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STUDY OF METHODS FOR EVALUATION OF THE PERT/COST MANAGEMENT SYSTEM

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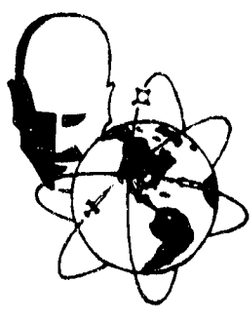

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FOREWORD

The author wishes to acknowledge the suggestions, ideas, and criticisms, all of which helped materially in the preparation of this document, furnished by the following persons:

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STUDY OF METHODS FOR EVALUATION OF THE PERT/COST MANAGEMENT SYSTEM

ABSTRACT

The Department of Defense, in June of 1962, promulgated PERT/COST as a new general purpose management system for use on major military system acquisition programs. Initial implementation and testing of PERT/COST are being accomplished by the Air Force on the F-111 (TFX) weapon system at the Aeronautical Systems Division (ASD) by a special Air Force Systems Command (AFSC) implementation team under the supervision of the PERT/COST subgroup of the AFSC PERT Control Board. Secondary applications of PERT/COST are being made at the Ballistic Systems Division (BSD) on the Mobile Mid-Range Ballistic Missile (MMRBM) program and at the Space Systems Division (SSD) on the Titan III program.

Mitre has investigated the question of how to evaluate the design of the PERT/COST management system. Four different approaches have been considered. This document presents the results of such effort.

The general conclusion is that there is no single, simple straightforward way of deriving value judgments as to the PERT/COST system design, or probably any other general purpose management system for that matter. Because of the unavailability of comparable cases and the lack of significant quantities of cases for statistical techniques, no scientifically recognized techniques, which exclude judgment on the part of the observer, appear possible. Furthermore, due to the interrelationships between a management system and the quality of its implementation operation (including the capability of the managers who use it), assessment of the value of the management system alone presents serious difficulties of both a theoretical and practical nature.

Subjective evaluation by use of carefully prepared questionnaires appears to be the only feasible approach at this time. Additional effort to develop techniques with an objective content is recommended. An evolutionary management system development program is strongly urged.

REVIEW AND APPROVAL

Publication of this technical documentary report does not constitute Air Force approval of the report's findings or conclusions. It is published only for the exchange and stimulation of ideas.

FRANCIS J. HOERMANN
Colonel, USAF
Comptroller

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SECTION I

INTRODUCTION

PERT/COST is the name of a newly devised management system, planned as an improvement over the basic PERT/TIME technique. The PERT/TIME technique is a management tool currently in use principally for program planning, scheduling and status reviews. The essential new characteristic provided by PERT/COST is its integration of explicit program cost planning and control with the PERT/TIME program planning and control technique.* There have been small-scale experiments of techniques similar to PERT/COST by the Air Force, the Navy, and a number of defense contractors over the past two or three years.

The Department of Defense (DOD) and the National Aeronautics and Space Administration (NASA) have recently agreed upon a common general design approach to PERT/COST. The Air Force has selected the F-111 (TFX) weapon system program for pilot testing of this approved PERT/COST design approach on a full-scale weapon system program. It has also selected the Titan III and the Mobile Mid-Range Ballistic Missile (MMRBM) programs to serve as secondary programs for additional Air Force experimentation with PERT/COST.

The MITRE Corporation and the Electronic Systems Division (ESD) of the Air Force Systems Command (AFSC) were initially requested to perform an independent evaluation of the approved PERT/COST management system design, as implemented on the TFX weapon system.

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*In this memorandum, the term PERT/TIME will be used to mean the planning, scheduling, and program status assessment tool, without a cost dimension. PERT/COST will be used to denote a PERT/TIME technique integrated with a cost planning and control technique. PERT will be used to refer to the technique generically, without implication that either PERT/TIME or PERT/COST in meant.

This document describes various approaches which MITRE considered in an attempt to propose a practical method of accomplishing such evaluation on an objective basis. Meanwhile, in the absence of a manageable technique for objective evaluation, the DOD is conducting its own evaluation of PERT/COST on a subjective basis by use of a questionnaire to all military agencies attempting its use.

SECTION II

GENERAL HISTORICAL BACKGROUND

PERT/TIME EXPERIENCE

The original or "classical" PERT/TIME technique was developed initially for the Special Projects Office of the U.S. Navy's Bureau of Weapons, for use on the Fleet Ballistic Missile (FBM) program. The Navy approach involved, as the author understands it, the use of separate networks on a contractor-by-contractor basis. Data are gathered and processed on that basis, and manually integrated by personnel at the Special Projects Office. It is generally understood that PERT/TIME has been an unqualified success on the FBM program.

Following the Navy's lead, the Air Force rapidly adopted the PERT/TIME technique, but applied it on an over-all system basis (as opposed to the contractor-by-contractor approach of the Navy). The Aeronautical Systems Division (ASD) of AFSC prepared its own PERT/TIME computer program, an improvement over the Navy program. This Air Force program is now known as PERT I. The Ballistic Systems Division (BSD) experimented with PERT II, a PERT/TIME variant and computer program especially tailored to the special requirements of missile programs. BSD and the Space Systems Division (SSD) used the over-all systems approach, but the latter employed a variant of PERT/TIME, known as TOPS, developed by the Aerospace Corporation. ESD and MITRE first used the Navy system and program, converting to PERT I when that became available in early 1962.

Table I gives some indication of the magnitude of the current (1963) use of PERT as a military systems management tool on a system-wide basis in the Air Force.

TABLE I

Application of PERT in a Military Systems Management

	ASD	BSD	ESD	SSD	TOTAL
Number of current System Programs Using PERT	6	3	10	4	23
Number of Current System Programs Which Do Not Use PERT and Never Attempted Its Use*	20	3	10	16	49
Rough Estimate of Procurement Value of System Programs Using PERT (in billions)	$6	$13	$1	$1	$21

*Generally, these programs were initiated before the PERT technique was available in the Air Force, and phaseover to PERT was not deemed feasible.

PERT is also used for nonsystems projects, such as GFAE procurement and advanced planning and research. Such use is beyond the scope of this memorandum.

In the Air Force, PERT/TIME did not initially meet with unqualified success. Serious difficulties were encountered on at least the following systems:

AFSC Division	Program
ASD	Dynasoar (PERT I)
BSD	Minuteman (PERT II)
ESD	465L (PERT I)
Other	SAMOS (TOPS)

However, the apparent successful applications of PERT/TIME seem to outnumber the apparent unsuccessful applications. And the general opinion is that PERT/TIME has proven itself as an Air Force systems management technique.*

NAVY PERT/COST DEVELOPMENTS

In 1961, the Navy sponsored a PERT/COST research and development effort by the Management Systems Corporation (MSC). The effort involved a survey of existing approaches to contractor program cost controls, a preliminary PERT/COST system design, feasibility tests to evaluate the preliminary design,** and a final PERT/COST system design document, incorporating the measures learned from such feasibility experiments. MSC completed this program in April 1962, releasing for review, at that time, a preliminary draft of a document entitled "The PERT/COST System Design."

AIR FORCE PERT/COST DEVELOPMENTS

Prior to December 1961, Air Force attention in the PERT field had been concentrated principally upon making PERT/TIME work effectively. However, experimentation in adding explicit resource data to PERT had been undertaken jointly by some contractors and System Program Office (SPO) directors at ASD. Techniques similar to PERT/COST for nonsystems were also being considered at ASD. At BSD, PERT II was being planned in such a way that it could accommodate PERT/COST when that system was developed. Some Air Force contractors were independently looking into the question.

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*It may be worth noting that the author is not aware of any carefully planned and executed independent evaluation of PERT/TIME. It may also be worth noting that a failure analysis study of the unsuccessful PERT applications might yield considerable dividends.

**These tests were conducted on portions of the FBM program at the Lockheed Mission Division, Sunnyvale, California, and at the General Electric Ordnance Division, Pittsfield, Massachusetts.

However, it is probably fair to say that, up to December 1961, the PERT efforts at the AFSC Divisions were directed principally toward getting PERT/TIME operational on a number of different programs simultaneously. Attention to PERT at AFSC Headquarters was directed mainly toward reducing the differences in approach between the several Divisions, so that there would be a single, uniform approach to PERT/TIME in the Air Force.

During the week of December 4 to 9, 1961, however, AFSC sponsored a PERT/COST conference at BSD Headquarters. Conferees included representatives from the AFSC Headquarters, the four AFSC system development divisions, the Navy, the Army, NASA, The MITRE Corporation, the Aerospace Corporation and the RAND Corporation. This group received briefings from 12 industry and management consultant organizations on the nature of their approaches to PERT/COST and the status of their efforts. The general conclusion of the conference was that it was time to undertake a concerted PERT/COST development effort, leading toward large-scale testing on a total weapon system basis.

Throughout the early months of 1962, therefore, the Air Force proceeded with planning and organizational preparation to develop an Air Force PERT/COST system. A detailed AFSC PERT Management and Development Plan was issued by AFSC Headquarters in April.

DOD/NASA PERT/COST DEVELOPMENTS

Upon issuance of the Navy's PERT/COST system design document in April 1962 for advance review, the separate Air Force and Navy PERT/COST design efforts were coalesced. A PERT coordinating committee had been previously established at DOD level to provide coordination between the services on PERT and to furnish a point of DOD contact with other government agencies, such as NASA, the Atomic Energy Commission (AEC), and the Federal Aviation Administration (FAA). As a result of deliberations at this level, the Navy/MSC

PERT/COST system design was approved, with modifications, and released publicly as the "DOD and NASA Guide, PERT/COST System Design," dated June 1962. This document provides the basic design of the system which is being implemented on the F-111 weapon system program.

SECTION III

AIR FORCE IMPLEMENTATION AND TEST OF PERT/COST

DOD INSTRUCTIONS

By memorandum dated 1 June 1962, the Secretary of Defense officially endorsed the DOD/NASA PERT/COST System Design Guide for adoption by all the military services effective 1 July 1962. Each of the military services was subsequently instructed to implement and test PERT/COST, on a priority basis, on at least one major program in the research and development stage. For this purpose, each service was to establish a PERT/COST implementation team. The DOD further stated that additional experimentation and development of PERT/COST would not be permitted without prior approval. While each service was expected to develop its own internal procedures for analyzing and using the PERT/COST management summary reports, all such procedures were to be reviewed by the Office of the Assistant Secretary of Defense (Installations and Logistics) to assure uniformity.

AIR FORCE SELECTION OF THE F-111 PROGRAM FOR TESTING OF PERT/COST*

AFSC, acting as the responsible USAF PERT control agency, appointed ASD as the key division for implementing PERT/COST, and selected the F-111 (TFX) program as the system program for the first full-scale PERT/COST testing. This PERT/COST effort on the F-111 program is to be carried out with high priority, but in such a manner that it does not provide major interference with the weapon system program. Insofar as possible, therefore, PERT/COST development and test activities are to be performed apart from the weapon

*The Navy has selected the Typhon System and certain FBM subsystems for its initial system tests of PERT/COST. The Army has selected the Mauler program for PERT/COST testing.

system program. The MMRBM program is presently designated as the follow-on or second PERT/COST test bed. A third program authorized to experimentally use PERT/COST is Titan III.

