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AN ANALYSIS OF MANAGEMENT CONTROL IN A COMPLEX LARGE-SCALE ENDEAVOR: THE SAFEGUARD BALLISTIC MISSILE DEFENSE SYSTEM PROGRAM

The University of Oklahoma PH.D. 1978

University Microfilms International 300 N. Zeeb Road, Ann Arbor, MI 48106 18 Bedford Row, London WC1R 4EJ, England

THE UNIVERSITY OF OKLAHOMA

GRADUATE COLLEGE

AN ANALYSIS OF MANAGEMENT CONTROL IN A COMPLEX LARGE-SCALE ENDEAVOR: THE SAFEGUARD BALLISTIC MISSILE DEFENSE SYSTEM PROGRAM

A DISSERTATION

SUBMITTED TO THE GRADUATE FACULTY

in partial fulfillment of the requirements for the

degree of

DOCTOR OF PHILOSOPHY

BY

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Norman, Oklahoma

1978

AN ANALYSIS OF MANAGEMENT CONTROL IN A COMPLEX LARGE-SCALE ENDEAVOR: THE SAFEGUARD BALLISTIC MISSILE DEFENSE SYSTEM PROGRAM

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CHAPTER I

INTRODUCTION

Management control is an integrative force in the management process and a vehicle for feedback in the management cycle. In a widely embraced delineation of the principal functions of management, the control function--in application with the other four functions of planning, organizing, staffing, and directing[1]--facilitates the synergism that results from cooperative interaction of the functions. Management control, as an activity, is a tool of all of the functions of management and, as a function, is a user of the tools of the other four functions. Viewed in this context, the control function introduces the element of closure to management action, enhances rationality in the decision-making process, and underscores the search for order in complex endeavors.

Purpose

The manifold tools and techniques of management control are a reflection of many managers' recognition of the need to measure performance and redirect deviations in diverse and complex managerial environments. The array of currently available tools and techniques ranges in complexity from simplistic to intricate; in precision, from stochastic to deterministic; in cost of

[1]Harold Koontz and Cyril J. O'Donnell, eds., Management: A Book of Readings, 3d ed. (New York: McGraw-Hill Book Company, 1972), pp. xi, 649.

development and operation, from inexpensive to expensive; in time-span coverage, from less than a day to many years; in form and type, from reflective to predictive; in breadth of coverage, from specific to corporate; in depth of coverage, from minute to general; in participative considerations, from unilateral to mutual; and in methodology from, manual to automatic. These illustrative descriptors suggest polarized as opposed to dichotomized states and imply existence of numerous continua along which specific tools and techniques may fall. The reaction of managers and non-managers to many of these tools and techniques is frequently clouded by ambivalence. Some may see controls as repressive, negative, and coercive while others may view them as constructive, affirmative, and supportive. Some may see them as replacements for human decision-making; others may see them as synthetic aids that enhance man-made decision-making; still other managers may view the formal tools and techniques of control as affording little or no improvement over venerated rules of thumb.

While management control activity is conceptually integrative in interaction with the other principal functions, the tools and techniques are not necessarily, in and of themselves, integrative. As an example, a management control technique associated with time performance is not necessarily inherently interactive with a control technique designed for technical performance. Similarly, a control tool aimed at cost performance is not necessarily inherently integrative in nature with technical performance control mechanisms. Alternatively, techniques for checking and redirecting technical performance frequently totally disregard both cost and time parameters. Stated in different terms, specific control tools seldom cut horizontally across functional lines. As a consequence, many control tools frequently do not permit a total systems view nor enhance coordination of interrelated functional activities. In short, individual control techniques are seldom naturally integrative; integrating threads capable of transcending organizational dimensions must be constructed in the tools through affirmative design.

Statement of Intent

This brief preamble begs the questions of whether integrated systems really exist as such and whether they should. In this regard, a question might be posed as to what integrated control systems mean in the context used herein: Are they available and viable, and what is their worth or value if they do exist?

In consideration of these fundamental issues and questions and the lack of existing theory or science, it is the specific intent of this study to discuss, analyze, and evaluate the reality of and the need for an integrated control system in a large-scale endeavor. Further, it is the concurrent and equally important intent of this study to examine management control throughout the life cycle of a complex military weapon system to discern changes in management control philosophy as a function of project maturity. Finally, it is the purpose of this study to examine the consideration that management can and should have a base line for integrated control that is transferable, adaptive, and dynamic.

In order to emphasize the thrust of this study, it is deemed prudent to enhance specificity by noting several considerations that underscore the essence of the intent. First, it is suggested that management thought has moved from a period in which it was deemed inherently desirable to construct, implement, and operate highly structured control systems into an era that postulates that it is not practical to define specific omnibus control systems for large-scale endeavors. This may signal a shift from more certain to less certain environments. In other words, the idea of control system universality is being questioned in view of the typical uniqueness of individual needs and the wide diversity of control tools and techniques available. Secondly, it appears that the management environment has grown increasingly complex, especially during the past several decades. This observation seems particularly true in the military and aerospace arenas. Finally, it is suggested that large-scale endeavors stress the tools and techniques of management control to the very boundaries of their specifications. That is, large-scale endeavors place far greater demands on the integrative requirements for the tools and techniques than do less complex activities. This is due primarily to the interrelatedness of larger numbers of individual activities or issues that must be performed or coordinated in complex programs if the end product is to be achieved.

In sum, it is the purpose of this study to examine a military weapon system in terms of the management control function. This examination will assess the use of integrated control in the project, analyze changes in management control throughout the life cycle of the system, and suggest notional considerations with regard to the transferability of an integrated control base line.

Study Target

The target of this study is program management of the Safeguard Missile Defense Organization (BMDO) and its predecessors. Activated in November, 1967, as the Sentinel System Organization,[1] the BMDO evolved over time with the many redefinitions of weapon system objectives. The management

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[1]U.S., Department of the Army, General Orders No. 48 (Washington, D.C.: Government Printing Office, 15 November 1967), p. 1.

philosophy enunciated and exercised by the BMDO also changed as a function of both the redirections of weapon system objectives and organizational realignments. The changes in organization structure and management doctrine that have occurred since the inception of the Safeguard and its predecessor programs are reflective of the volatile political environment in which they existed.

