technique. As was the case with the Work Breakdown Structure, previously discussed, the primary area of application is internal control, with customer reporting a secondary major use. Research indicates that PERT/Cost, the time-and-cost-oriented network technique, evidently is a controversial topic within the industry. Only 23 per cent of the total population replied affirmatively to the question, "Do you feel that PERT/Cost is a useful tool in your business?" In this one item the general attitude of the total industry appears to be summarized. If PERT/Cost is of no use to the contractor, then the Criteria approach would have to be cataloged in much the same way since the two techniques are so similar in nature. The only possible alternative to this interpretation would be an understanding that many members of industry envision PERT/Cost as a very regimented system, difficult to maintain and previously used simply to submit customer reports. If, in fact, the

Criteria can be shown to be something which submits a PERT/ Cost type report from a more flexible system, then the contractor may be positively inclined. Thus far, there is little evidence to indicate that this trend is developing; therefore, it appears that the Criteria approach must be stringently pressed from the customer side if it is to be implemented.

Milestone charts were found useful to all members of the total population. It is likely that future developments in technical performance measurement will come from this type of management tool due to its wide acceptance and need in the industry. The earned value concept was also widely used by the majority of those surveyed, although many respondents expressed doubt as to their near term ability to calculate earned value statistics.

Review

Every feasible attempt was made herein to check response inconsistencies or non-traditional conclusions which were obtained. The findings indicated in this chapter validate the original hypothesis that the government will continue to press for implementation of a Criteria-type planning and control system for its contractors throughout the entire acquisition network.

The primary research effort basically explored managerial planning and control techniques and attitudes associated with the weapons acquisition process. These results indicate significant Criteria involvement among the larger companies in the industry. Associated with this is an increasing emphasis on contractual cost performance and significant resource expenditures for development and implementation of sophisticated computerized planning and control systems. Contemporary efforts to implement the Criteria are typified by these events. Future studies of the weapons acquisition process should confirm the increased level of contractor conformity noted in this research. The Criteria is producing conformance to a pre-established managerial control process which monitors the development process and its associated time, cost, and performance parameters.

CHAPTER VII

SUMMARY AND CONCLUSIONS

Summary

The methodological approach to this subject has been deductive. Descriptive material of each chapter was designed to proceed concentrically one step closer to the specific problem areas of the Criteria. Chapter I defined the general problem area, a specific set of objectives within this area, the methodology of research, and the overall plan of the paper. It was initially hypothesized that the Cost/ Schedule Control Systems Criteria, shortened to "Criteria" throughout this research, would have a significant impact upon the typical military contractor's way of doing business. The stated objective of this research effort was to explore the total impact which such a system would have on aerospace and electronic contractors.

Chapter II discussed the broad environment of defense. Development of a modern aerospace weapons system consumes considerable periods of time and great resources. All too often, the government, as a customer, finds performance lacking in such programs. On the other hand, a contractor often finds the financial incentives of weapons system development to be under increasing downward pressure. Previously, the government allowed original cost projections to become larger through contractual changes. In such an environment, contractors were generally willing to allow customer involvement in various stages of the total systems development cycle; but, as profit came under scrutiny by the customer, many contractors appeared to withdraw and keep internal data available only at the lower levels of the organization. This effectively concealed the total cost of the device until the customer was heavily committed to the program.

Since World War II, the United States has maintained a strong defense consciousness; the current annual expenditures for weapons systems procurement approach $22 billion. Historically, our defense posture has been to attempt tremendous advances in the state of weapons technology with each new generation of weapons systems. This philosophy is reflected across the entire segment of military procurement, but is especially noticeable in Air Force and Navy weapons systems. Much of the current development and production effort within the aerospace and electronics industries continues to reflect significant technological advances.

Chapter II concluded with an analysis of the various aspects of uncertainty implicit in weapons system development. The original decision to develop a particular weapon system is uncertain due to lack of timely international intelligence data. Additional elements of uncertainty, which are both internal and external to the contractor organization, have been identified throughout the acquisition process. The general level of uncertainty in the weapons system is reflected by vacillating cost, schedule, and performance parameters for the specific program. Marshall and Meckling of the RAND Corporation examined cost and schedule performance for twenty-two major items of military equipment. The remarkable conclusion of this work was that the typical cost overrun for this population of weapons systems was between 140 per cent and 220 per cent above initial estimates, depending upon which of two sets of assumptions were followed. The average system time overrun in this same population sample was two years, or 150 per cent above the originally planned delivery dates. Total cycle time for new major aerospace systems is noted to be approximately ten years during which time over $500 million is typically consumed. During this long time period, the contractor is subject to a set of uncertainties that seem to defy logical pre-planning. The monopsonistic market buyer is uncertain about the future of a system; the contractor is uncertain about long run plans related to the system, and the general internal approach to system development is plagued with equal uncertainties. Throughout this process, the level of uncertainty is found to be an inverse function of the level of definition. For example, if the need for a particular system could be clearly established and the performance characteristics well specified, then contractor performance would be greatly improved, since the general level of internal uncertainties is more manageable.