ROLES OF PARTICIPATING ORGANIZATIONS

The AFSC PERT Control Board (PCB) is the official AFSC organization with over-all responsibility for the development of PERT/COST and its application and testing on Air Force system programs. The PCB is responsible for review and approval of proposed changes to, or deviations from, the DOD/NASA PERT/COST System Design Guide and the approved or planned AFSC PERT configurations, including contractor and military service input and output data-reporting formats. To assist it in this activity, the PCB has established a PERT/COST subgroup to monitor all authorized PERT/COST efforts.

A special AFSC PERT/COST implementation team has been formed to adapt PERT/COST to the F-111 program, implement it, and assist in its initial operation. The chief of the implementation team is responsible for the management of this effort and for the detailed application of PERT/COST procedures and techniques to the weapon system program. The PERT/COST implementation team has four major subdivisions:

(a) Design and Development

(b) Implementation

(c) Organization and Manning, and

(d) Integration and Analysis.

Specific tasks assigned to the Design and Development group are to be accomplished by joint participation of personnel from the PERT staff groups of ASD, BSC, ESD, and SSD under the administration and control of the chief of the AFSC implementation team. Insofar as design details affect the F-111 program, they are subject to the approval of the F-111 SPO Director.

The Commander, ASD, is responsible for the conduct of the PERT/COST pilot test on the F-111 program, including development of procedures, supervision and control of the AFSC PERT/COST implementation team, and deliniation of responsibilities between the implementation team and the TFX system program director.

The Commanders, ESD, BSD, and SSD, are to provide manpower and other support as agreed upon between representatives of the AFSC PCB and such divisions.

The Commander, BSD, assisted by personnel of the Aerospace Corporation is also to provide the implementation team with BSD representatives who will not only assist in the F-111 PERT/COST system application, but will also coordinate and agree upon the details of PERT/COST as it will be applied to the MMRBM program (and subsequent BSD programs). The BSD representatives will provide the nucleus for a later BSD PERT/COST implementation team.

The Commander, ASD, is authorized to contract for outside assistance, subject to the limitations and requirements of AFSC Memorandum, dated 29 May 1962, entitled: "Use of Consultant Firms to Support Management Programs." The Management Systems Corporation has been employed to act in an advisory capacity to the AFSC implementation team at ASD.

PRELIMINARY GUIDELINES FOR PERT/COST EVALUATION

The AFSC PERT Management and Development Plan of April 1962 (as amended) tentatively suggests that PERT/COST performance be measured, in general, by the capability of the system to meet its objectives and, more specifically, by certain particular criteria such as timeliness and regularity of reports, accuracy of data, etc. At the time this Plan was issued, however, it was well understood that the method of evaluating PERT/COST had yet to be worked out. This memorandum, therefore, reflects the first comprehensive

attempt to develop a way or ways to evaluate PERT/COST on an objective basis. As such, it has been written with the material in the AFSC PERT Management and Development Plan in mind, but not in any way constrained by the plan.

SECTION IV

TWO BASIC TYPES OF EVALUATION

MANAGEMENT SYSTEM LIFE CYCLE CONCEPTS

A management information system (which is what the PERT/COST system is), or any data system, may be generally considered to have a system life cycle of a type analogous to a command information system life cycle, in terms of a conceptual phase, an implementation (acquisition) phase, and an operational phase.

In a conceptual phase, one's attention is focused on activities such as the following: recognition of a need for improvement over the current mode of management operations, including a management analysis; definition of the functional requirements deemed necessary or desirable to improve the situation to acceptable limits; investigation of currently known alternative management system design approaches (including the current mode of management operations as one alternative) which will fulfill the functional requirements, and selection of a preferred approach; preparation of an over-all system design concept, or selection of a preferred system design concept from among possible alternatives; and, finally, preparation of preliminary system designs. Pilot testing of a system prototype in a small and controlled part of the management environment is probably the most advanced step that might be ascribed to the conceptual phase.

The system implementation phase involves such matters as: the writing of detailed procedures; establishment of data flow content, frequency and format; writing of any necessary computer programs; acquisition of all necessary data-processing and communication equipment; training of personnel who must provide data inputs to the system, and indoctrination of persons who will use

outputs of the system for management decision-making or other action; and integration of the system with the other management systems or techniques alongside of which it is to operate. It includes provision of the initial operational inputs to the system and analysis of initial system operational outputs to assure that the management system is operating in the manner intended.

A system operational phase involves use of the system for management decision-making and other action. As the name implies, this phase also includes steady-state operations for an indefinite period.

It is not the purpose of this report to explore in detail all of the possible steps or the sequence of steps involved in management systems development (such matters are, within limits, reasonably debatable in today's state-of-the-art).* Rather, the life cycle of a management system is compared to that of other military systems to point up the fact that there are two fundamentally different types of system testing and evaluation in a management system life cycle, just as there are in other types of systems, namely:

(a) "system design evaluation," which evaluates the adequacy of the design of the system; and

(b) "system operational evaluation," which tests whether the system as implemented is, in fact, performing as it was designed to perform.

SYSTEM DESIGN EVALUATION

The first type of system evaluation, "system design evaluation" (or "system design verification"), should be performed in all phases of a system life cycle, though with different techniques in each phase. The purpose of such continued evaluation through the life cycle is to assure sound (hopefully, optimal) system

*See, for example, AFR 300-2, AFR 300-3, AFM 171-9, AFR 375-1,2,3,4.

design. As such, it involves continual analysis of the operational requirements, the operational environment, and the proposed system design, as the design progresses from approach to functional specification, to concept, to preliminary design, to final design. At each level of detail, system design evaluation is performed to evaluate design alternatives and trade-offs.

Specifically, in the case of a particular proposed PERT/COST design, a system design evaluation seeks to provide answers to the following types of questions:

I. Does the proposed PERT/COST system design meet the needs of management?
   (a) What are the management requirements to be met?
   (b) Is the design (at each level of detailing) conceptually sound?
   (c) What areas of the system design warrant the most attention?
   (d) Are there other design concepts (including existing techniques) which are superior to the proposed design (again at each level of abstraction)?
   (e) What are the most likely causes of system failure, and what are the consequences of failure?

II. Will the proposed PERT/COST system design be compatible with its proposed operational environment?
   (a) What is the proposed operational environment?
   (b) Is the design conceptually sound for operation in such environment?
   (c) Is there sufficient flexibility in either the environment or the proposed system, or both, so that they can be modified for compatibility?
   (d) What are the consequences of identified incompatibilities with the proposed system environment?

In the conceptual and implementation phases, the tools of design evaluation (studies, experimental simulations, and tests) are aimed at increasingly comprehensive and accurate understanding of the needs to be served by the system, the environment, and the design approach, (concept and details) as they are developed. Before a management system is operational, the most comprehensive of such tools is probably the full-scale pilot test of a management system prototype. In the operational phase, one can use the system as implemented for testing purposes. This provides a feedback to design from real-world operations.

Design evaluation, at the total system level as well as at the functional and technical lower levels, is a continuous search for better definition of requirements, validation of proposed requirements, and the search for and evaluation of alternative design approaches. The results of design evaluation take the form of guidance to persons responsible for system design. Properly employed, the main thrust of design evaluation will be, as previously noted, to promote preferred (hopefully optimal) system design.

This report is addressed, principally, to the question of how to perform design evaluation.

SYSTEM OPERATIONAL EVALUATION

The second type of system evaluation may be termed "system operational evaluation." This term refers to the process of ascertaining whether or not a system, which has been designed, developed, installed, and brought to operational status, does, in fact, operate in the manner for which the system was designed. This type of evaluation does not investigate whether the system design is optimum, or even sound, but, rather, whether the stated system design objectives have, in fact, been achieved.

In the specific case of PERT/COST, an operational evaluation program would be conducted to provide answers to the following types of questions:

I. Does the management system, as installed on the TFX weapon system, meet the approved PERT/COST system design objectives?
   (a) What are the system design objectives and limits, functional and technical, if any? Are they being met?
   (b) Are the accuracy and frequency of the data within specified limits?
   (c) Is the system as reliable as the design calls for?
   (d) Do the people, hardware, software, and operating procedures, separately and collectively, function as they should?
   (e) If deficiencies are noted, can they be corrected?

It would appear that the most appropriate methods of performing this type of evaluation are field surveys and controlled tests. Field surveys consist of observing the system in operation and interrogating personnel who rely upon the system or who play an integral part in various aspects of the system's operation. Field testing involves such steps as observing the effects of feeding controlled information into the system; introducing operational deviations at various points to test system sensitivity; attempting to "penetrate" the system (i.e., deliberately injecting a misleading rosy or bleak picture); attempting to "saturate" it (i.e., deliberately burying management under too much data); or attempting to "disconcert" the system (e.g., introducing program changes more rapidly than they can be handled).

The results of such tests can serve a double purpose. First, they serve to acquaint all concerned with the practical limits of reliable system operation. They either confirm that the approved system design requirements have been

met in full or that some of them have not been achieved. The consequences of not meeting requirements are demonstrated.

Second, the results of this type of testing can be a valuable input for further system design evaluation. Design objectives may be met, but management's real needs may not be attained; in such a case, there is probably a deficiency in the original design requirements. Conversely, a design objective may be missed, but the operational consequences may be significant; in such a case there was probably an overstatement in the original design requirements. In either case, a reconsideration of design concept may be in order.

SECTION V

FACTORS AFFECTING PERT/COST EVALUATION

NEED FOR A BASIC PERT/COST EVALUATION

Many aspects can be considered in evaluating a management system such as PERT/COST. The question is: what factors should be evaluated? Before answering this question, a review of some of the alternate possibilities for a focus for evaluation is in order.

In its most simple form, PERT/COST is a data system. On the basis of certain data inputs, it creates other data outputs. One could evaluate PERT/COST as a data-processing and transmission system without critical examination of the quality of the data inputs or the value of the outputs (see Fig. 1).

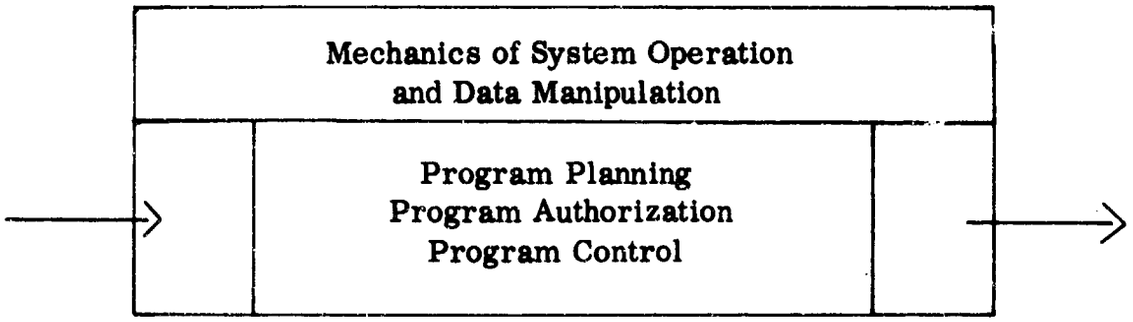

Fig. 1. Program Model

A slightly broader approach to PERT/COST evaluation would involve separate consideration of the quality of the outputs to management. The quality of the outputs is a function of the internal characteristics of the PERT/COST system and of the quality of the data inputs. The quality of the data inputs would, therefore, be included in this type of approach. It may be useful to term the inputs and the program model as "Management Investment" and the outputs as "Management Returns" (see Fig. 2). The following diagram may assist in illustrating this focus for evaluation.