The Safeguard program was selected for study for a number of reasons. First, it represents one of the most complex large-scale programs ever undertaken by the Department of Defense (DoD). In commenting on Safeguard management before a House Subcommittee, Deputy Secretary of Defense Packard stated:

> I am convinced that this is a sound program from the engineering standpoint. I think we have, without any question, excellent management in this program, even though it is a large and complicated one.[1]

In a more explicit vein, Dr. John S. Foster, Jr., Director of Defense Research and Engineering, DoD, stated in 1971:

> It seems to me that most people in the Congress and in the development business know that about the biggest R&D enterprise that the Department of Defense has just now is the development and deployment of Safeguard. Certainly it's about the toughest. None is better or more successful and probably none gets more attention.[2]

A second reason for selecting the Safeguard program attaches to the fact that it and its predecessor programs span the total life-cycle spectrum of a weapon system, and Safeguard is a recent program. Ordered into production

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[1] Statement of the Deputy Secretary of Defense David Packard before the Subcommittee on Department of Defense of the Committee on Appropriations, House of Representatives, Washington, D.C., 10 April 1970.

[2] Address by John S. Foster, Jr., Director of Defense Research and Engineering, DoD, before the Safeguard Manager's Meeting, St. Louis, Missouri, 17 November 1971.

under the name Sentinel in 1967, realigned under the name Safeguard in 1969, and terminated in 1977, Safeguard experienced program adolescence, maturity, and decline in approximately ten years. The management concepts that followed this same pattern are of interest.

Third, Safeguard was a highly visible program in terms of public and Congressional interest. The intensity of this interest perhaps is best illustrated by opening remarks made by Senator Henry M. Jackson, Chairman of the Subcommittee on Military Applications of the Joint Committee on Atomic Energy, several weeks after the deployment decision announcement:

> We want to bring to the Congress and the public the latest information on plans by the executive department concerning the U.S. antiballistic missile program. The decision, announced on September 18, 1967, that our Government would undertake the development of a so-called thin ABM defense has significant implications for our national security. We expect the responsible officials, within the bounds of security, to discuss in public and in detail this recently announced program. I believe it is important that as much information as possible should be made available to the American people so that they can better understand the issues involved.[1]

The Safeguard program is singular in DoD in terms of long-range national and Congressional visibility and was the only strategic weapon system in the Department of the Army while an active program.

Finally, the Safeguard program was designated for "system management" as opposed to "project management." This exceptional designation makes specific and critical chain-of-command distinctions in establishing Department of the Army policies, responsibilities, and procedures relative to weapon system program management. As an example, at the time of the original determination,

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[1]U.S., Congress, Joint Committee on Atomic Energy, Scope, Magnitude, and Implications of the United States Antiballistic Missile Program, Hearings, before the Subcommittee on Military Applications, 90th Cong., 1st sess., 1967, p. 2.

system management[1] was reserved for weapon systems, the development and deployment of which, "...would significantly influence elements of the national interest other than the purely military for an extensive period in the future."[2] Further, this designation could be made in addition to a project manager.[3] In terms of responsibility, a project manager was responsible for "...full line authority for the centralized management of a specific project."[4] On the other hand, a system manager "...exercises coordination and directive authority over nonmateriel-oriented activities associated with the total system development and operational control over materiel development itself."[5] The greater responsibility of the Safeguard System Manager above a typical project manager inherently demanded higher order management control than that required in "project" managed weapon systems.

The four factors just cited make Safeguard a unique and complex military weapon system program. The management task imposed by adding production and deployment to the existing ongoing development, the high national priority of the program, and the extraordinary investment of resources coupled with the need for significant advances in technology made Safeguard a management control challenge of sizable proportions.[6] As Johnson, Kast, and

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[1]The title "System Manager" and the designation "system management" have been redesignated "Program Manager" and "program management" respectively pursuant to U.S., Department of the Army, Research and Development: Project Management, Army Regulation No. 70-17 (Washington, D.C., 16 June 1975), pp. 1-2, A-2 - A-3.

[2]U.S., Department of the Army, System/Project Management, Army Regulation No. 70-17 (Washington, D.C., 19 January 1968), p. 3.

[3]Ibid. [4]Ibid. [5]Ibid.

[6]U.S., Army Materiel Command, Organizational Plan for U.S. Army Support of Nike-X Deployment (Redstone Arsenal, Alabama: Nike-X Project Office, 20 January 1965, revised 19 March 1965), p. 4.

Rosenzweig stress, civilian projects, for all of their magnitude, "...do not approach the complexities involved in the management of military and space programs."[1]

Research Methodology

This study examines management control in the Safeguard Ballistic Missile Defense System Program. In order to approach this task effectively, it was necessary to subdivide the total effort into comfortable elements of meaningful dimensions. To this end, a three-dimensional, twenty-four cell analysis matrix was developed; it is consistent both with the program management of Safeguard and with similar large-scale endeavors. Specifically, the matrix rows (the horizontal planes) are defined by structured, functional parameters; the matrix columns (the vertical planes) are defined by sequenced, program life-cycle phases; and the matrix files (the depth planes) are defined by hierarchic, decision-making levels. The parameter-phase-level (PPL) analysis matrix is fully developed in Chapter IV. It is discussed briefly in the following few paragraphs of this section to provide insight into the research methodology.

Functional structuring of the matrix rows was selected as a result of three pertinent considerations. First, functional departmentalization is one of the most widely used forms of organizational structure,[2] and this design form is

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[1]Richard A. Johnson, Fremont E. Kast, and James E. Rosenzweig, The Theory and Management of Systems, 3d ed. (New York: McGraw-Hill Book Company, 1973), p. 391.

[2]This conclusion is suggested by such authors as James L. Gibson, John M. Ivancevich, and James H. Donnelly, Jr., Organizations: Structure, Processes, Behavior (Dallas: Business Publications, Inc., 1973), p. 147; and William H. Newman, Charles E. Summer, and E. Kirby Warren, The Process of Management: Concepts, Behavior, and Practice, 3d ed. (Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1972), p. 27.

found extensively in manufacturing firms.[1] As a consequence, the functional breakout enjoys established acceptance as a recognized departmentalization scheme. Secondly, the functional organization is typically the base over which the program management organization is super-imposed in a matrix form of organizational design.[2] The fact that private industry frequently makes use of the matrix organization design adds further emphasis to the use of the functional breakout for matrix row definitions. Finally, the Ballistic Missile Defense Organization is functionally oriented, and selection of a functional base facilitates the evaluative processes of this study.

The use of a time dimension for column definitions is an aid in evaluating management control dynamics during the life cycle of the Safeguard program. Most complex systems evolve from state to state through some ordering of activity over time, with each phase suggesting its own unique requirements and creating revised or new priorities.[3] Viewing management control in terms of program life-cycle phases permited exploration of the techniques and requirements in their natural state, which is a dynamic one.