Chapter III focused on the individual weapons system acquisition process and analyzed it from the standpoint of the hardware item and its total cost over the entire life cycle. Contemporary weapons systems cost from six to ten million dollars each, and the cost growth curve is an increasing function with time. Systems which constitute the next generation of aircraft will continue exponential growth rates due to the increasing levels of technology implicit in these programs. Most of the systems produced in the sixties had development costs approaching 20 per cent of the total operational investment, up from less than 5 per cent for systems produced during World War II.

The final section of Chapter III was concerned with contemporary weapons systems. In this analysis it was shown that military procurement is currently very big business and will probably continue to be equally large over the next decade. Cost overruns for large systems are still common, although somewhat reduced in size from typical cost performance in the fifties. Contemporary system data indicate that overruns of 50 per cent to 100 per cent are most common and that time schedules are being better met by most contractors. Several recent programs have been terminated for cost reasons, thus indicating an emerging trend in the government procurement philosophy toward significantly more cost consciousness. There is strong evidence to indicate that pre-planning of weapons system development tasks is ineffective due to uncertainties implicit in the situation. On the other hand, there is also strong indication that defense expenditures will be increasingly open to question and critical analysis. A paradox develops because there is insufficient proof that any presently known system is capable of indicating program status so long as high performance goals are being pursued and time is tightly constrained by the procuring agency. The most likely approach to future procurement decisions will be slower development cycles, multiple program activities oriented towards a single objective, less technological advance attempted, and increased cost and time constraints consistent with required technical performance. Within this environment, total systems cost will be stressed and an increasing level of system pre-planning appears likely.

Chapter IV discussed the historical evolution of the Criteria and other management control systems. It was noted in this discussion that the evolution of management control systems is closely linked to parallel developments in information technology within American industry. Government involvement in contractor planning and control systems was first noted during World War II. Early attempts in this segment of the procurement picture were primarily involved with highly labor-indigenous manufacturing and assembly operations. After the war, the cost and complexity of a modern aircraft weapons system increased dramatically with an associated increase in the contractor's technical skill requirements. Where the big problem of the late forties was learning curve slopes, by the mid-fifties non-repetitive engineering efforts and other previously insignificant cost elements had become of increased interest. In response to this new aspect of system management, a network-oriented control technique was conceived, and the government soon adopted this approach for the time control of large weapons systems. PERT--Program Evaluation Review Technique--is an acronym which identifies an approach to the management of large, costly, and complex weapons systems programs. By 1964, the earlier time-oriented PERT method was merged with a cost collection framework in order to measure not only schedule status, but also cost performance for the program. This second technique, titled PERT/Cost, was made possible by the increased capabilities of high speed computer systems. For the first time, large amounts of data relating to program operation could be extracted and presented for analysis.

The PERT/Cost approach to procurement was made a mandatory requirement on many weapons system development programs but was generally disliked by the using contractor due to its inflexible nature and strong input discipline. By the mid-sixties the Department of Defense began to try to develop the PERT/Cost concept on a more flexible plane. In this effort, it was envisioned that individual contractors could generate cost, schedule and performance reports so that "systems analysts" within the department could operate on a broad spectrum of environmental data in order to reach a near optimum approach to overall defense spending for the country. Basically, the Department of Defense approach is fourfold in nature. A working criteria system within the contractor organization will supply decision-making data to the following four elements: (1) programming and budgeting system, (2) contract funds status report, (3) economic information system, and (4) other system cost information reports. From the overall Department of Defense viewpoint, such a system is required in order to generate reliable and timely data to the external systems environment. By late 1966, the Cost/Schedule, Planning and Control System was created to supply such data for selected Air Force contracts. The Criteria approach thus is an evolving technique which descended directly from earlier network techniques, in particular from the PERT/Time and PERT/Cost approaches of the early sixties.

Typical Criteria implementation cost during a two- to three-year period was approximately $600,000 per company. Since this initial introductory period, many smaller contractors have become involved with the Criteria, and the larger companies have had to expend additional resources in order to meet the Criteria requirements. Due to this stimulation from a large and powerful customer, significant strides have been made in the development of management information systems within both the aerospace and electronics industries. The current approach to Criteria implementation is to design an internal set of systems which will, it is hoped, perform internal control for the contractor as well as satisfy government data requirements.