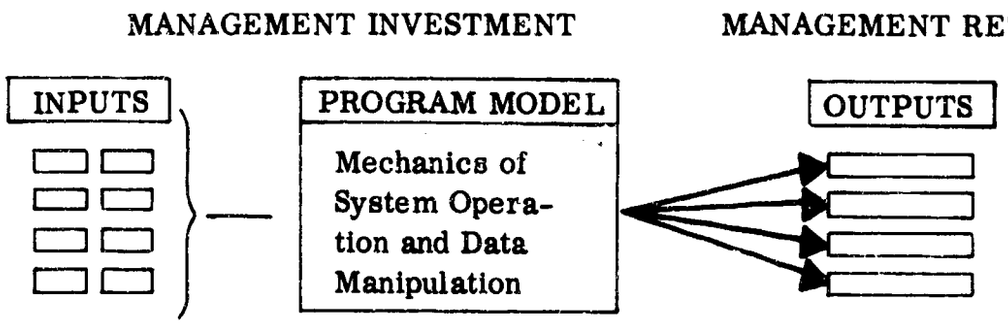

Fig. 2. Relationship of Inputs versus Outputs

Broadening the approach still further, one can add consideration of the cost of management investment in PERT/COST and the benefits of the returns furnished by PERT/COST. The former involves the theoretically easy tasks of identifying and summing all costs reasonably attributable to making the PERT/COST system work. The latter involves serious difficulties. PERT/COST does not itself manage a program. It simply furnishes information upon which, one hopes, more timely and better quality management decisions can be made. Between PERT/COST and its effect upon a military program is management, and management will make decisions and take action on all information at its command. Casual relationships between PERT/COST outputs and their impact upon the military program may not (but, in some cases, may) be identifiable (see Fig. 3).

A further broadening of the evaluation base for PERT/COST would include the impact of the system on the SPO and prime contractor management teams caused by

(a) the activities required of each of them in order to make PERT/COST operate, and

(b) the availability of the information from PERT/COST in the places and at the times called for by the system.

This approach is illustrated in Fig. 4.

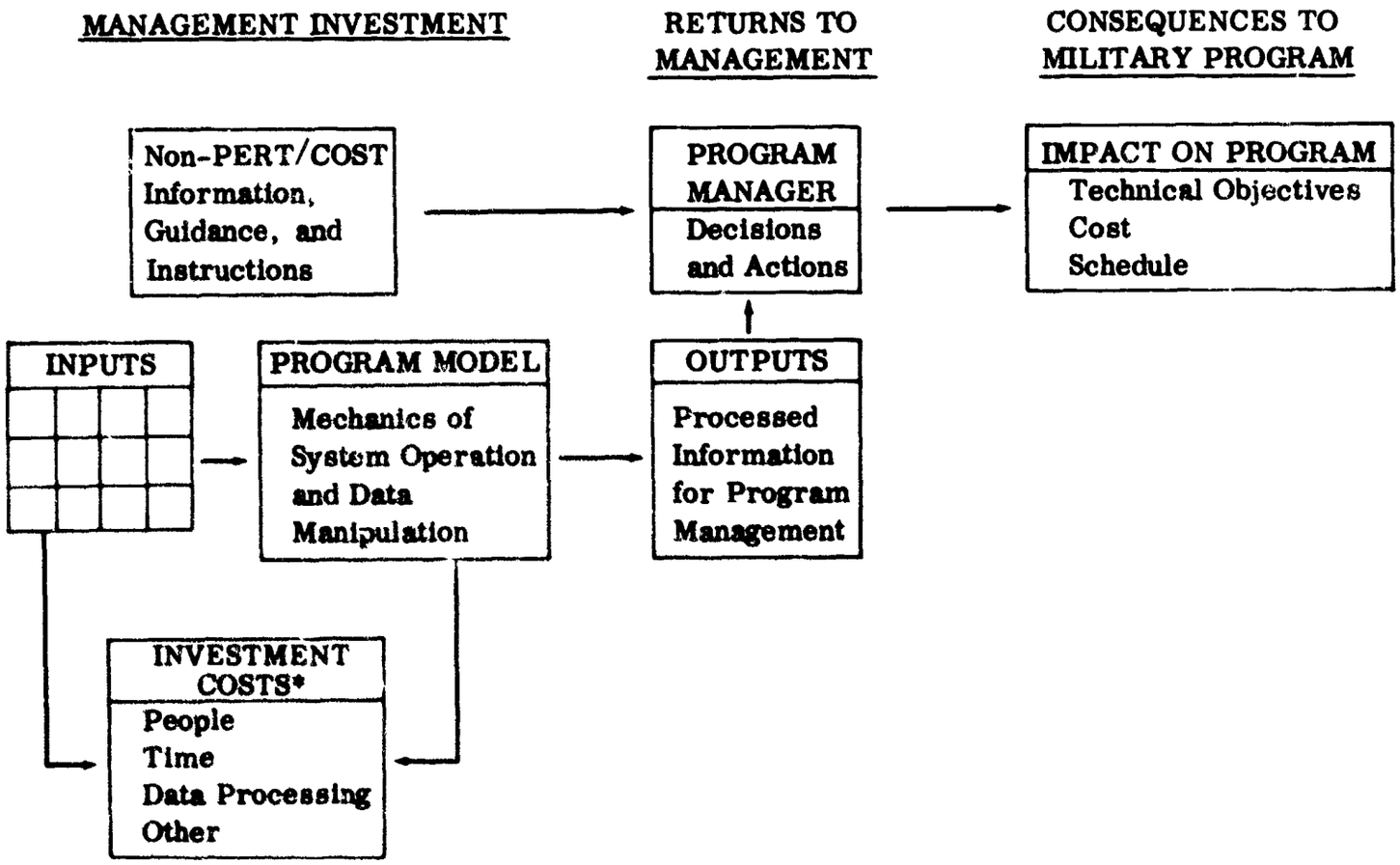

Fig. 3. Effect of PERT/COST on a Military Program

*Includes one-time costs for PERT/COST system implementation on the particular military system, continuing costs for system operation throughout the life of the system, and perhaps a pro-rata allocation of PERT/COST R&D and computer programming costs.

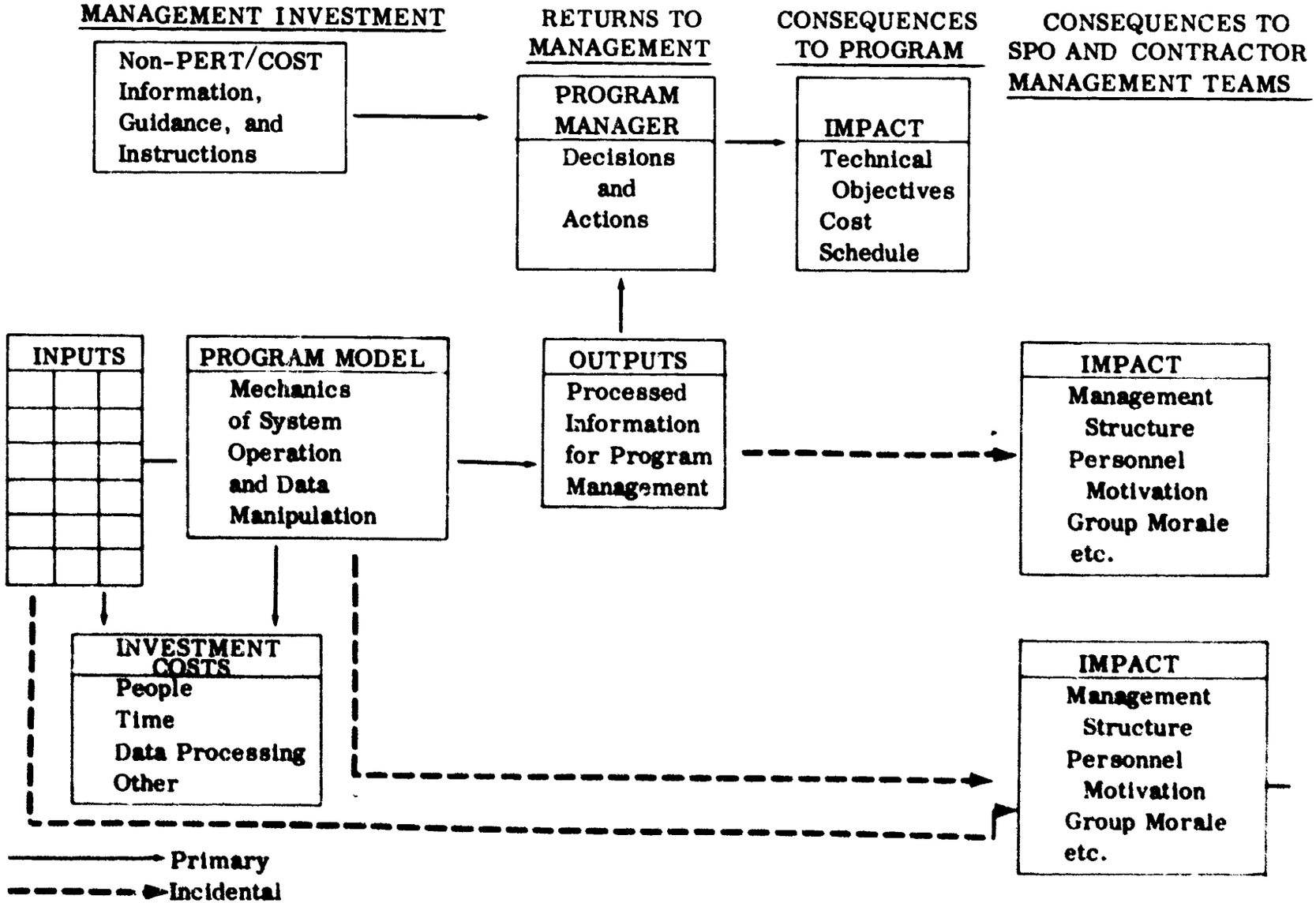

Fig. 4. Impact of PERT/COST on the SPO and Prime Contractor Management Teams

It would appear that at least one final broadening of the focus for evaluation is possible. PERT/COST will probably have some effect on other military and industrial management levels and groups; it will probably also have an effect on various other information reports not directly relevant to military programs. In short, the presence of PERT/COST will affect the military management environment just as, conversely, the environment affects the system (see Fig. 5).

From the foregoing discussion, it seems apparent that there are many criteria for evaluating PERT/COST. The following categories are suggested as focal points:

PRIMARY: The system inputs, program model, and outputs.

SECONDARY: The program management decisions and actions—the impact on the program at both the SPO and higher levels, and the cost of the management system.

IGNORED: All incidental effects—the impact on management groups at the SPO, contractor and other management levels.