The third dimension in the matrix is decision-making level, and it is used to define the matrix files. All managers exercise some form of control in the accomplishment of their assigned responsibilities.[4] Not only does this

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[1]James H. Donnelly, Jr., James L. Gibson, and John M. Ivancevich, Fundamentals of Management: Functions, Behavior, Models, rev. ed. (Dallas: Business Publications, Inc., 1975), p. 80.

[2]David I. Cleland and William R. King, Management: A Systems Approach (New York: McGraw-Hill Book Company, 1972), pp. 337-39.

[3]Ibid., pp. 149-51.

[4]Robert J. Mockler, The Management Control Process (New York: Appleton-Century-Crofts, 1972), pp. 4-7.

normally vary by function; it also varies by some form of institutionalized hierarchic level.[1] In many instances, the control mechanisms at the lower levels may be integrated into the corporate controls at the upper levels,[2] but the management levels at which actions may be initiated or decisions made is a function of the gravity or significance of the issue. Gibson, Ivancevich, and Donnelly sum the role of decision-making in the organization by emphasizing that "...decision-making is the crux of organizational life."[3]

The PPL analysis matrix used in this study is depicted in Figure 1. It will be noted that the functional categories are a synthesis of typical military/aerospace functionalization--finance, engineering, manufacturing, quality control, and so forth. This specific delineation was used in order to keep the analysis at a manageable level without detracting from its utility or authenticity, provide coverage of the principal functional activities inherent in integrated control, and permit rapid association with a variety of functional breakouts. With regard to this last point, the cost parameter is generally equated to the finance or financial management functions; the schedule parameter is generally equated to schedule control functions; and the technical performance parameter generally equates to a combination of functions such as system engineering, configuration management, product assurance, and logistics support.

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[1] Army management doctrine requires that the decision-making authority be clearly identified in the chain of command. See U.S., Department of the Army, Management: Army Management Doctrine, Army Regulation No. 5-1 (Washington, D.C., 6 August 1973), p. 2.

[2] Mockler, The Management Control Process, p. 5.

[3] Gibson, Ivancevich, and Donnelly, Organizations: Structure, Processes, Behavior, p. 187.

Graphic concept is adapted from an illustration by Gordan O. Pehrson in "Management Control in the Military Departments," in Management Control Systems, eds. Donald G. Malcolm and Alan J. Rowe (New York: John Wiley & Sons, Inc., 1960), p. 80.

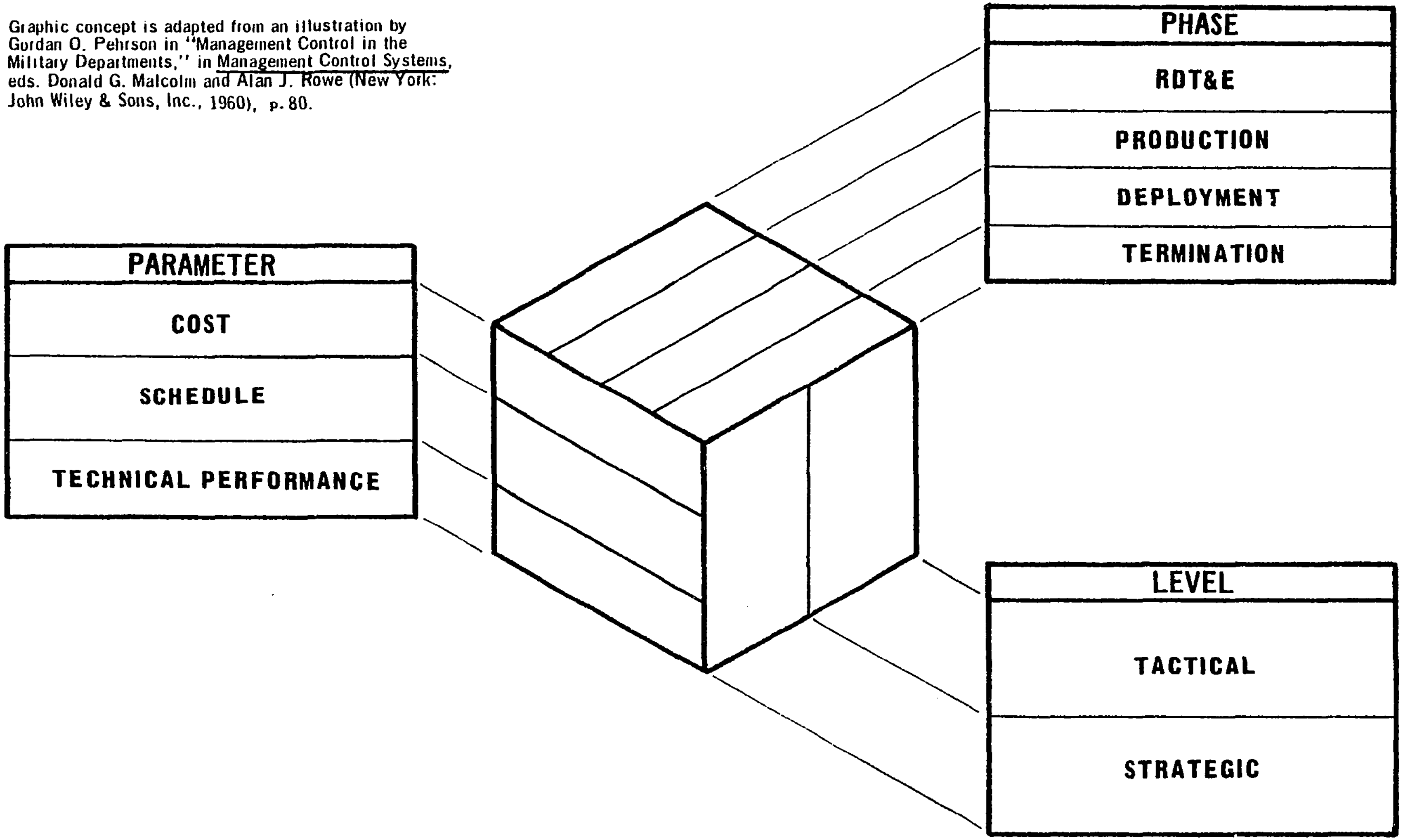

Fig. 1. Parameter–Phase–Level (PPL) Analysis Matrix

These three critical parameters are widely accepted as general dimensions for measuring program performance.[1] It is recognized that organizational performance measurement might include total system standards such as ethical standards, organizational morale, personnel development, and other administrative factors, but these are not directly associated with project performance. As a consequence, they are outside the scope of this study. It is also apparent that these three parameters were notionally constructed and related in defining the general objectives of the management information automation requirements.[2]

The life-cycle phases portrayed in Figure 1 are generally representative of weapon system evolution. While other means utilizing other variables are available,[3] large-scale endeavors typically evolve through identifiable phases from conceptualization to termination.[4] The scheme selected for this study

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[1] See, for example, David I. Cleland and William R. King, Systems Analysis and Project Management, 2d ed. (New York: McGraw-Hill Book Company, 1975), pp. 191-92; Logistics Management Institute, Introduction to Military Program Management (Washington, D.C., March 1971), p. 26; and J. Stanley Baumgartner, "Why Project Management?" National Defense 60 (September-October 1975): 112.