Chapter V reviewed the seven basic source documents which essentially define the Criteria. Associated with a definition of the Criteria concept is a set of terms and nomenclature which are implicit in the operation of the system described. There are several basic tenets of the Criteria, each of which involves broad segments of the contractor's organizational structure. The primary reason for inception of the Criteria was to provide cost, schedule, and technical performance data regarding selected acquisitions to the top levels of the Department of Defense in support of the newly-structured Planning, Programming and Budgeting System. Such a system requires that individual contractors supply data on a consistent, reliable, and timely basis. Theoretically, the Criteria approach allows the contractor flexibility in designing his individual planning and control system. The cognizant procuring agency essentially demands only that the total effort be controlled to the extent that the work is clearly defined, organizational units specifically delegated, internal schedules and budgets established, and variances calculated for planned versus actual performance. Contractors report that the pursuit of these objectives influences all of the functional elements of their internal organization as well as traditional methods of weapons system development.

The central purpose of the Criteria is to integrate analytically time, cost, and performance parameters. Definitive concepts related to earned value and Work Breakdown Structures are prerequisite to this task. In essence, the earned value technique provides the means for an integrated measurement of cost and schedule performance against plan. Planned value of work accomplished (PVWA) is thus designed to indicate the performance of a specific set of tasks versus the original budgeted cost of these tasks. Planned value of work scheduled (PVWS), on the other hand, measures the anticipated fund expenditure at some designated point in time. Earned value variances are thus found to be useful for comparing both schedule and cost performance versus the original plan. Earned value parameters have given individual contractors many problems since their inception in the early sixties. The technique requires that budgets be established for each element of the total task; each budget must then be time-phased over an appropriate time period and, finally, task accomplishment must be measured so that the earned value calculations can be made. Each step in this process necessitates a sophisticated management information system.

Before earned value calculations can be utilized, the entire task must be first viewed as a total entity, then divided into manageable units. The Work Breakdown Structure (WBS), as defined in Military Standard 881, provides an operational approach to this problem. This concept is now being required on almost all military procurement contracts and appears to be a prerequisite to full scale Criteria implementation. The WBS is currently well accepted and utilized throughout broad segments of military procurement and must certainly be recognized as one of the early impacts of Criteria implementation efforts.

The validation process represents the mechanical bridge from theory to application for the contractor. The procuring agency is responsible for internal evaluation of a contractor's planning and control system. During the early Criteria implementation period, contractors had only marginal success in satisfying system requirements. Redundant internal control systems and program change procedures were the most frequent reasons for failure of individual contractor systems. Many contractors complained during this period that the Criteria documentation was vague; the system expense exceeded its benefit, and the required system parameters were beyond their existing capability.

Two broad areas of Criteria impact on the individual contractor's method of operation were observed. First, the search for a usable Technical Performance Measurement (TPM) system has resulted in the expenditure of a great deal of contractor resources. Thus far, this impact appears to be more conceptual than tangible in that no one method or system has yet evolved from the search. Second, many changes are now being noted in contractors' internal control systems. Basically, these changes can be summarized as an increase in the rigor and sophistication of internal management systems. Also, a remarkable degree of industry conformity is emerging from the structuring of these systems. The contractor is observing an increased emphasis on the overall task rather than a single functional area within the organization. It appears that the Criteria is stimulating the typical military contractor to refine planning and control systems in association with a much broader managerial approach to the weapons development process. The Criteria system is viewed as a highly complex man-machine management system from which there is great potential benefit, given the proper operating environment.

Chapter VI described the primary research. Interviews, case studies, and multiple questionnaire surveys were used to document the scope and impact of the Criteria on aerospace and electronics contractors. From the fiscal 1968 list of the "top 100" contractors, 69 corporations were chosen as having an aerospace or electronics orientation. This group was identified as the industry sample, and a questionnaire was circulated to document certain previously defined problem areas. One of the original premises was that the Criteria impacts would be experienced within the larger companies first and later within many of the smaller ones. For this reason, seven of the larger companies who had been previously involved with government management control regulations were chosen as a control group through which early questions could be tested or identified. Research data revealed that all of the top eleven corporations in the sample had been exposed to the Criteria, while only three companies in the lower four deciles were aware of the Criteria existence.

Comparison of contractual types for the questionnaire sample and the total defense procurement population revealed a wide diversity. The control group was characterized by a low incidence of fixed price contracts and high percentage of fixed price incentive contracts. On the other hand, the remainder of the sample population more closely resembled the total defense procurement population statistics. The implications of these statistics are important for the following four reasons:

1. Fixed price contracts are felt by managers to be less susceptible to customer involvement.

2. The degree of Criteria impact is directly hinged to the ability of the procuring agency to negotiate fixed price relationships with its various contractors.