In the first category, attention is directed to those aspects of program information acquisition, structuring, and presentation where PERT/COST involves use of different (and presumably improved) techniques over those that would otherwise by employed. Evaluation in depth is recommended.

In the second category, less detailed evaluation is recommended because decisions and actions by management, and their impact on the program, involve use of information other than PERT/COST. Also, the presence of management judgment must be taken into account. Factors extraneous to the function of PERT/COST necessarily enter. Whatever the focus, however, criteria must be established for evaluating and measuring PERT/COST against some standard applicable to such criteria.

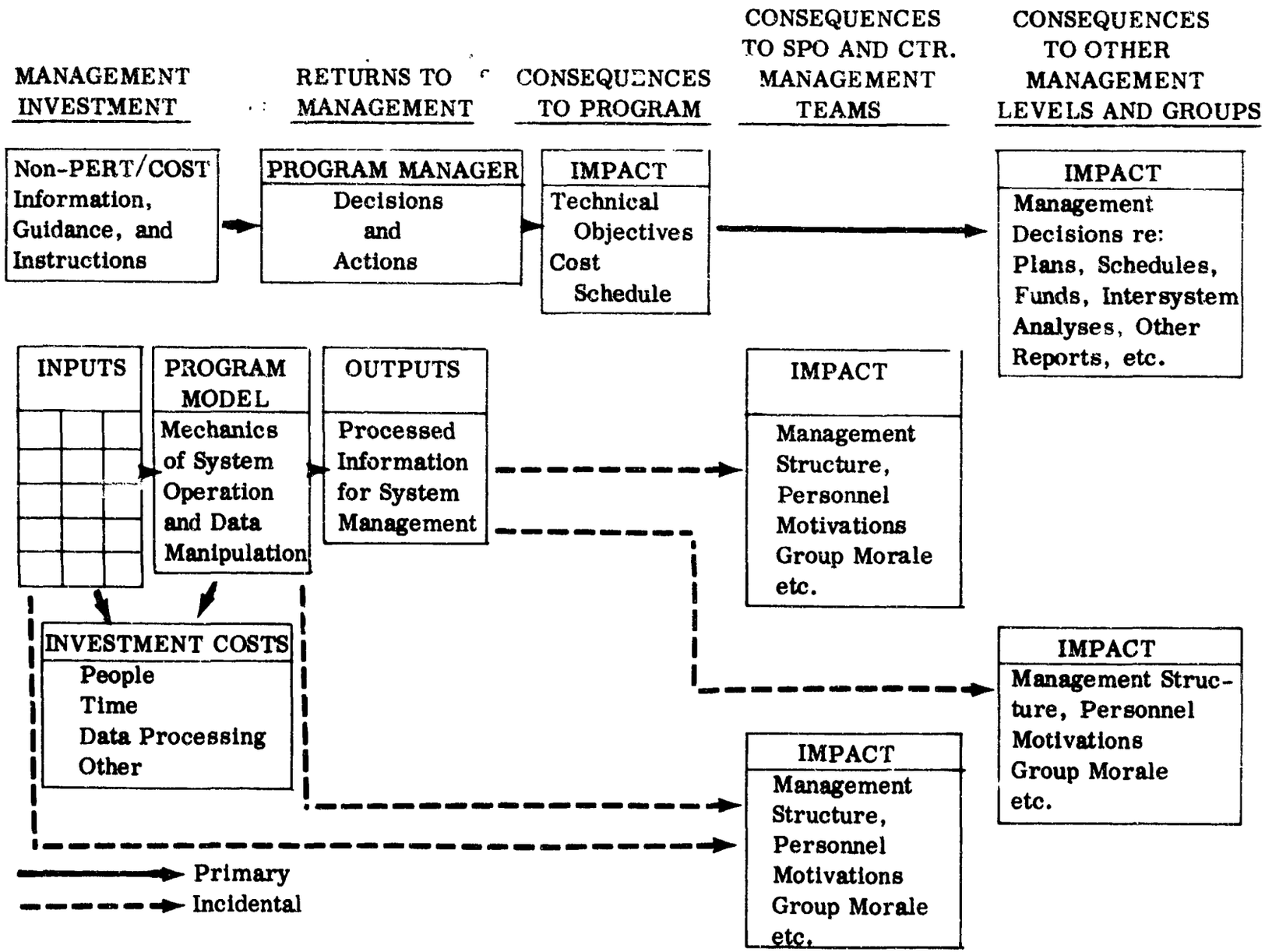

Fig. 5. Effect of PERT/COST on Military Management Environment

The cost of PERT/COST is considered to be of secondary importance for two reasons. First, much of the cost of PERT/COST would have been incurred even in the absence of PERT/COST for activities such as developing program plans, a work breakdown structure, an account code structure, periodic assessment of status, and so on. While PERT/COST requires that many of these activities be performed in a somewhat different manner, the same general type of activity would still have to be accomplished without PERT/COST.* Consequently, the cost of PERT/COST will probably be quite difficult, if not impossible, to disentangle from the cost of a non-PERT/COST approach; at the same time, it is not expected**to be significantly different. Second, the cost of PERT/COST should not be considered without reference to the savings (if any) to the program expected. Such savings (if any) are difficult to identify because of the effect of management judgment and the presence of non-PERT/COST information in the decision-making process.

Any impacts caused by PERT/COST upon SPO and other management-level organizations are incidental to or side effects of its use. For this reason, it appears appropriate to ignore them, whether their value is positive or negative. Should these impacts be of large magnitude, however, they may warrant further attention.

In addition to choosing limits for the PERT/COST process, it is also necessary to select limits relative to the management levels and the military program life cycle phases to be considered.

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* This proposition assumes government contractors already possess estimating and accounting systems capable of providing project control information in detail.

** This expectation is an intuitive one on the part of the author. Some diversity of intuitive opinion may be expected on this point.

The DOD/NASA PERT/COST System Design Guide states that the purpose of PERT/COST is to improve the management techniques at all levels of management. For the purpose of any PERT/COST evaluation, it is recommended that "all levels of management" be considered to include program management at only the SPO level, the AFSC Division and Headquarters levels, and one management level beneath the SPO project level (e.g., contractor project management). It is recognized that DOD, USAF Headquarters, USAF Logistics Command, USAF Training Command, and USAF Using Commands and others, are also levels of military management concerned with the planning, progress, and status of military systems acquisition, or parts thereof. Similarly, there are industrial management levels, above and below those mentioned above, vitally interested in the planning, progress, and status of a program, or parts thereof. However, to keep the evaluation effort manageable, it is probably satisfactory to continue attention to the four management levels mentioned above.

The DOD/NASA PERT/COST System Design Guide also states that PERT/COST is designed to meet the needs of managers at all steps in the life of a program. In the acquisition of a major military system, there are at least three major different types of activities of particular importance:

(a) program planning

(b) program authorizing and directing (selecting program participants, contracting with industry, negotiating interagency charters with supporting government agencies, etc.), and

(c) program controlling (including any partial replanning and reauthorizing necessary from time to time).

The foregoing steps fall, principally, the the Program Definition and Acquisition Phases of the life cycle of a military system program. Accordingly, for purposes of any PERT/COST evaluation, it is recommended that the Conceptual Phase and the Operational Phase of the military system program not be considered.

LACK OF AN OBJECTIVE, QUANTITATIVE STANDARD

One way to evaluate a management system is to ascertain whether it fulfills (or will fulfill) some objective, applicable standard.

In the case of PERT/COST (and perhaps other management systems, for that matter), there is no preestablished objective, quantitative standard. Probably the closest thing to a standard is the statement of PERT/COST design objectives in the DOD/NASA PERT/COST System Design Guide namely:

> Complex research and development projects can be managed effectively if project managers have the means to plan and control the schedules and costs of the work required to achieve their technical performance objectives. The serious schedule slippages and cost overruns that have been experienced on many weapon and space programs indicate that managers at all levels need improved techniques at all stages in a project to:
>
> — define the work to be performed;
>
> — develop more realistic schedule and cost estimates based on the resources planned to perform the work;
>
> — determine where resources should be applied to best achieve the time, cost, and technical performance objectives;
>
> — identify those areas developing potential delays or cost overruns in time to permit corrective action.

For example, managers at each level must be able to determine:

> — whether the current estimated time and cost for completing the entire project are realistic;
>
> — whether the project is meeting the committed schedule and cost estimate and, if not, the extent of any difference;

— whether requirements for manpower and other resources have been planned realistically to minimize premium costs and idle time;

— how manpower and other resources can be shifted to expedite critical activities;

— how manpower and other resources made available by changes in the project tasks can best be utilized.

The PERT/COST system, an extension of the basic PERT/TIME system, has been developed to meet these planning and control needs of each level of management.

At present, therefore, the PERT/COST design objectives for the F-111 program are relative. They will be "met" (literally at least) by any improvement achieved in the above factors through the use of PERT/COST.

In the absence of an independent effort in investigate and determine objective, quanitiative standards, it is necessary to conclude, at this point, that any evaluation must be accomplished by means which do not require such overall standards.

LACK OF A COMPARABLE ALTERNATIVE

Another way to evaluate a management system is to compare the results achieved in two or more comparable cases, one or more of which uses PERT/COST and one or more of which does not use PERT.

However, each military program is unique; there is no other program which is comparable. Other programs with other contractors and other SPOs involve different military systems, different technical and management problems, different contract structures and different management teams. One might consider other military programs on which the prime contractor participated in a major capacity in the past. In the case of the F-111, with General Dynamics (Ft. Worth) as the prime airframe contractor, it would be the B-58 weapon

system program. However, this program preceded the F-111 program by some six to eight years, had different technical and management problems, a different contract structure, and, in fact, a substantially different management team. In addition, a further difficulty with such a comparison is that the B-58 program did not use the basic PERT/TIME management system. This would make it very difficult to separate any advantages of PERT/COST from those which might more properly be attributed to PERT/TIME.

INFEASIBILITY OF A STATISTICAL APPROACH

Theoretically, another way to evaluate PERT/COST on an objective basis would be to utilize an approach in which use or non-use of PERT/COST is assigned randomly to a number of programs. It would then be possible to use statistical methods to determine whether there is a significant relationship between use of PERT/COST and accomplishment of program objectives. The number of programs which would be needed to obtain significant results depends upon the similarity of the program. This approach suffers from two major difficulties:

(a) a technique for measurement of program success or failure and the time lag involved in the process, and

(b) the necessity for random assignment of controls in the management of major national defense programs.

This approach does not appear feasible as a practical matter.

SECTION VI

APPROACHES TO PERT/COST EVALUATION

OBJECTIVE EVALUATION BY MANAGEMENT TASK

One approach considered in depth for an objective evaluation of PERT/COST was based upon the proposition that, basically, all of the management activities required to carry out PERT/COST are, in one way or another, present in every other thorough-going approach to military program management. That is, PERT/COST does not involve any essentially new management function but, rather, provides a new technique for fulfilling them.

The concept was that the smallest basic pieces of PERT/COST can be individually tested and evaluated first. (These pieces are referred to in the DOD/NASA PERT/COST System Design Guide as "Management Tasks.") Then the pieces could be combined into meaningful management aggregates, say, the program planning stage, the program authorization and direction stage, and the program control stage, for further testing and evaluation. Finally, PERT/COST could be evaluated on an over-all system basis.