[2] U.S., Army Sentinel System Command, Data Automation Requirement (DAR) (Huntsville, Alabama, 9 April 1968), p. B-1.

[3] As an example, the phase variables might be ordered to fiscal appropriation categories, skill categories of personnel assigned through time, or operational readiness characteristics.

[3] See, for example, other identity schemes in Daniel D. Roman, Research and Development Management: The Economics and Administration of Technology (Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1968), pp. 232-39; and Richard B. Chase and Nicholas J. Aquilano, Production and Operations Management: A Life Cycle Approach (Homewood, Illinois: Richard D. Irwin, Inc., 1973), pp. 13-15. Additionally, a brief but enlightening summation of the Air Force Life Cycle may be found in Lee V. Gossick, "Management of System Acquisition Programs in the Air Force," Defense Industry Bulletin 7 (Summer 1971): 23-29.

provided maximum distinction between phases without distorting accuracy. While activities relating to weapon feasibility such as the conceptual phase, validation phase, and advanced development typically precede the initiation of the research, development, test, and evaluation (RDT&E) phase, they have been omitted from the life cycle depicted in Figure 1. The phasing depicted is consistent with Safeguard program evolution, from the original deployment decision in 1967 through termination activities in 1977. While it is recognized that control must begin at the point of conceptualization of an idea requiring expenditure of organization resources,[1] the selection of this point in the Safeguard life cycle reflects the departure from relatively routine to relatively complex control requirements, and from relatively informal to relatively formal control methods.

The fact that the phases are portrayed as being separate and distinct should not be construed as suggesting that concurrency between phases does not exist, for it frequently does occur. Concurrency in large-scale endeavors, particularly in weapon systems, is prevalent.

The two decision-making levels specified in Figure 1 are active levels of specific interest in this analysis. The relationship of these two levels to a continuum of levels is depicted in Figure 2. The levels are in descending order of long-term importance and scope from top to bottom correlated to a stylized, broadly defined organizational hierarchy similarly depicted in descending order.

It will be noted that the "suprastrategic" decision-making level is related to the political structure composed, in part, of the citizenry and the

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[1]Cleland and King, Systems Analysis and Project Management, p. 336.

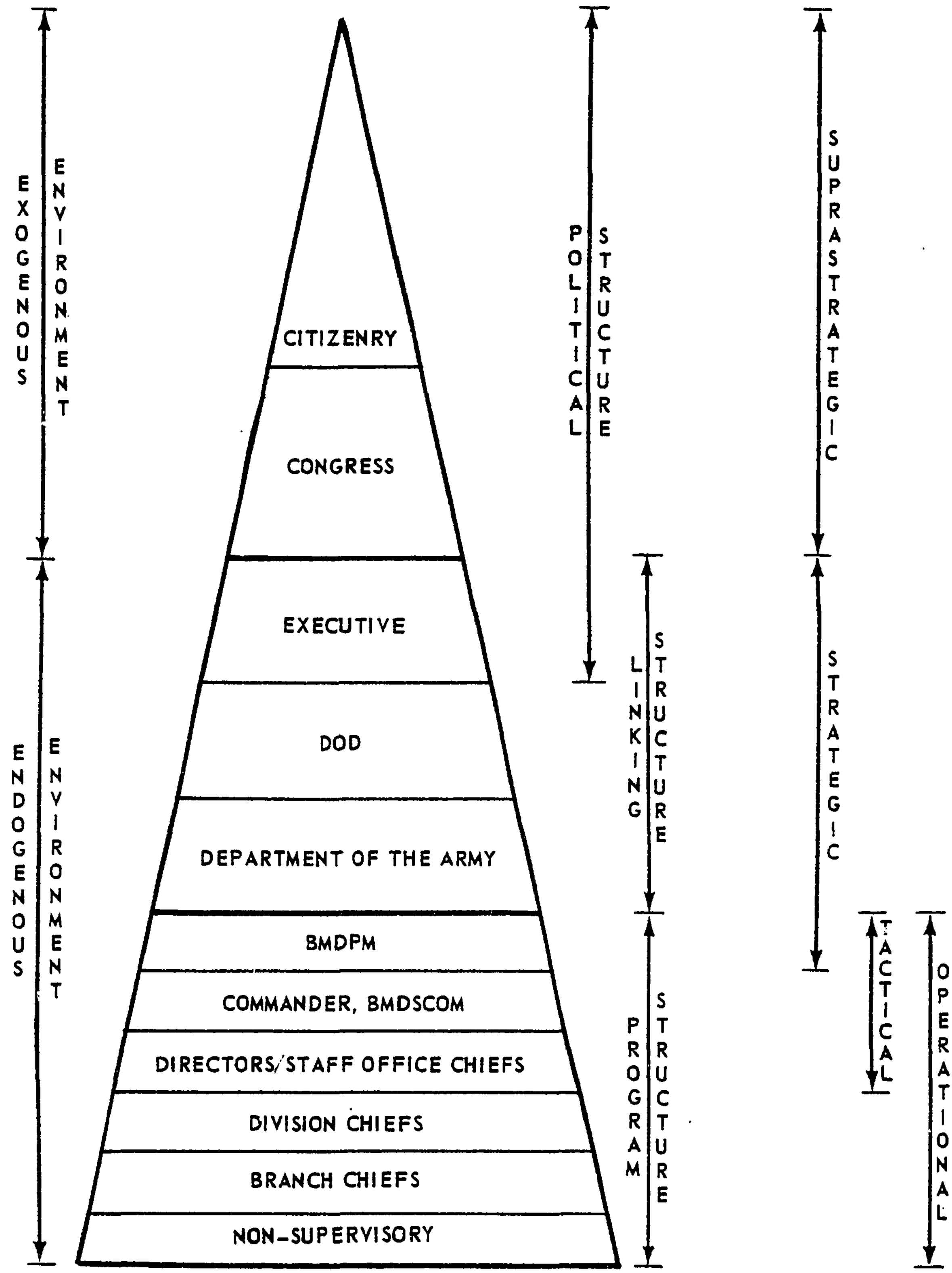

Fig. 2. Decision/Organization Hierarchy

Congress. This is considered the exogenous environment. While it certainly influences program direction, it is relatively unstructured and broad in scope. The program manager had only limited ability to influence this decision level; as a consequence, it was not a pivotal factor driving the development of program control philosophy. The "suprastrategic" decision-making level is not directly addressed in this study.