3. Major subcontractors operating under fixed price contracts may not have to take on the full set of managerial controls that are imposed on the prime contractor who is operating under an incentive contract.

4. The government has publicly stated that fixed price contracts will be less strictly monitored, yet it is questionable whether such a document will really decrease the need for program "visibility."

Points one and two indicate that a simple increase in the application of fixed price contracts will decrease emphasis on more sophisticated contractor planning and control systems, while the final two points seem to contradict this conclusion. Most sample companies indicated that the contractual form does have some effect on resulting government involvement in program development. However, primary research data and Criteria documentation imply that the government will become increasingly involved in program performance regardless of the future trend in contractual relationships.

The questionnaire survey of the industry revealed that the amount of human resource involved in a typical weapons development program is quite large, approaching 25,000 for the average company. One of the basic managerial problems is the effective utilization of this broad group of resources. The larger companies in the survey have a greater number of technical staff personnel than companies of smaller size. Since there is no significant difference between profit margins for the two segments of the total industry sample, it is theorized that the government considers this added technical staff cost necessary for supplying additional reports and data. It then follows that increased Criteria involvement by smaller contractors should lead to a corresponding increase in technical staff personnel to generate the necessary data for satisfaction of Criteria requirements, even though the Criteria itself does not contain specific reporting requirements.

Fifty per cent of the control group companies felt that the Criteria system would not improve their ability to spot problem areas in advance, while 70 per cent of the remainder of the survey responded similarly. The estimated cost of operating such a system for a $100 million weapons program was 1.8 per cent of contract cost for the control group and 4.2 per cent for the remainder of the sample population. An independent study made during the case study phase of this research effort led to an operating cost estimate of from 3 per cent to 5 per cent of contract value. Over the last three years, members of the control group have spent an average of $2.8 million on systems design and implementation of Criteria requirements. The smaller companies constituting the remainder of the population have spent an average of approximately $475 thousand per company during the same period.

One section of the questionnaire asked managers to rank their ability to plan the future outcome of a program in terms of actual cost, time, and performance versus original estimates. Three different groups were then surveyed and their responses ranked. In each case, responses indicated that time could be best controlled, followed by performance, and finally, cost. Another section of the questionnaire focused on six elements which were frequently mentioned, during the interview stage of the research, as causes for suboptimal program performance. Although there was some disparity among the response order of the three survey groups, all agreed that the following three items were primary contributors to suboptimal performance: (1) high state-of-the-art programs, (2) varying customer desires, and (3) time restrictions ("crash programs"). It is interesting and pertinent to note that managers from all three survey groups expressed the opinion that program performance is typically reduced by factors external to the contractor's development process. The irony of this conclusion is that often the cause of inferior performance is apparently the overeager customer who simply wants the best product for his money, in the shortest period of time.

The results of the questionnaire survey summarize the Criteria impacts in the recent past, but much of the real impact is yet to be observed as a result of their restricted exposure to date. As the Criteria is required in more large systems development programs, there will be continued emphasis for the large contractor, as well as the smaller subcontractor, to undertake implementation of this concept.

Conclusions

The conclusions of this study can best be emphasized through an evaluation of each of the initial hypotheses presented in Chapter I. Basic Criteria requirements, the implementation process, and some significant problem areas have been focused upon and studied throughout the research process. This section will relate the resulting conclusions directly to the hypotheses. The more significant future impacts which the Criteria concept will have on contractor operations will be extrapolated from this discussion.

Evaluation of the First Hypothesis

The first hypothesis stated that implementation of the Cost/Schedule Control Systems Criteria will have a significant impact on most contractors involved in major weapons system procurement. The three significant areas of system cost, operational impact, and attitudinal impact require discussion to evaluate this hypothesis.

System cost.--The most noticeable impact of the Criteria requirements is the high cost of implementation and operation. Data collected from the questionnaire surveys in both the case study company and the industry sample show a significant cost associated with initial systems design and resulting implementation. Representative cost for Criteria implementation ranges from approximately $500 thousand for the smaller companies to $2.8 million for the larger aerospace companies. Recurring operating cost for the system is estimated by survey and interview respondents to be between 1.8 per cent and 4.2 per cent of total contract value. Independent estimates made during the case study effort place the operating cost within the range of 3 per cent to 5 per cent of contract value.