Appendix I sets forth in detail an approach to evaluation of PERT/COST by analysis of management tasks. It contains:

(a) a brief statement of the objective of each management task required by PERT/COST;

(b) a statement of the probable impact of the use of PERT/COST (subject to verification in the actual evaluation);

(c) typical questions one must answer to evaluate the particular task in question separately;

(d) Possible criteria applicable in each case; and

(e) some pertinent comments.

The advantages of this approach are that the system is broken into pieces small enough to enable development of more precise evaluation criteria. At

such level of detail, moreover, it may be possible to make a decision on objective grounds between the management task in PERT/COST and its equivalent task using a PERT/TIME, standard cost management technique.

This approach, however, also presents several difficulties. The major shortcoming is that it is directed toward the input side of the management system, that is, a basic assumption is that if each of the necessary tasks to provide management with needed information is improved, program management will be improved. It views the management system through the eyes of the management information system staff, not the managers whom the system serves.

The next difficulty with the approach is that a method of aggregating is not readily apparent. While this approach eases the problem of lack of comparable alternatives, it does not really resolve the problems mentioned in Section IV.

OBJECTIVE EVALUATION BY MANAGEMENT FUNCTION

The next approach considered for an objective evaluation of PERT/COST was based upon the proposition that in order to manage a program, there are certain management decisions and actions (generally referred to as functions) which must be conducted. They involve identifying certain features of the program, making certain decisions, structuring a program team, communicating certain authorizations, and so forth. Such functions must be performed whether or not PERT/COST is used.

The concept was that it should be possible to define all such major management functions. When this is established, it should be possible to determine whether or not the use of PERT/COST offers any improvement for a particular function of program management. Then the pieces could be combined into meaningful management aggregates, say, the same three as used in the management task approach, with some generalizations about the system as a whole.

An advantage of this approach is that the system is being evaluated from the viewpoint of a manager using the system. Appendix II sets forth this approach to evaluation of PERT/COST on the basis of management function.

There are several difficulties in this approach. It does not resolve the fundamental problems noted in Section IV. Moreover, the several subfunctions noted in Appendix II are probably more subject to debate than are the management tasks noted in Appendix I. Finally, the criteria by which one will compare PERT/COST against a standard or an alternate become more nebulous and less quantifiable.

While the management function approach is probably theoretically preferable to the management task approach, due to its orientation toward the management system user, it appears to be much more difficult to carry out as a practical matter.

OBJECTIVE EVALUATION USING THE DOD/NASA PERT/COST SYSTEM DESIGN GUIDE

A third approach to the evaluation of PERT/COST was considered. The starting point of this approach was the statement of PERT/COST system design objectives, quoted earlier in this Section. These objectives are listed on the following page.

DOD/NASA Objective	Applicable Program Stage
1. Improved techniques to define the work to be performed	Planning
2. Improved techniques to develop more realistic schedule and cost estimates based upon the resources planned for such work	Planning
3. Improved techniques to determine how best to apply the resources to achieve time, cost and technical objectives and minimize idle time	Planning
4. Improved techniques to determine how best to shift resources for expediting critical activities and to utilize resources made available by task changes	Control
5. Improved techniques to determine whether the project is meeting the committed schedule and cost estimate and, if not, the extent of any difference	Control

Stated somewhat more simply, the DOD/NASA PERT/COST objectives are:

Planning Stage	Control Stage
Identification of work to be performed	Program progress and cost status monitoring
Realistic schedules	Comparison of status with authorized plans -- deviation anticipation
Realistic cost estimates	
Efficient application of resources over time	Replanning, reauthorization as necessary to compensate for inadequate planning, changes, and deviations

It can be observed that the program planning stage represents PERT/COST in a static mode. Types of criteria that can be applied to this mode are shown as follows:

Criteria Relating to Planning Realism

Accuracy
Inclusiveness
Precision
Nonambiguousness
Dependencies and constraints explicit
Ground rules and assumptions explicit

Criteria Relating to Planning Usefulness

Clarity
Simplicity
Correlatability of
Work to be done
Military system design
Available resources
Authorized resources
Schedules
Estimated cost
Dependencies and constraints

Criteria Relating to Management Environment

Correlatability of plans to:
- Technical fields of interest
- Air Force management structure
- Contractor management structure

The program authorization stage similarly represents a static mode of PERT/COST. But since the DOD/NASA guide does not include any design objectives relating to the authorization stage, this stage will be ignored for present purposes.

The program control stage, on the other hand, represents a dynamic mode of PERT/COST. To the extent the control stage involves replanning, the previous criteria listing is relevant. In addition, other types of criteria also apply to this dynamic mode:

Criteria Relating to Data Communication and Processing

- Appropriateness of data sources
- Appropriateness of data recipients
- Efficiency of communications
- Efficiency of data processing
- Quantity of data
- Accuracy of data
- Precision of data

Criteria Relating to Data Usefulness

- Relevance of data
- Timeliness of data
- Regularity of data
- Clarity of data presentation
- Penetrability
- Saturability
- Disconcertability

Criteria Relating to Management Environment

- Simplicity of operation
- Compatibility with Air Force management structure
- Compatibility with contractor management structure
- Compatibility with personnel motivation

In any evaluation of PERT/COST, one must recognize that PERT/COST serves three major management functions: planning, authorization and direction, and control. These functions can be considered separately — one can use PERT/COST for planning, but not authorization and control; one can use PERT/COST for planning and authorization, but not control — or as a whole. In order to perform an evaluation of PERT/COST as a whole within the framework of the DOD/NASA design objectives, it is necessary to assign degrees of relative importance to the several objectives noted. It would appear desirable to first make a gross allocation of weights between the planning stage and the control stage. On the grounds that the former is an indispensible forerunner of the latter, and that better planning (and authorization) will ease the problem of program control, let us apply a 60:40 weighting. That is, for PERT/COST as a whole, planning accounts for 60 percent of the value and control for 40 percent.

Next, within planning function, let us further assign weights to the relative importance of the four ennumerated DOD/NASA objectives. On the grounds that identification of the work to be performed is the primary step about which the others revolve, let us assign to it a weight double that of each of the other three (see Table 2).

Table 2

Planning Stage Efforts versus Objectives

Objectives	Bases (%)	
	100	60
Identification of Work to Be Performed	40	24
Realistic Schedules	20	12
Realistic Cost Estimates	20	12
Efficient Application of Resources over Time	20	12
Totals	100	60

Table 3

Planning Stage Objective No. 1:

Identification of Work to Be Performed

Criteria	Weight (%)
Inclusiveness	20
Accuracy	20
Explicitness of Dependencies and Constraints	20
Explicitness of Ground Rules and Assumptions	20
Clarity	5
Simplicity	5
Correlatability of Work to Be Done, Military System Design, Available Resources, Authorized Resources, Schedules, Estimated Cost, Dependencies and Constraints	10
Total	100

SUBJECTIVE EVALUATION

An alternative approach to objective evaluation, with its inherent difficulties, is subject evaluation, which can be used to derive value judgments about PERT/COST. Such judgments may well constitute the best, and indeed only, source of informed opinion of the benefits and limitations of PERT/COST for some time to come.

A subjective evaluation would be carried out by means of questionnaires to and interviews with responsible persons who may be expected to be informed on the management value of PERT/COST to them as key personnel in the program management team.*

*See "Management Information Systems Evaluation Methodology," C.C. Joyce, Jr., Mitre W-6221.

The bulk of exploratory effort into ways of evaluating PERT/COST was directed to objective techniques rather than subjective ones. Consequently, this document will not discuss the benefits and limitations of the subjective approach, except to indicate its existence as an avenue of possible action.

DESIGN EVALUATION CONCLUSION CATEGORIES

Since the PERT/COST evaluation is actually planned and the empirical data gathered, it should be done in such a manner so that:

(a) poor results due to inadequate implementation can be separated from poor results due to poor system design;

(b) poor results due to inadequate program management judgment can be separated from poor results due to poor system design;

(c) Benefits attributable to PERT/COST can be separated from those obtainable from PERT/TIME coupled with other cost planning, correlating and control techniques.

(d) it can be concluded that PERT/COST is valuable for program planning, but not necessarily so for program authorization and direction or program control;

(e) it can be concluded that PERT/COST is valuable for program planning and program authorization and direction, but not necessarily so for program control; and

(f) it is possible to ascertain that PERT/COST is particularly valuable for decisions and actions at the SPO Director level, but not necessarily for AFSC Headquarters or AFSC Division Headquarters levels or for contractor managements (or any permutation and combination of the above).

While definition would be desirable in a great number of other areas as well, the areas cited are probably the larger, involved ones which must be dealt with in order to say anything meaningful about the value of PERT/COST.

SECTION VII

CONCLUSIONS AND RECOMMENDATIONS

NO STRAIGHTFORWARD WAY TO EVALUATE PERT/COST

The major conclusion of this study is inescapable: there is no straightforward way to evaluate PERT/COST. The value of the system is intimately related to both the quality of its implementation and the capability and willingness of the appropriate managers to use it. The consequences of using the system can be ramified indefinitely. Military programs are not comparable, and standards do not exist. While value judgments about PERT and PERT/COST can be made meaningfully by those experienced in their use, there is no available methodology or established skill base capable of evaluating PERT/COST professionally on either an objective or a subjective basis.

SUBJECTIVE DESIGN EVALUATION FOR IMMEDIATE PURPOSES

In the absence of a clear-cut approach to an objective evaluation of PERT/COST, the DOD is proceeding with a preliminary PERT/COST evaluation on a subjective basis by means of carefully prepared questionnaires to the services, divisions and SPO Directors or their equivalents. This appears to be the correct approach at this time, since it is feasible, and since no objective alternate can be proposed. It should be recognized, however, that as much care and effort should go into preparing a subjective evaluation as into an objective one, if the data obtained are to provide a sound basis for meaningful judgments about the value of PERT/COST.

The DOD's current approach of questioning the results on all programs using PERT/COST is better than the original concept of evaluating PERT/COST only on the F-111 program. This approach will help to disentangle the cause

and effect relationships attributable to PERT/COST from those attributable to individual system idiosyncrasies.

It is doubtful that any program has been using PERT/COST long enough to have significant results from its operation.* The tangible benefits to date, if any, from PERT/COST may be expected to be derived from its static mode in program planning and program authorization and direction.

NEED FOR DEVELOPMENT OF EVALUATION TECHNIQUES

The evaluation of management systems, generally, is a subject that appears not to have been explored in depth as yet. The literature on the subject is meagre and unrewarding. Techniques for evaluating various other types of systems, both military and data systems, have been developed, but their possible adaptation for management systems has not yet (apparently) been attempted.

The need to develop a methodology and skills for evaluating management systems design covers not only the after-the-fact evaluations of systems in the field, but also tools for design verification and validation which can be employed to assist better design while a management system is still in its conceptual stage. Two approaches would seem to have great potential. One is to investigate the use of system design simulation for management systems -- possibly utilizing the evolving technology associated with ESD's System Design Laboratory for electronic systems. The other is to sponsor the cataloguing of the various management system designer's real life design constraints -- dealing with such matters as human factor design limitations, data-handling lag times, security provisions, and similar factors. An evolving management system designer's handbook (patterned somewhat after the various designer's

*As of June 1963.

handbooks pioneered at ASD) would be of great value in validating the building blocks of system design.