The endogenous environment includes the linking structure that acts as the primary integrator between the political structure in the exogenous environment and the program structure. The strategic and tactical decision-making levels are operative in the endogenous environment and are fundamental to the analysis in this study. The operational level of decision-making attaches to activity or process elements of control and is driven, in large measure, by the philosophies and actions emanating from the strategic and tactical decision-making levels. Since actions at this level tend generally to underscore and be reactive to conceptual and methodological strategy defined for higher decision levels, the operational decision-making level is not a specific level of interest in this study.

It may be seen in Figure 2 that the levels of decision-making overlap. This is intended to portray both the lack of precise definition of the levels at their boundaries and the fact that some individuals consistently operate in more than one level. As an example, the Ballistic Missile Defense System Manager normally operated in the strategic and tactical levels, but he occasionally elected to operate in the operational level as well. These decision-making levels are conceptually fashioned in concert with the pyramid model of the organization. They also suggest a framework for development of structured decision models in management control.[1]

The foregoing description of the PPL analysis matrix is intentionally brief. It is intended as an overview to provide preliminary insight into the research methodology. The complete matrix is developed in detail in Chapter IV.

One final point needs to be mentioned here, and that concerns the sequence in which cells are analyzed. Four of the twenty-four cells in the matrix are depicted in exploded views in Figure 3. The cells were randomly selected to demonstrate specific cell dimensioning. Random selection of cells will not suffice, however, for systematic analysis of the matrix. Rather, analysis ordering is priority sequenced through the parameter dimension, then through the phase dimension, and then through the level dimension. In other words, the cost parameter was examined first at the RDT&E appropriation for both decision levels. Next, production costs were examined at both levels of decision-making. This sequence ordering continued until all costs had been examined, and then the schedule parameter was examined. This process continued until all twenty-four cells had been completely explored.

Boundaries of Inquiry

This study was bounded by three major considerations: quantitative and behavioral, public and private sector, and definitional. These boundary conditions are discussed in the succeeding paragraphs of this section.

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[1]An informative article on decision models in management information systems may be found in Ralph H. Sprague and Hugh J. Watson, "MIS Concepts," Journal of Systems Management, Part I, 26 (January 1975): 34-37 and Part II, 26 (February 1975): 35-40. In addition, an excellent discussion that considers the same concept, but from a difference approach, is by Franz Edelman, "The Manager Looks at MIS," Computer Decisions 3 (August 1971): 14-18.

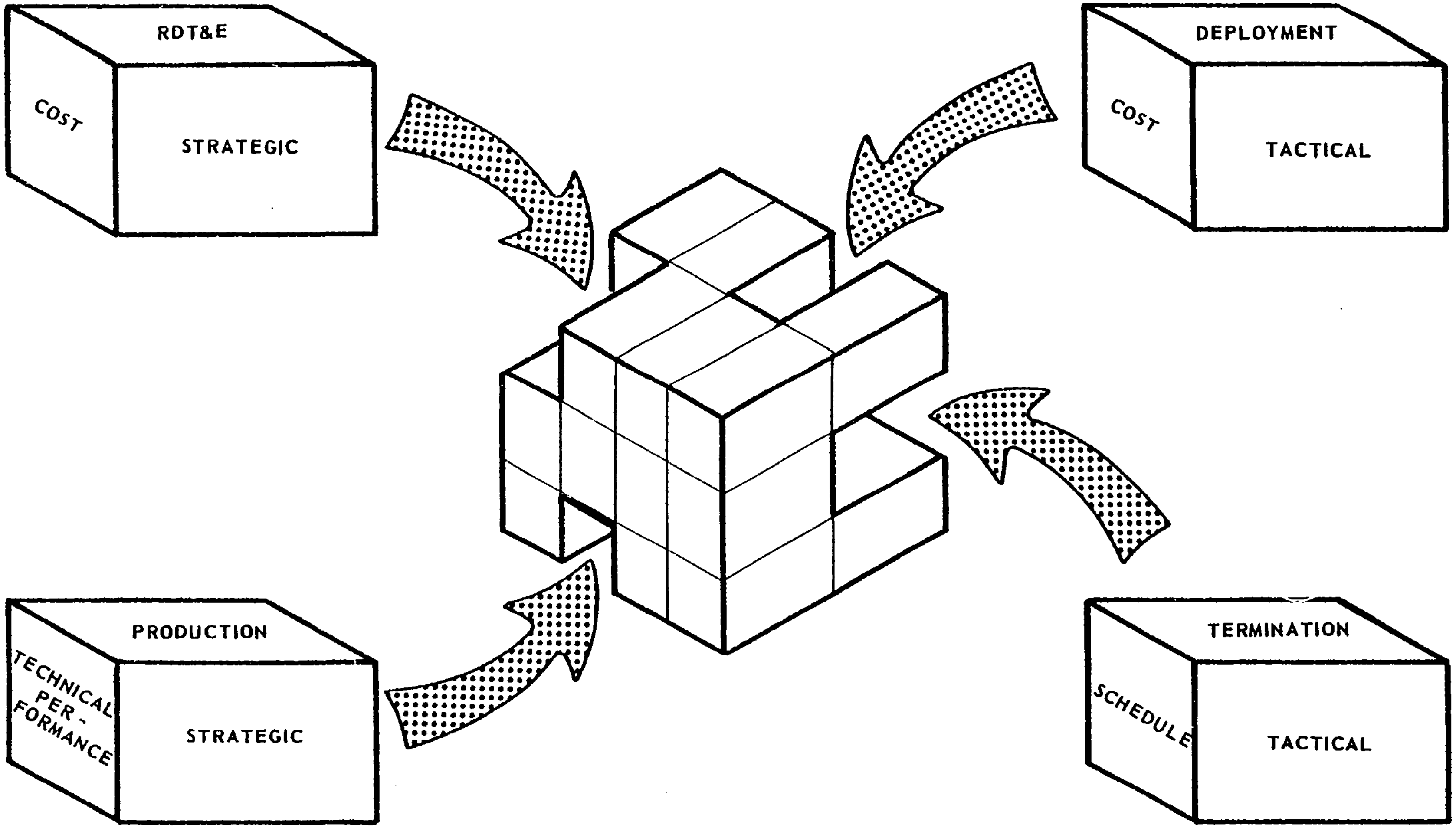

Fig. 3. PPL Analysis Matrix Cell Identification

Quantitative and Behavioral Considerations

One of the major expectations of management control is that it will guide appropriate individual behavior. Tannenbaum equates control with influence and suggests that appropriate behavioral response to control mechanisms and their outputs is the logical goal of control systems.[1] He views managerial control, in its most elemental form, as an intent-influence-response cycle that is affected by many elements of "social causation."[2] Newman endorses the behavioral aspects of managerial control and argues that management frequently becomes so involved in the techniques and mechanics of control that it loses sight of its purpose.[3]