Operational impact.--The Criteria is changing and will continue to change operational procedures of the using contractor. The validation process focuses on five specific areas; however, there are approximately nine operational areas to which specific reference is made in the Criteria documentation.[1] Research data indicate that the typical contractor is being forced to alter internal operating procedures in order to conform to Criteria requirements in the following nine areas: (1) task organization, (2) responsibility assignment, (3) planning and budgeting, (4) work authorization, (5) resource accounting, (6) resource management, (7) planning future progress, (8) technical performance measurement, and (9) change control. The impact of the Criteria in each of these areas will be described in the following paragraphs.

The requirement for task organization implicitly assumes that a total plan of the system under contract can be made, designating all authorized work and related

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[1]This entire checklist is reproduced in Appendix D.

resources necessary to meet requirements. The Work Breakdown Structure is envisioned as the mechanism by which the task will be divided for the sake of analysis and control. Implicit in this approach is the assumption that the task can be logically planned in advance and a sequence of operations chosen. Many of the smaller contractors are still organized functionally and the WBS approach is distinctly hardware or task oriented. In such instances, there will be strong pressure for the contractor to change organizational relationships to a matrix-type organization. Some contractors have approached this problem by conforming with the Criteria requirements in regard to the Work Breakdown Structure, and then using an automated cross reference system to regenerate the necessary data for functional control operations. Regardless of the method, contractors will have to generate product data for their customer, and this may, in turn, cause the organizational structure to be molded around the external data requirements.

The requirement for stricter <u>responsibility assignment</u> differs greatly from current practices observed in the industry. In theory, the splintering of large unwieldy projects into smaller, more manageable units permits responsibility to be shared. On the other hand, this process increases the coordinative task of project management. On at least two observed occasions, the approach to responsibility assignment changed from the traditional organizational practices of using functional titles to the use of non-functional titles. In one case, a specific individual was placed in charge of the Criteria implementation for the total program. He was viewed as an "interface manager" between the operating units and the management system required to satisfy the Criteria control system. Grumman Aircraft provided the second example of how responsibility assignment is changing organizational mores. In this case, a title and a position were created for an individual placed in charge of managing all government-furnished equipment (GFE) for the F-14 program. Other examples could be given; however, the ones given should illustrate the point that a system which requires that individuals be assigned specific task responsibilities will cause the organizational structure to change significantly from functional departmentation. Much of this change is currently, and will likely continue to be, reflected in non-functional titles for many operating managers.

Criteria validation requires that planning and budgeting processes exhibit four attributes: (1) be representative of the described job, (2) establish cost elements within the substructure which delineate labor, material, and other direct costs, (3) include "time phasing" of the resource expenditure plan, and (4) classify work as either direct, apportioned, or level-of-effort.[2] Once these are accomplished, the control process is imposed, using these data as a standard for comparison.

Three very significant consequences exist as a result of Criteria requirements in this area. First, there is an increasing emphasis on the planning and budgeting process. Thus, if an overrun exists, it will do so because the cost, schedule, or technical performance has fallen behind expected plans. Second, there is an increased emphasis on preliminary budgets submitted for contractual negotiations. Previously, a budget was simply a device with which to start the program; however, there is increasing pressure to maintain a rigid program budget. The $11 million spent by Lockheed for the C-5A contract during the initial budget and proposal stage is an example of the current emphasis being placed on original budgets. As the Criteria spreads through the industry, the concept of rigid budgets will increasingly affect the smaller contractor. A third consequence, and one of the biggest problems with the increased emphasis on pre-established budgets, is the fact that they are derived under considerable uncertainty and are often deficient in many areas. From the government viewpoint, a fixed budget may be desirable for comparative purposes over

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[2] "Time phasing" means that a particular resource expenditure plan has a time dimension as well as a level of commitment.

the long run, but the contractor cannot effectively use such a device for internal control operations. A budget derived in such an environment is often no more than an estimate, yet there is a strong possibility that this will be forgotten later when cost overruns begin to occur. Contractor profits are suffering in many cases where high risk programs have been undertaken without the financial protection of the customer. Either the contractor will have to accept more risk, or the government will have to provide the contractor with an increased financial incentive for participating in risky military business.

The validation requirement for formalized work authorization procedures is essentially a program for control of committed funds. In the past, programs frequently spent more than they were authorized. This was generally a result of excessive spending by lower level managers exceeding their degree of responsibility. Most of the interviewed managers agreed that a system for tight control of funds will be difficult to enforce, but will be necessary for the contractors' own survival.[3]

From a broad impact viewpoint, the Criteria will probably have its major organizational impact in the area of resource accounting. Many of the smaller contractors do not have

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[3]Note the corporate financial strain now being experienced by Lockheed Aircraft Company as a result of cost overruns on the C-5A development program.

sufficient cost collection systems to satisfy the Criteria requirements. The recording of applied direct costs, on a basis consistent with budgets in a formal system that is controlled by the general books of account, requires an increased level of sophistication for many contractor systems. For others, the problem is more procedural than hardware, but changes in the formal accounting system will be required in almost every case.