The methodology should encompass subjective evaluations as well as objective ones, because it is probable that the theoretical and practical difficulties of the objective approach will necessitate some mixed subjective/objective approach to be used indefinitely.

THE NEED FOR RECOGNITION OF AN EVOLUTIONARY APPROACH FOR MANAGEMENT SYSTEMS DEVELOPMENT

The PERT/COST system has already passed through a number of steps in the normal management system life cycle. The general recognition of need occurred in 1960-61. Management analyses and preliminary PERT/COST system design were accomplished in 1961-62. The general DOD/NASA PERT/COST System Design Guide appeared in 1962, and the specific Air Force manuals in 1963. An approved system concept and, in fact, design details, has been officially approved for implementation today. In short, only one system alternative is currently* under consideration, although there are some variations in its proposed applications to various systems.

It has proven useful to plan the development of some Air Force command systems on an evolutionary basis, that is, a controlled multistage effort (see Fig. 6a) instead of a single one-time-through life cycle (see Fig. 6b). The timing of the stages in Fig. 6b is planned so that the lessons learned from previous stages can be made available for design of the system in later ones. On management systems, operations under an early stage of model of the system are not converted to a later one until the capability of the later stage or model has been adequately demonstrated. If the phase-over involves too much an effort for any one particular program, it is possible for that program to use the old, outmoded system through to program completion.

*As of June 1963

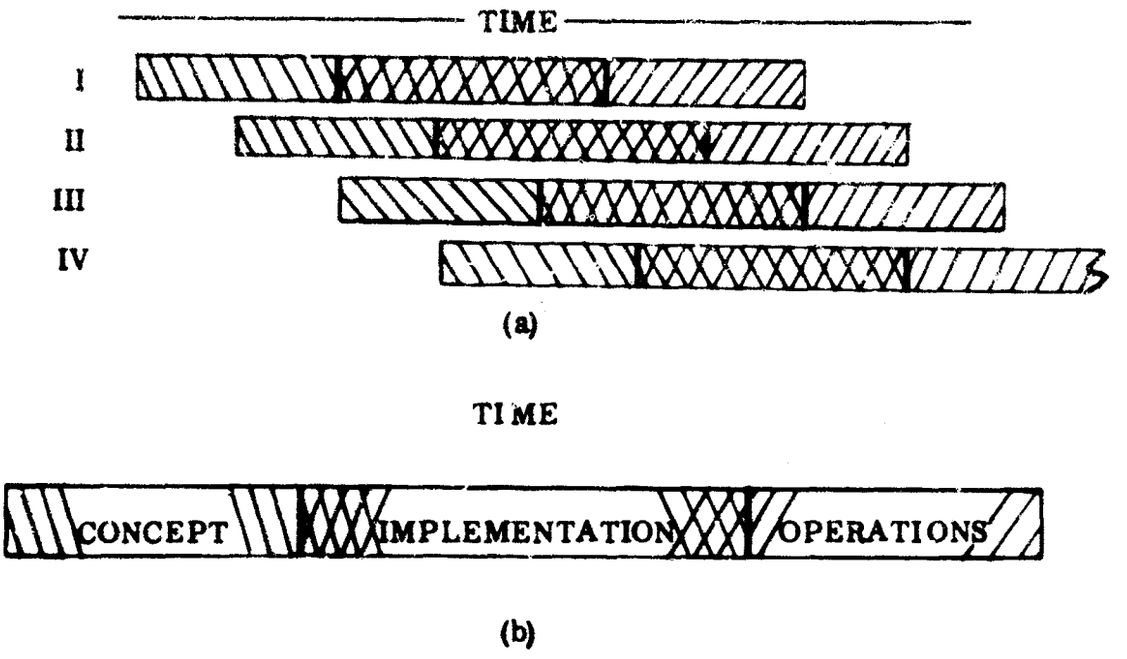

Fig. 6. Evolutionary Development versus Single Life Cycle

The evolutionary approach appears to be most useful in situations where the objectives of the system cannot or have not been clearly defined. It is ideal in cases where the ultimate capability to be required of the system cannot be foreseen, but where the direction toward which increasing system capabilities should be oriented is predictable. In short, an evolutionary approach is a good technique for controlling the development of a system capability in an orderly fashion over a period of time.

PERT/COST appears to belong in the class of systems which benefit from use of the evolutionary development concept. For example, the system has already evolved from Navy PERT to Air Force PERT I, PERT II, and PERT III. PERT/COST, or PERT IV, as it is referred to in Fig. 7, is not being considered. It is apparent to all who are close to the present effort that PERT IV is not the ultimate in military program management systems, but only a

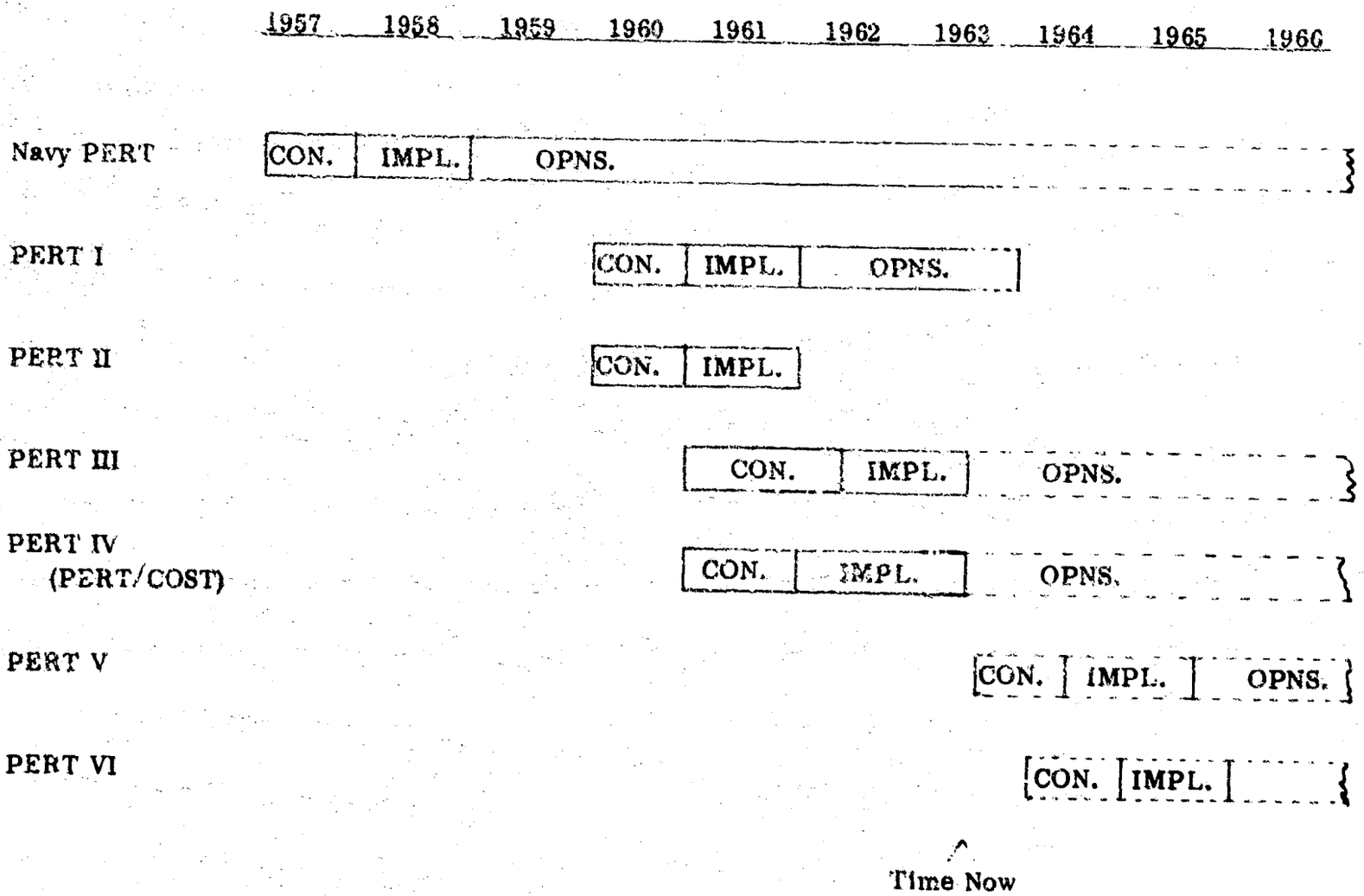

Fig. 7. Evolutionary PERT Development

stepping-stone toward even better management systems in the future. Hence, we are, in fact, already participating in an evolutionary development type of effort. This fact should be recognized and used as a cornerstone of future Air Force and DOD planning for future management systems development.

Initiative in PERT matters was originally exercised in a number of quarters (Navy, ASD and BSD). What has actually occurred up to June 1963, together with a forecast of a centrally coordinated future development effort, is shown in Fig. 7.

Figure 7 also reflects some of the overlapping and duplication of effort in this field which has occurred to date because initiative in the development of management system has been exercised at the field-operating division level.

If an orderly process of management system design improvement is to be achieved, it is essential that the process be centrally controlled and that future improvements are planned so as to take advantage of the design evaluations is prior stages. It would seem unnecessary to proceed on a "concurrent" basis to develop and implement proposed additional management system improvements before earlier management system stages are understood and evaluated.