Various conceptions of control involving behavioral considerations of power, authority, and influence give rise to a multitude of interrelated issues such as appropriateness of divergent leadership styles, interpersonal and group dynamics analysis, motivational effectiveness, communications techniques, and organizational conflict. While these issues are of vital concern to the logical progression and extension of management thought, they tend to diffuse the central thrust of this study. In similar fashion, the inherent validity of Newman's argument is not denied, but the behavioral implications are not of immediate concern. The boundaries of this study are limited essentially to the quantitative and mechanistic aspects of managerial control. Granted, the success of

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[1]Arnold S. Tannenbaum, Social Psychology of the Work Organization (Belmont, California: Wadsworth Publishing Company, Inc., 1966), p. 84.

[2]Arnold S. Tannenbaum, Control in Organizations (New York: McGraw-Hill Book Company, 1968), pp. 5-7.

[3]William H. Newman, Constructive Control: Design and Use of Control Systems (Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1975), p. 4.

management control ultimately lies with people, but good people alone do not solve management control problems effectively without order. References are occasionally made to behavioral considerations, but only in a tangential and concomitant manner. The behavioral considerations are left for pursuit by behavioralists, in the hope that they will integrate systems theory into a body of knowledge relating managerial control to human response and organizational functioning.[1]

Public and Private Sector Considerations

Management theory and practice have undergone significant change since the conclusion of World War II. This change has been particularly evident in management of our major defense programs.[2] As a consequence, the government of the United States (with particular reference to the DoD and the National Aeronautics and Space Administration) has been instrumental in stimulating the development of many innovative and creative management control tools and techniques. This situation was largely a consequence of changes in technology that occurred during the 1950s. Weaponry and peripheral equipment became extremely complex. Additionally, weapons came to be viewed as "systems" involving not just individual components of hardware, but integrated items of total weaponry; support and maintenance equipment; real estate for

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[1]Some existing works on personal responses to management control include Robert Dubin, Human Relations in Administration, 4th ed. (Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1974), Chap. 19; Fred Luthans, Organizational Behavior: A Modern Behavioral Approach to Management (New York: McGraw-Hill Book Company, 1973), Chap. 12; Newman, Summer, and Warren, The Process of Management: Concepts, Behavior, and Practice, Chap. 26; Tannenbaum, Control in Organizations; and Joan Woodward, ed., Industrial Organization: Behavior and Control (London: Oxford University Press, 1970).

[2]Cleland and King, Systems Analysis and Project Management, pp. 211-12.

launching sites; selection, training, and care of operating and maintenance personnel and their dependents; preparation of technical documentation; and development of relationships in terms of companion strategic and tactical offensive and defensive systems.[1]

The systems concept became a "way of thinking" about the management process.[2] Application of this systems approach in the military services is a prime example. Applied to administration of large-scale, complex, military projects, the use of the basic concepts of integration, coordination, and concern with the total entity over its full life cycle has been separately defined as "weapon system management." The terminology is somewhat new, but the concept has evolved with technological change.[3] While some of the newer techniques of management control were fostered by the public sector, the development and application frequently occurred in the private sector. The use of the "weapon system management" concept was not limited to the DoD, but was implemented in such agencies as the National Aeronautics and Space Administration as well. Additionally, many of the original techniques have been refined in the private sector for totally private sector application.[4] The civilian

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[1]J. Stanley Baumgartner, The Lonely Warriors: Case for the Military-Industrial Complex (Los Angeles: Nash Publishing, 1970), pp. 128-29.

[2]David I. Cleland and David C. Dellinger, "Changing Patterns in Management Theory," Defense Industry Bulletin 2 (January 1966): 2.

[3]Richard A. Johnson, Fremont E. Kast, and James E. Rosenzweig, The Theory and Management of Systems (New York: McGraw-Hill Book Company, Inc., 1963), pp. 113-35 and Fremont E. Kast and James E. Rosenzweig, "Weapon System Management and Organizational Relationships," Journal of the Academy of Management 4 (December 1961): 198-204.

[4]An interesting early analysis of weapon system management in nonmilitary applications may be found in Fremont E. Kast and James E. Rosenzweig, Management in the Space Age (New York: Exposition Press, 1962).

counterpart to the term "weapon system management" has been referred to as the "product mission concept."[1]

In light of this background, it does not seem inappropriate to utilize large-scale endeavors as typified by a complex public sector project as a vehicle for examining management control. Without the public sector requirement, in most cases, the private sector would not have had management control problems of the magnitude typified by "weapon system" managed projects.[2] On the other hand, without private sector active participation, the public sector, in all probability, could not have developed the sophisticated management control methodologies required. In sum, for purposes of this study, the program management control techniques of the two sectors in managing a complex weapon system are essentially inseparable. In this case, "pride of authorship" is not an element germane to the analysis, and the distinction between public and private sector activities is evident only in the government-contractor relationship.

Definitional Considerations

It is necessary at this point to survey briefly the major relevant philosophical considerations and definitions frequently associated with the terms "control" and "controlling" as used in a management theory context.

Managerial control is variously defined by different authors and is used in diverse connotations.[3] There are a number of popular definitions; and while it

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[1] James E. Rosenzweig, "The Weapon Systems Management Concept and Electronic Data Processing," Management Science 6 (January 1960): 149.

[2] Kast and Rosenzweig, Management in the Space Age, p. 49.

[3] Clayton Reeser, Management: Functions and Modern Concepts (Glenview, Illinois: Scott, Foresman and Company, 1973), p. 352.

is generally accepted that the control function is inherent in many forms of human endeavor and is a part of the management process, specific definitions frequently vary significantly both in terms of content and intent. For example, Donnelly, Gibson, and Ivancevich in the revised edition of their principles text define the controlling function as "All managerial activity that is undertaken to assure that actual operations go according to plan."[1] They state further that "...control was the emphasis of scientific management."[2] Drucker distinguishes between controls and control. Controls relate to measurement and information attaching to means while control is synonymous with direction and pertains to an end; that is, it is "...normative and concerned with what ought to be."[3] For Drucker, real control in an organization is "...the ground of behavior and the cause of action."[4] In other words, ultimate control lies in human decisions for "...controls must become personal motivation that leads to control."[5] Bedford defines two primary tasks in managerial control: first, a motivational function to prevent variation; second, a corrective function seeking to re-establish planned activity if and when deviations occur.[6] His definition also underscores the concept of more than human activity involvement:

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[1]Donnelly, Gibson, and Ivancevich, Fundamentals of Management: Functions, Behavior, Models, p. 415.