The resource accounting requirement states that labor, material, or other direct resources must be charged at the point of usage. This will cause difficulty for some since it requires a degree of sophistication not yet attained in many companies. The material accountability requirement will be one of the most difficult operational problems due to the conflicting objectives created by the customer. The contractor needs to know the total level of material commitment for such things as progress billings and cash flow analysis. The new requirement now specifies that material will also be tracked through the inventory cycle and specifically identified upon entering into the actual production cycle.

The requirements in this area necessitate broad systems changes for the typical contractor. Improved material resource data will emphasize the dollar commitment in inventory which has not yet been consumed by the work-in-process. The contractor must now spend more time considering not only how many components of an item are required, but also how a more accurate determination can be made of when these will be needed. One result of this broad industry change will be an improvement in the ability to retrieve historical cost information. This, in turn, will have an impact on the method of making cost estimates and proposals, as well as on resource accounting techniques. These benefits are not being fully realized at the present time, however, because of the general complexity of the requirements in this areas.

Implementation of the Criteria will bring together data relating to all phases of the total <u>resource management system</u>. Interrelationships of the overall effort will become more apparent, and there will be a tendency for management to centralize many of the major program decisions and some of the decisions previously made at subordinate levels of the organization. A prerequisite of this will be that the reported data are found to be accurate, timely, and sensitive enough for high level managerial decision making.

In addition to the improved availability of data, there will be an increased emphasis on the total set of program performance parameters. A management approach involving the trade-off of cost, time, and performance becomes an execution of economic theory. Associated with these data is an increased awareness of the earned value concept and variance analysis. Since earned value requires sophisticated data regarding actual accomplishment, there will be pressure upon contractors to upgrade reporting systems. This will be particularly noticeable for the smaller contractors who are presently using pseudo-manual systems. For other contractors, using a disjointed set of operating systems, there will be an increased emphasis for systems integration.

There is also an increased emphasis on planning future progress and, assuming the continued use of the Criteria or some similar system, this emphasis will continue to grow. Plans must be continually updated with new estimates for time of completion, Work Breakdown Structure cost estimates, and plans for the achievement of technical objectives. The contractor must show evidence that such data are being distributed and used internally. In addition, plans must be formalized showing approaches for correcting discrepancies in the overall operation. Continual efforts must be made to forecast program operational parameters for ultimate cost, schedule, and performance of the system.

The total dimensions of technical performance measurement have not yet been defined, and a practical method of implementing such a system is also not well defined. Due to this lack of guidance, contractors are proceeding along diverse paths in achieving this objective. Basically, the process involves the establishment of quantitative performance parameters, estimating the present ability to achieve this level of performance, and then tracking the actual progress through the development program. If it can be shown in early applications that contractors can, in fact, predict their future ability to meet performance objectives, then technical performance measurement systems will pervade the industry. On the other hand, if such systems are found to have little validity, then this portion of the original Criteria should fall out of the total system. Currently, the milestone approach is most commonly used in conjunction with the Work Breakdown Structure to indicate, on a rough scale, the achievement of technical objectives. All the surveyed companies were familiar with the milestone approach and others were using similar network oriented methods. Until a firm policy decision is made by the Department of Defense, many companies will continue to experiment with multiple approaches to the technical performance measurement problem. The Criteria has already had a great impact by requiring the innovation of techniques to measure performance and set quantitative goals for achievement. Further significant changes should evolve from this early effort.

A criteria system attempts to maintain the integrity of an original budget through a set of restrictive change control procedures. Past history reveals that contractors often use the change mechanism to increase budgets which are inadequate due to poor original estimates or deficient performance. The Criteria requires that work packages that have been opened cannot be changed. Changes may be made to unopened work packages so long as formal documentation is used to show the extent of these changes and the reasons therefor. Before contractual relief can be gained by the contractor, he must be able to substantiate that cost increases are caused by changes in the original scope of the contract or reprogramming changes dictated by the customer. For changes in the contractual "baseline," the government on-site representative has automatic access to the indicated records for the purpose of supporting contractors' claims. The government is holding firm to this requirement and allowing the contractor's profit to suffer or vanish completely. In many of the contemporary weapons systems programs, this aspect of the Criteria has proved to be disastrous. In some cases, the contracting agency was unable to substantiate cost claims by use of the formal internal systems; therefore, increased costs were absorbed by the contractor.