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APPENDIX I

EVALUATION OF PERT/COST BY MANAGEMENT TASKS

A. Program Planning Stage

MANAGEMENT TASK	TASK OBJECTIVES	PERT/COST IMPACT	EVALUATION QUESTIONS	POSSIBLE CRITERIA	COMMENTS
Preparation of the project work breakdown structure	To provide a framework for planning and controlling a project which — Reduces a large, complex task into a number of smaller pieces, accomplishment of which will accomplish the over all task — Furnishes a common base for communication about the project — Furnishes a basis for schedule planning and control To provide a framework for assignment of project management responsibilities	Required by PERT/COST However, some project work breakdown structure is required regardless of PERT/COST	What is the project work breakdown structure for management control purposes under PERT/COST? What project work breakdown structure would have been used if PERT/COST were not involved? Is the PERT/COST work breakdown structure better than the non-PERT/COST work breakdown structure for management control purposes?	Inclusiveness Correlation to functional structure of the weapon or electronic system Correlation to the technical fields involved Correlation to the distribution of project management responsibility Correlation to Air Force management organization structure Correlation to management organization structure of contractors and subcontractors Correlation to contractor schedule and cost planning and control procedures	PERT/COST attempts to require a project work breakdown structure that can serve as an integrated base for technical control, cost control, and planning and schedule control. The har question here is to weigh the advantage of a project breakdown structure designed for integrated use with the disadvantage it may cause in the technical or planning and scheduling areas by being designed to accommodate cost controls

A. Program Planning Stage (Cont'd)

MANAGEMENT TASK	TASK OBJECTIVES	PERT/COST IMPACT	EVALUATION QUESTIONS	POSSIBLE CRITERIA	COMMENTS
Task and work package definition	To subdivide all project end items progressively until all are identified and defined in sufficient detail for manloading, planning and scheduling, and cost estimating and control To define the basic units (defined as work packages in PERT/COST) for which cost estimates are made and against which actual costs are collected and compared with estimate	Required by PERT/COST ~ However, some sort of task definition (by which work and accounting authorizations are opened and closed) is normally required	What is the definition of tasks under PERT/COST? What would have been the definition of tasks for the project if PERT/COST had not been used? Is the PERT/COST type of task definition better than the non-PERT/COST type of task definition for management control purposes?	Meaningfulness of size of package for project management purposes Clarity of work package definition Correlation to project planning and control structure Correlation to distribution of project management responsibility	Work packages are the roots that feed the PERT/COST management system tree. They provide the bottom level for information input. All cost and progress information is summarized from this level. This would therefore seem that accuracy, clarity and proper size are of paramount importance.
Preparation of the account code structure	To provide an accounting framework which enables one to collect actual costs against the lowest level work packages separately and summarize them in accordance with the work breakdown structure	Required by PERT/COST However, some sort of account code structure is required regardless of PERT/COST	What is the project account code structure? What would have been the account code structure if PERT/COST were not involved? Is the account code structure under PERT/COST or the non-PERT/COST type account code structure better for management control purposes?	Correlation between the account code structure and work packages and the work breakdown structure No. of account code nos. to be used. Frequency of change in account code numbers for any given employee or group of employees Frequency of policing the charging of actual costs	Human beings have to live by the account code structure --and charge every manhour, material dollar and subcontract cost against it. Simplicity and foolproofness are desired as well as the logical collection and summarization of cost data to management. If the account code structure is de facto unworkable, the entire value of PERT/COST is compromised.

A. Program Planning Stage (Cont'd)

MANAGEMENT TASK	TASK OBJECTIVES	PERT COST IMPACT	EVALUATION QUESTIONS	POSSIBLE CRITERIA	COMMENTS
Construction of PERT COST Networks	To develop a graphic display visually relates all project tasks to one another in a manner which shows dependency constraints, and therefore shows planned sequencing of work tasks	Networks are required by PERT TIME. PERT COST apparently involves use of modified PERT TIME networks.	How were the program PERT COST networks prepared? What difference is there between the PERT COST type of networks and the PERT TIME type of networks? What type of network is better for management control purposes?	Identification of all activities and events of significance Identification of all dependency constraints of significance Accuracy Simplicity Clarity	A program network is a visual portrayal of the total project plan. It is a project model Its value lies in its being true to life in all important features yet as simple as possible, and providing the information and capability for its manipulation.
Time estimation	To understand the probable time duration required to perform each piece of a project and the program as a whole To provide a basis for realistic project scheduling To provide a basis for realistic planning of resources to accomplish a project on schedule	Required by PERT TIME However, the coincidence of PERT COST may involve some modification of PERT TIME approach	How were the detail PERT COST time estimates prepared and total program duration calculated? What difference is there between the PERT COST and PERT TIME here? Which approach is better for management control purposes?	Accuracy of estimates Size of unit for which time estimates are obtained Analogical basis for making estimates Confidence in the accuracy of the estimates Simplicity of ground rules and assumptions underlying the estimates Accuracy in calculating total program duration	If the time estimation process for PERT COST is the same as PERT TIME no evaluation of this aspect of PERT COST is necessary. If the process is different, due to changes in the project breakdown structure and definition of work tasks and packages, or the like, we need to know if such changes represent an improvement, degradation or are insignificant.

A. Program Planning Stage (Cont'd)

MANAGEMENT TASK	TASK OBJECTIVES	PERT/COST IMPACT	EVALUATION QUESTIONS	POSSIBLE CRITERIA	COMMENTS
Project scheduling	To relate a program plan to a calendar and designate specified dates for the start and completion of significant activities	Required by PERT/COST Also required by PERT/TIME Some such management task is required regardless of use of PERT/TIME or PERT/COST	How is the program scheduled using PERT/COST? What difference is there between the schedules under the PERT/COST and the PERT/TIME techniques? Which type of schedule is better for management control purposes?	Realism with respect to technical constraints Realism with respect to resource availability Realism with respect to organization administration Realism with respect to individual motivation	Scheduling is a management art by which those responsible set specific obligations on subordinate groups to meet designated performance benchmarks on certain dates. Ideally, schedules should be tight enough to make people work hard and ingeneously to meet them, but not be impossible.

A. Program Planning Stage (Cont'd)

MANAGEMENT TASK	TASK OBJECTIVES	PERT/COST IMPACT	EVALUATION QUESTIONS	POSSIBLE CRITERIA	COMMENTS
Determination of manpower and other resource requirements by work package and conversion to dollar estimates	To obtain estimates of the resources and the dollar cost of such resources needed to accomplish an entire project and every piece of it down through the project breakdown structure to work packages To provide a basis for project cost planning To provide a basis for negotiating costs with contractors	Required by PERT/COST However, some sort of technique for estimating pieces of a program at some predetermined level of detail is required regardless of use of PERT/COST	How is this task handled under the PERT/COST technique? What other ways is such a task accomplished in the absence of PERT/COST? If the PERT/COST approach to this management task better than other means by which this task is accomplished?	Inclusiveness Accuracy Precision Analogical Basis Confidence Simplicity of ground rules and assumptions underlying estimates	No program cost control technique can be better than the basic cost estimates upon which it is based. It is of basic importance to know whether PERT/COST really provides better basic estimates and cost plans. Particular attention may be needed for treatment of unusual elements such as industrial facilities, noncontractor costs, allowance for changes, type of contracting, etc.

A. Program Planning Stage (Cont'd)

MANAGEMENT TASK	TASK OBJECTIVES	PERT/COST IMPACT	EVALUATION QUESTIONS	POSSIBLE CRITERIA	COMMENTS
Recycling of planning	By successive iterations to improve project planning until a balance is achieved between cost and schedule requirements and technical objectives	Capability to recycle is inherent in PERT/COST Such capability is required by any military system planning technique, and is present in the PERT/TIME technique for non-cost aspects of planning	Is re-cycling of the planning stage better under the PERT/COST approach or under non-PERT/COST techniques?	Time required for an iteration No. of people required for an iteration No. of iterations required	In considering the capability for recycling, one should bear in mind the need for it. The better the original planning, the less need there is for recycling.
Identification of cost sensitive areas of program planning	To provide a warning flag for those aspects of system design and program planning where slight deviations will cause large deviations in cost	Query whether this management task is an approved part of the PERT/COST technique Better management practices include the identification of program parameters and system design parameters that are cost sensitive	How is this management task performed under the PERT/COST technique, is at all? How would this task have been performed in the absence of PERT/COST? Is the PERT/COST approach better than the non-PERT/COST approach?	No. of areas identified Type of sensitivity identified Degree of sensitivity	Management needs to know about not only those areas of a program which are causing difficulty but also those areas which are not causing difficulty but which would be serious if trouble arose.

B. The Program Authorization Stage

MANAGEMENT TASK	TASK OBJECTIVES	PERT/COST IMPACT	EVALUATION QUESTIONS	POSSIBLE CRITERIA	COMMENTS
Contract negotiation of project work description	To establish a mutually acceptable definition of a project to obtain a contractor's legal commitment to undertake it.	Not presently identified Every project contracted out to industry requires agreement upon a statement of work which identified what it is that the government is procuring.	Does PERT/COST cause a change in the way a work statement is negotiated? Is the PERT/COST way of negotiating a work statement better than the way that would be used in the absence of PERT/COST?	Clarity Absence of ambiguity Correlation to cost estimates Correlation to schedules Clear statement of required inputs to contractor upon which his performance is conditioned	Contract negotiation of a project work description represents the assignment and acceptance of responsibility for a portion of a total military project. The tie-ins to other parts of the project need to be understood. All conditions unique to the project (e.g., access to a missile range) need to be identified and recorded. Constraints beyond the control of the contractor must be identified and the responsibility for them allocated.
Contract negotiation of over-all program schedules.	To establish a mutually acceptable statement of project schedules to obtain a contractor's legal commitment to meet them	Not presently identified Probably no change from PERT/TIME	What is the effect of t availability of PERT/COST data upon the contract schedule negotiation process? It is better to introduce PERT/COST schedule planning information into contract negotiations or not?	Clarity Absence of ambiguity Correlation to work description Correlation to cost estimates	Same as foregoing

B. The Program Authorization Stage (Cont'd)

MANAGEMENT TASK	TASK OBJECTIVES	PERT/COST IMPACT	EVALUATION QUESTIONS	POSSIBLE CRITERIA	COMMENTS
Contract negotiation of over-all project cost estimates, target prices, etc.	To establish a mutually acceptable agreement to pay a contractor for performing the project within the established schedule and cost limitations	Not presently identified However, it seems probable that use of PERT/COST in the planning stage will have a direct and considerable impact of some sort on the negotiation of project costs	Probably none	Do costs get negotiated higher or lower? Are negotiated costs more or less realistic, i.e., approximations of actual costs to follow?	It seems doubtful that this task can be evaluated prior to completion, when data on negotiated costs, changes and final actual costs are known.
Establishment of detailed schedules for end items, milestones and work packages	To establish authorized dates for starting and completing of every activity of interest to project management	Not [illegible]ly identified Probably no change from PERT/TIME	Probably none	Clarity of differentiating the areas of separate interests for separate management groups	Assuming the SPO Director to be the principal beneficiary of the PERT/COST system, should the amount of detail should first be appropriate for his level of responsibility. On the assumption that PERT/COST should also be a working tool of the contractors and other agencies involved, however, it would be appropriate to evaluate whether or not PERT/COST was in fact useful to lower echelon contractor/agency management levels.
Establishment of detailed budgets for end items and work packages	To establish authorized expenditures for every work package, component, subsystem and system in the project	Required by PERT/COST However, normally a contractor will establish detailed budgets of some sort for each project	How does the PERT/ approach differ from other program budget techniques? If the PERT/COST approach better?	Same as foregoing	Same as foregoing

C. The Program Control Stage

MANAGEMENT TASK	TASK OBJECTIVES	PERT/COST IMPACT	EVALUATION QUESTIONS	POSSIBLE CRITERIA	COMMENTS
Recording of actual progress data against planned, detailed activities	To know whether program plans for each work package are being met ahead, behind, or on schedule.	Required by PERT/TIME Probably no special PERT/COST impact	Evaluation probably not required	Accuracy Precision Lag Time Quantity of Data Simplicity Penetrability Saturability Disconcertability	In the recording of basic input information, human factors play a large role in establishing how worthwhile will be the data ultimately developed. The mechanical aspects of the system play a minimum role.
Integration and summarization of actual progress data on total program basis	To know whether the work accomplished – at every level of aggregation of interest to management – is ahead, behind, or on schedule.	Required by PERT/TIME However, coincidence of PERT/COST with PERT/TIME may have a side effect upon this management task	How is this management task handled under PERT/TIME? How is it handled using PERT/COST? Is the PERT/COST approach better than the PERT/TIME approach? Or is it at least as good?	Same as foregoing	In the manipulation of the basic input data to integrate and summarize total program data, the techniques of data processing play a larger role and human factors a lesser one.
Accumulation of actual cost data against the project account code structure	To account for all costs properly chargeable against the project To allocate costs against defined portions of the task in the manner established for management purposes and for cost estimating and budgeting purposes To know whether the cost of work accomplished on each work package is over, under or equal to the cost estimated and/or budgeted for such work	Required by PERT/COST However, every project management technique requires cost data to be accumulated against some project account code structure	How is this task handled under PERT/COST? How is this task handled in the absence of PERT/COST? Which is better?	Same as foregoing	Same as comment on recording actual progress data