[2]Ibid., p. 99.

[3]Peter F. Drucker, Management: Tasks, Responsibilities, Practices (New York: Harper & Row, Publishers, 1974), p. 494.

[4]Ibid., p. 504.

[5]Ibid., p. 495.

[6]Norton M. Bedford, "Managerial Control," in Contemporary Management: Issues and Viewpoints, ed. by Joseph W. McGuire (Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1974), p. 512.

> Managerial control is the process of directing a set of persons, equipment, and materials according to an established plan of action toward a specified objective. Essentially, managerial control functions by comparing achieved outcomes with desired outcomes and adjusting operations so that the gap between the two is reduced.[1]

Thus, Bedford suggests a system or integrated view of control involving a "set" of input resources. Koontz and O'Donnell generalize control as that function that insures that plans succeed. They regard the function "...as one of establishing standards against which performance can be measured, measuring performance, and correcting deviations from the standards or plans."[2] Gross asserts the "domination over" connotation of control,[3] and this definition is also recognized by Resser as a candidate in the melee.[4] Newman specifically suggests that confusion may be avoided by "...not using 'control' loosely to embrace power, authority, influence, and leadership."[5] He stresses the future-orientation, behavioral, and cybernetic aspects of control.[6]

Sherwin emphasizes the assertion that controlling and managing are not the same thing and should not be equated. Sherwin states that "The essence of control is action which adjusts operations to predetermined standards."[7]

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[1] Ibid.

[2] Koontz and O'Donnell, Management: A Book of Readings, p. 649.

[3] Bertram M. Gross, The Managing of Organizations: The Administrative Struggle, Vol. 1 (New York: Free Press of Glencoe, 1964), p. 264.

[4] Reeser, Management: Functions and Modern Concepts, p. 352.

[5] Newman, Constructive Control: Design and Use of Control Systems, p. 5.

[6] Ibid., pp. 3-6.

[7] Douglas S. Sherwin, "The Meaning of Control," Dun's Review and Modern Industry (January 1956), pp. 44 ff., reprinted by Koontz and O'Donnell, Management: A Book of Readings, p. 652.

Emch also emphasizes the dynamic nature of control by equating it with action.[1] Goodwin takes the position that the etymology of the English verb "to control" (from its original French contrôler) requires, in the interest of clarity and accuracy, that control be equated with checking, testing, or verifying only and that adjustment is not a proper task of controlling. Goodwin suggests substitution of the word "surveillance" for the word "control" in management theory.[2] Urwick takes specific and emphatic exception to Goodwin's analysis by stressing the difference in the vernacular and technical (management) senses.[3] Urwick sees the vernacular meaning of control as to restrain, direct, or dominate.[4] He supports the technical definition of control meaning to check, test, or verify as the proper management form.[5] Tannenbaum notes this definitional distinction, but indicates that the word "control" is now commonly used in a broader sense in management theory synonymously with the "...notions of influence and power."[6]

Some authors have explored the subject of management control attempting to develop comprehensive foundations for principles, theory, and practice. Koontz was one of the first contemporary authors to seek a conceptual

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[1]Arnold F. Emch, "Control Means Action," Harvard Business Review 32 (July-August 1954): 92-98.

[2]E. S. L. Goodwin, "Control: A Brief Excursion on the Meaning of a Word," Michigan Business Review 12 (January 1960): 13-17, 28.

[3]Lyndall F. Urwick, "The Meaning of Control," Michigan Business Review 12 (November 1960): 9-13.

[4]Ibid., p. 11.

[5]Ibid.

[6]Tannenbaum, Control in Organizations, p. 5.

framework by identifying four principles of control,[1] which he expanded to fourteen in a subsequent article.[2] Luneski described "broad" and "narrow" classifications of definitions of control.[3] Powell attempts to formulate a working philosophy of management control, "...which lies in decisions 'by people harmoniously at work' at all levels of the organization."[4] The Graduate School of Business of Stanford University sponsored a Seminar on Basic Research in Management Control in 1963 to permit researchers in management control to discuss their work with each other.[5] Some six years later, Mockler edited a book of readings that brought together articles addressing both theory and articles aimed at the many techniques of management control.[6] Mockler's 1972 text presents an integrated view of management control activities in a business setting.[7]

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[1]Harold Koontz, "A Preliminary Statement of Principles of Planning and Control," Journal of the Academy of Management 1 (April 1958): 45-61.

[2]Harold Koontz, "Management Control: A Suggested Formulation of Principles," California Management Review 1 (Winter 1959): 47-55.

[3]Chris Luneski, "Some Aspects of the Meaning of Control," Accounting Review 39 (July 1964): 591-97.

[4]Ray M. Powell, "Principles of Modern Management Control," Financial Executive 34 (April 1966): 54, 56, 58, 60.

[5]Formal papers presented during the three day seminar are contained in Charles P. Bonini, Robert K. Jaedicke, and Harvey M. Wagner, eds., Management Controls: New Directions in Basic Research (New York: McGraw-Hill Book Company, 1964).

[6]Robert J. Mockler, ed., Readings in Management Control (New York: Appleton-Century-Crofts, 1970).

[7]Mockler, The Management Control Process.

In consideration of the differing definitions utilized by various authors,[1] it appears that three categories of definitions accommodate the majority of common usages:

(1) Administration, supervision, or domination in the sense of power and authority over subordinates. It should be noted that in the business setting, this function is referred to by some authors as "direct" or "lead."

(2) Measurement, reporting, or surveillance in the sense that the function is limited to the flow and collection of information only, implying that regulation, adjustment, and correction occur as a consequence of other functions or self-control.

(3) Regulation in the sense of assessing, evaluating, or checking status and directing corrective action if and as necessary based on feedback. This use of the term generally suggests control as the final and integrating function in the management cycle that closes the loop.