The impacts described in the operational areas are thus significant and in agreement with the first hypothesis. However, the overall impact will be in more than the dollar cost or operational areas. Successful implementation requires a significant attitudinal change by the human element within the organization. This final broad area of Criteria impact will be discussed in association with the second hypothesis.

Evaluation of the Second Hypothesis

The second hypothesis stated that contractors are adverse to the Criteria and its associated level of government involvement. In essence, contractor attitudes toward the Criteria were hypothesized to be negative. Beyond an intuitive reaction to questionnaire answers and personal observations, this hypothesis is quite difficult to analyze. The Criteria system, as currently designed by the government, appears to relay differing images of utility to the various parties of the acquisition process. On one side, the government as a customer views the Criteria as a solution to many of its cost and schedule problems noted over the past years. The contractor, on the other side of the implementation fence, views the Criteria mainly as an infringement on his classical management prerogatives and an added cost in the development of future weapons systems. Other groups, such as management theoreticians, view the implementation of network management techniques as a beginning of total system models for the firm. Each of these views represents a part of the total potential impact of the Criteria.

Questionnaire responses lend strong credence to this hypothesis in that contractor management proved to be basically against the increased level of rigor and sophistication implicit in a Criteria-type system. Some responses indicate that top management neither understands nor wants a system like the one required by the Criteria. On the other hand, the procuring agencies are using this system as a major condition for contractual source selection; therefore, all large companies that wish to stay in the defense procurement environment are being forced to adopt the Criteria methodology in order to be eligible for new contracts. Thus, in spite of their negative feelings, contractors are being forced into submission. At present, the controversy surrounding Criteria implementation does not involve the procedure as much as the attitude. Most noticeable in this category is the typical human resistance to change from traditional methods.

Case study observations revealed that imposed systems of the Criteria type often cause employees to undermine an otherwise logical system. Rather than make changes to an existing system, the new system is often added parallel to it. An obvious result of this is redundant control systems, one of which serves the internal operation and the other used for customer reporting. It is one thing for the government to require that the Contract Work Breakdown Structure (CWBS) be used for internal control as well as Criteria operation, but it is another matter for this to occur in fact. The case study provided an example of this problem. A central management systems development staff group designed a tracking system to locate parts in assembly. In theory, this system was less complicated than some already in operation, but in operation the system failed. Resistance to change was one major factor in the failure of this system, although many of the other behavioral problems discussed below also contributed to failure.

As systems become more automated and operating procedures more complex, the input requirements become increasingly regimented. The result is that many managers and other personnel feel subordinate to the operating system. One result noted in the case study example was that managers would willingly make data inputs to a system only so long as the benefit from such activities was greater than the effort involved in the system maintenance. Interviewees commented that in some functional areas of the industry, such as engineering, there has been a long history of a less structured managerial style. An increase in the regimentation of control reporting is, therefore, not a popular concept. All research data indicate that engineering managers are opposed to the level of systems discipline required to successfully implement the Criteria.[4]

Not only will implementation of the Criteria challenge the engineering manager, but increasing emphasis will be placed on structuring broader corporate managerial attitudes, in general. Managers strive toward making their overall function appear well controlled. This objective can best be

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[4]Systems discipline is the term often used to describe an individual or organizational unit that exhibits the regimentation required by a sophisticated system.

achieved within a single organizational unit if the manager freely allocates funds and resources among the various activities. One common method of doing this is to allocate or assign charges from slipping activities--over-budget work packages--to other work packages which are under-budget. If this is not carefully controlled, individual item cost accuracy will be illusory. Managers must not only be working under a formal control system, but must also be dedicated to its success before maximum results can be achieved. To date, there is little to indicate that this attitudinal gap has been bridged.

Questionnaire responses and interview comments indicated a general lack of top management interest in the Criteria. Such an attitude is difficult to explain if the idea is accepted that a Criteria system will supply any portion of the organization with more data than it has had under traditional systems. Some of the surveyed companies had existing management information systems which satisfied their internal purposes, and they were opposed to the additional Criteria requirements. In these cases, the objection was not to the availability of more internal data, but more probably to the availability of more data to the customer and increased operational expenses for the organization. A. A. Kaufman, Vice President of Litton Systems, recently summarized the existing industry attitudes toward Criteria-type systems and warned of a significant potential problem regarding the

Criteria. He stated that "Industry has the capacity to supply enough fictional data to deceive both the government and themselves."[5] The current level of contractor resistance to the Criteria has shown some signs of weakening over the past year. However, there is still strong opposition to the increased level of program "visibility" implicit in Criteria implementation.