C. The Program Control Stage (Cont'd)

MANAGEMENT TASK	TASK OBJECTIVES	PERT/COST IMPACT	EVALUATION QUESTIONS	POSSIBLE CRITERIA	COMMENTS
Integration and summarization of actual cost data on total project basis	To know whether the cost of work accomplished – at every level of aggregation of interest to management is over, under or equal to the cost estimated and/or budgeted for such work	Required by PERT/COST However, every project management technique requires summarization of total project cost data on some basis	How is this task handled under PERT/COST? How is this task handled in the absence of PERT/COST? Which is better?	Same as foregoing	Same as comment on integrating and summarizing progress data
Preparation of revised estimates of time required to complete the project	To know whether the time required for work remaining to be accomplished is currently estimated as equal to, or greater or less than the amount originally planned for such remaining work. To be able to forecast program schedule overruns	Required by PERT/TIME However, the coincidence of PERT/COST may involve some modifications in the PERT/TIME approach	How is this task handled under PERT/COST? How is this task handled in the absence of PERT/COST? Which is better?	Accuracy of estimates Size of unit for which time estimates are obtained Analogical basis for making estimates Confidence in the accuracy of the estimates Simplicity of ground rules and assumptions underlying the estimates Accuracy in calculation of total program duration	Criteria are the same as those suggested for evaluation of the initial estimate of program duration.

C. The Program Control Stage (Cont'd)

MANAGEMENT TASK	TASK OBJECTIVES	PERT/COST IMPACT	EVALUATION QUESTIONS	POSSIBLE CRITERIA	COMMENTS
Preparation of revised estimates of cost required to complete the project	To know whether the cost required for work remaining to be accomplished is currently estimated as equal to, or greater or less than the amount originally planned for such remaining work To be able to forecast program cost overruns	Required by PERT/COST Not routinely required in the absence of PERT/COST	How is this task handled under PERT/COST? How, if at all, is this task accomplished in the absence of PERT/COST? Which is better?	Inclusiveness – i.e., all costs accounted for Accuracy Precision Analogical basis for making the estimates Confidence in the accuracy of the estimates Simplicity of ground rules and assumptions underlying the estimates	Criteria are the same as those suggested for evaluation of the initial estimate of program cost.
Presentation of status reports (including staff recommendations) to management	To inform the program director of the current status of the program To inform the program director about the nature and consequences of deviations from authorized plans To identify possible courses of action to resolve program trouble spots and to recommend a preferred approach	Required by PERT/COST However, in the absence of PERT/COST, project status analysis is normally performed anyway, but is based upon other information sources	How is this task handled under PERT/COST? How is it handled in the absence of PERT/COST? Which is better?	As to program status presentation: Accuracy Clarity of Problem Identification Simplicity Timeliness Regularity Inclusion of all important features relevant to problems identified	It is likely that the program status analyses and proposed courses of action will vary, depending upon the size and pace of the program and the special desires and requirements of the program director. Since the SPO director is responsible for the system, and PERT/COST is to assist him carry out this responsibility, his desires at this "man/system" interface point should probably be deferred to.
Management decision-making on project direction or pace, and program redirection (if necessary)	To modify previous program authorizations & directions in accordance with approved changes in plans To communicate program directions to every organization affected by them	Intrinsically required However, PERT/COST IS expressly designed to affect this process	How is this task performed under PERT/COST? How would this task be handled without PERT/COST? Which is better?	Confidence in decisions Rapidity in making decisions Degree of reliance on PERT/COST data	It is PERT/COST we are attempting to evaluate, not the managerial competence of the SPO director or his staff. Bad decisions can be made on the best of data; and good decisions on the skimpiest of data. For this reason we omit consideration of the decision as such.

C. The Program Control Stage (Cont'd)

MANAGEMENT TASK	TASK OBJECTIVES	PERT/COST IMPACT	EVALUATION QUESTIONS	POSSIBLE CRITERIA	COMMENTS
Modification of plans schedules and budgets to reflect program redirections	To revise established plans, schedules and budgets to reflect authorized program changes	Required by PERT/COST However, such task is required whether or not one uses PERT/COST	How is this task performed under PERT/COST? How would it be handled without PERT/COST? Which is better?	Rapidity of adjustment Error rate per adjustment	None

APPENDIX II

EVALUATION OF PERT/COST BY MANAGEMENT FUNCTION

MANAGEMENT FUNCTION	PURPOSES OF FUNCTION	IMPACT OF PERT/COST	PERT/COST DESIGN GUIDE OBJECTIVES	EVALUATION QUESTIONS	POSSIBLE CRITERIA	COMMENTS
Program planning	To formulate a balanced program plan which: — Identifies the steps necessary to accomplish all technical objectives within the constraints of cost, schedule and resource availability — Provides realistic schedules and cost estimates — Makes sound allocations of available resources and accurate forecasts of the type, amount and timing of resource requirements — Identifies sensitive areas of program planning To document planning in such a way that responsibility for accomplishing discrete parts of the program can be clearly identified, assigned and authorized. To document planning in such a way that actual accomplishment can be readily compared against program plans (including cost and schedule as well as technical objectives).	PERT/COST appears to have little impact task of identifying and correlating all of the steps necessary to accomplish a total program. However, it does provide a common framework for making time and cost estimates. PERT/COST appears to require lower level product aggregations of cost planning than may have been the case without PERT/COST.	Improved techniques to: — Define work to be performed — Develop more realistic schedule and cost estimates based upon resources planned for the work — Determine how best to apply the resources to achieve time, cost and technical objectives and minimize premium and idle time costs — Determine how best to shift resources for expediting critical activities and to utilize resources made available by task changes — Determine whether the project is meeting the committed schedule and cost estimate and, if not, the extent of any difference	Does PERT/COST facilitate better program planning, i.e., better: — Identification of the work that is to be done and the interrelationships of the various parts of work to one another — Time estimating and program scheduling — Cost estimating and program budgeting — Highlighting of areas of high risk to technical objectives, costs or schedules — Basis for allocating resources to expedite critical activities, and to avoid premium and idle time costs	Accuracy with which the plans reflect the work to be done Clarity with which resource (money, time, people, facilities, etc.), requirements, pre-related to the work to be done Realism of plans with respect to internal and external constraints Rapidity of accomplishing the planning function Adaptability of plans to program authorization function Adaptability of plans to program control function	The proposed evaluation criteria are intended to relate to the entire initial program planning function as a single process. An alternative would be to summarize all of the management tasks that together constitute the program planning stage. By either approach, the objective is to provide a rational process by which one can arrive at a judgment concerning the relative value of PERT/COST as contrasted with non-PERT/COST.

MANAGEMENT FUNCTION	PURPOSES OF FUNCTION	IMPACT OF PERT/COST	PERT/COST DESIGN GUIDE OBJECTIVES	EVALUATION QUESTIONS	POSSIBLE CRITERIA	COMMENTS
Program Work Authorization	To select those organizations which are best qualified to undertake responsibility for performing designated parts of the overall program. To communicate to each those aspects of the program for which each is responsible To provide each organization with the resources required or agreed upon. To furnish appropriate authorization and directions. To document the officially authorized program in such a way that actual accomplishment can be readily ascertained (including cost and schedule as well as technical objectives) and deviations promptly identified	It would appear that the major impact of PERT/COST will be in the identification and scheduling of resource requirements and more close relation of such requirements to discrete parts of the total program.	Improved techniques to: – Define the work to be performed – Develop more realistic schedule and cost estimates based upon the resources planned for the work – Determine how best to apply the resources to achieve time, cost and technical objectives and minimize premium and idle time costs – Determine how best to shift resources for expediting critical activities and to utilize resources made available by changes – Determine whether the project is meeting the committed schedule and cost estimate and, if not, the extent of and difference	Does PERT/COST facilitate better program work authorizations; i.e., better: – Identification of the work to be done by each program participant and of its interrelationships with work to be done by others – Negotiation of work statements, costs and schedules – Allocation of resources between program participants and within separate activities of each separate participant? – Frame of reference against which to measure actual performance	Accuracy and clarity with which the authorizations reflect the work to be done Realism of authorization with respect to constraints internal and external to each program participant Realism with which resources can be made available in order to accomplish the work authorized Rapidity of accomplishing the authorization function Adaptability of program authorizations to program control function	One major area of the authorization function omitted from consideration here is the selection of program participants. The reason for the omission is that this task involves a fairly complex process of which PERT/COST would be a small part at most. For present purposes it does not seem worthwhile to investigate the relative utility of PERT/COST in this process.

MANAGEMENT FUNCTION	PURPOSES OF FUNCTION	IMPACT OF PERT/COST	PERT/COST DESIGN GUIDE OBJECTIVES	EVALUATION QUESTIONS	POSSIBLE CRITERIA	COMMENTS
Program Control	To assess current status of the program at regular intervals and at such other times as may be desirable To identify inadequacies in program planning and initiate re-planning activies as promptly as possible To identify deviations from program technical, cost, and schedule plans and initiate corrective action as promptly as possible (Preventing program cost overruns, schedule slippages and technical performance deficiencies) To reallocate resources from activities which are or become less critical to over-all program success to those which are more critical To assess the consequences of program changes (both actual and hypothetical) and initiate re-planning and program redirection as appropriate to maintain a balanced program	Probably the major impact of PERT/COST will be in the program control function, since it provides a means of correlating cost to progress as well as elapsed time and is designed to provide a continuous correlation between plans and progress on a single basis that integrates technical performance, cost and schedule. Most non-PERT/COST systems (in the author's experience) relate technical progress and cost to elapsed time but not to each other.	Improved techniques to – Define work to be performed – Develop more realistic schedule and cost estimates based upon resources planned for the work. – Determine how best to apply the resources to achieve time, cost and technical objectives and minimize premium and idle time costs – Determine how best to shift resources for expediting critical activities and to utilize resources made available by task changes – Determine whether the project is meeting the committed schedule and cost estimate and if not, the extent of any difference	Does PERT/COST facilitate better program control, i.e., better: – Assessment of current status (including cost, schedule & technical objectives) and comparison with the officially authorized program – Techniques for replanning and redirection of program activities when program changes occur, or program planning deficiencies are identified, or actual performance deviates from plans – Techniques to reallocate resources to meet critical need and otherwise to make efficient use of available resources	Accuracy of status assessment Timeliness of status assessment Promptness of early warning of deviations from authorized plans Validity of forecasts of status at completion of the program Ease of making reallocations of resources Correlation to program planning and redirection functions Rapidity of simulating program changes	None