Evaluation of the Third Hypothesis

The third hypothesis stated that the Criteria represents a marked change in government philosophy regarding contractor performance measurement. Data collected during this research indicate that there is a significant correlation between Criteria implementation and improvements being made to contractor performance measurement systems and procedures.

Cost performance.--Survey data show that cost performance is being more stringently monitored in major weapons system development programs. Questionnaire responses further substantiate that cost performance is being increasingly emphasized relative to performance and schedule parameters. In all areas, the Criteria appears to represent an increasing government reaction to weapons systems cost overruns.

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[5] A comment made at the National Contract Management Association Seminar, Washington, D.C., August 8, 1969.

Time performance.--According to questionnaire and interview sources, time performance is easier to predict than either cost or technical performance. The maturation of network management techniques during the sixties has had a significant effect on this aspect of contract management. Little support could be found for the assumption that Criteria-type approach would have an additional effect on existing contractor scheduling methods.

Technical performance.--The Criteria requirements are having a significant effect on contractor procedures regarding the measurement and control of technical performance. This aspect of the Criteria remains the major undefined and unsolved segment of the overall set of requirements. In essence, the government is looking for increased predictability, not only for cost and time performance but for technical performance as well. The Criteria are the first known formal approach to this aspect of contract management. Thus, the third hypothesis is well substantiated in this area.

Format flexibility.--Traditionally, government requirements have become quite regimented and formalized. It was the initial premise of the Department of Defense that the Criteria be a broad set of system characteristics which essentially define only output requirements. Under this assumption, the contractor is allowed to supply internal definition and structure to his own system. To date, this initial premise has not been violated. There is, however, an increasing amount of documentation regarding content, structure, rules, interpretation, and other related items. Many contractors are finding it easier to follow the large companies' lead rather than to innovate. This trend is leading to a remarkably structured and uniform approach to system implementation with an accompanying loss in individual innovation. As the level of flexibility decreases, the Criteria requirements become quite similar to the myriad of previous governmental regulations. Thus, as far as flexibility is concerned, it seems unfair to lable the Criteria approach a significant departure, in philosophy, from previous Department of Defense regulations.

Four key areas have been discussed as representing potential marked changes in government regulatory philosophy. Analysis in these areas confirms this hypothesis in only two of the areas: increased emphasis on cost performance and formal pressure on contractors to develop more sophisticated technical performance measurement systems. Little support could be found to support the hypothesis in regard to changes in scheduling requirements or format flexibility.

Evaluation of the Fourth Hypothesis

The premise of the fourth hypothesis is that no single managerial technique is capable of satisfying the broad spectrum of requisite Criteria conditions. Implementation of the Criteria requires a highly sophisticated information system to monitor cost, time, and technical performance. Most contractors are approaching the implementation process by attempting to integrate existing accounting, inventory and production systems into a broader data collection package.

It obviously is a great task to integrate inter-organizational systems, but the real problem is even greater than this. Texas Instruments and other primary subcontractors are being required to generate data for a broad cross section of prime contractors. If such is to be the case in the future, the smaller contractor's system will have to be compatible with all of the larger contractors with whom they may do business. If the original Criteria concept remains intact, then the impact will be much more than just an integration of contractor sub-systems.

The research survey revealed a universal reliance on network management techniques to satisfy cost and schedule requirements; however, technical performance measurement is relatively unaffected by such an approach. Two problems arise from the nature of network techniques. First, the PERT technique assumes a predetermined and logical sequence of events necessary to develop, test, and produce a weapons system. The case study research performed in association with this report indicates that this assumption may not be valid. For example, the testing cycle can be performed in numerous ways and is often changed to facilitate availability of equipment, to adapt to unforeseen circumstances, or for other reasons. Sequences of events are often changed throughout the cycle, and such changes interfere with the operation of a PERT control system. Second, the PERT technique has been designed for use in large, non-repetitive programs. Since large production programs fall within the boundaries of the Criteria, there is good reason to question the applicability of a network approach for high volume production programs. Peter Schoderbek and Lester Digman have explored this problem and concluded that PERT's applicability is secondary as a program moves from the development stage to the repetitive production operation.[6]

The scope of the Criteria is such that a total information system is needed to satisfy all of the requirements. No single managerial technique such as cost accounting systems, production control devices, or PERT/Cost is sufficient to satisfy these Criteria requirements either within the internal organization or for a multi-organizational system.

Future Implications of the Criteria

The long range evolution of the Criteria concept will be dictated by the success of this technique regarding the

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[6]Peter P. Schoderbek and Lester A. Digman, "Third Generation, PERT/LOB," Harvard Business Review (September-October, 1967), pp. 100-110.