In a broad sense, there exists a definitional trichotomy which involves widely divergent definitions and a multiplicity of implications. Pursuit of these ambiguities in search of a codifying definition would be most interesting, but such a task is outside the scope of this study. The third of the three categories of definitions, which equates control with regulation, is the one generally embraced by this study. This usage highlights the integrative aspects of the

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[1]An excellent classic synthesis of significant conceptualizations of managerial functions, with specific emphasis on planning and control definitions, may be found in Robert N. Anthony, Planning and Control Systems: A Framework for Analysis (Boston: Graduate School of Business Administration, Harvard University, 1965), pp. 129-47. A comprehensive review of existing literature on management control may be found in Giovanni B. Giglioni and Arthur G. Bedeian, "A Conspectus of Management Control Theory: 1900-1972," Academy of Management Journal 17 (June 1974): 292-305.

control function and encompasses the tasks of evaluation or measurement of status and adjustment or correction of deviations. Equally important, it provides the foundation for adaptive, dynamic, and future-oriented regulation of organized endeavors, thereby enhancing their constructive and meaningful functioning.

One distinction is made in this study, however, that is at variance with authors who state or imply that the basis of control is a standard or static plan. This concept of the control process denies the dynamic nature of many complex, large-scale endeavors, or suggests the availability of omniscient planners, or both. This interpretation is a static view and argues that the theme of control is to assure the closest possible compliance of actual performance to plans. This restrictive view is referred to as the "conformance fallacy" by Anthony.[1] He suggests that:

> Management control is the process by which managers assure that resources are obtained and used effectively and efficiently in the accomplishment of the organization's objectives.[2]

Mockler amplifies this view of management control in these terms:

> Management control is a systematic effort to set performance standards consistent with planning objectives to design information feedback systems, to compare actual performance with these predetermined standards, to determine whether there are any deviations and to measure their significance, and to take any action required to assure that all corporate resources are being used in the most effective and efficient way possible in achieving corporate objectives.[3]

Both of these definitions stress the positive characteristics of the control function.

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[1]Anthony, Planning and Control Systems: A Framework for Analysis, pp. 28-30.

[2]Ibid., p. 17.

[3]Mockler, The Management Control Process, p. 2.

The concept used throughout this study envisions a dynamic environment with the adjustment or correction facet of the control process potentially applicable to all parameters of the situation, not just the operational factors. It means that all variables are considered at each decision point in a dynamic, proactive manner. This concept suggests adaptive tools and techniques utilized by cognitive human managers in a participative management environment involving all resources associated with the endeavor. It assures the inclusion of human beings in the control process without denying the possiblity of automated, automatic controls and control techniques. This concept highlights the potential applicability of the adjustment process to all pertinent resources and implies the prospective aspect of the control process. It also underscores the compelling nature of control suggested by Murdick and Ross: "Plans are not self-achieving or decisions self-implementing; carrying them out means prescribing the activities of personnel at designated times."[1] In sum, the essence of this concept of control is the regulation or ordered progression of an endeavor toward its desired goals, based on total situational assessment and optimal corrective action. As stated at the outset of this chapter, management control, as an activity, is a tool of all functions of management, and controlling, as a function, is a user of the other four functions. This view of controlling and management control is graphically illustrated in Figure 4.

While this conceptualization of the control function is broader than is generally proposed, it does not materially complicate the already difficult task of defining practical separation between the five principal functions of management. This observation is particularly pertinent in regard to the planning

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[1]Robert G. Murdick and Joel E. Ross, Information Systems for Modern Management (Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1971), p. 49.

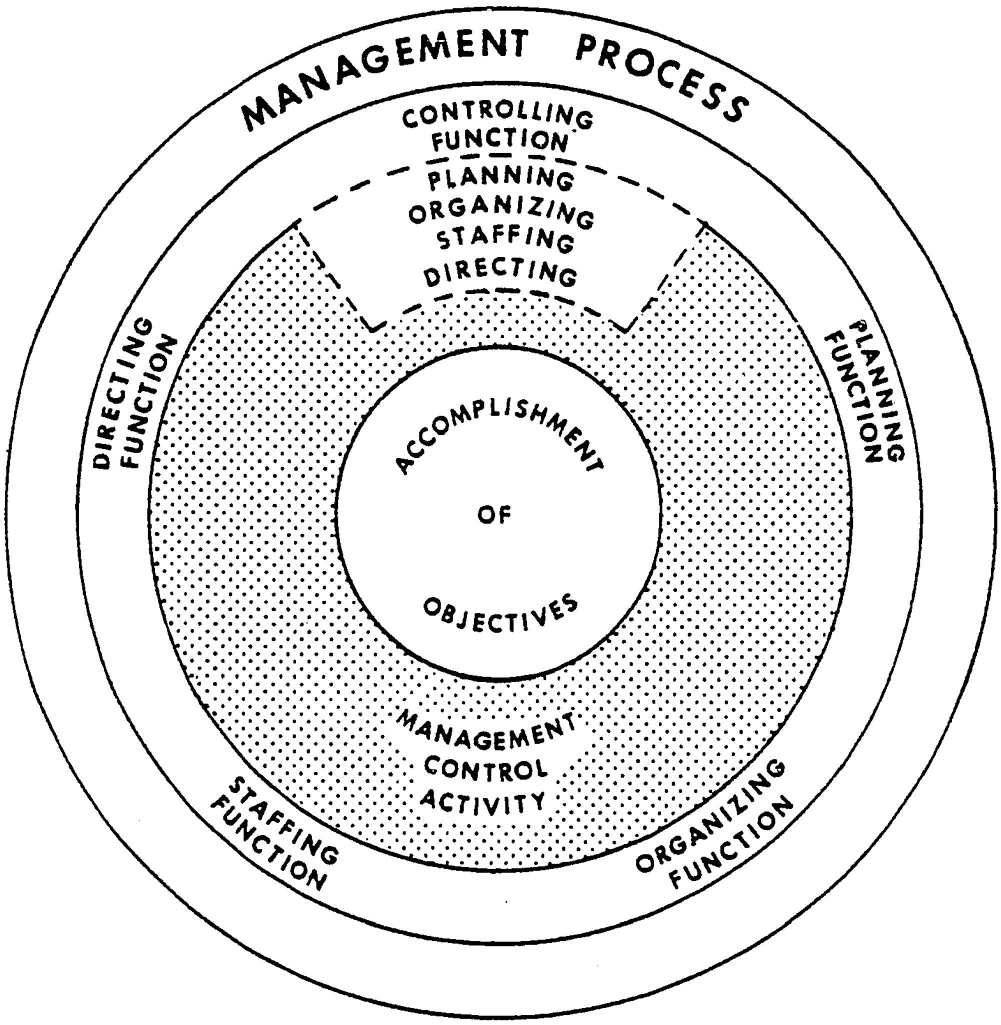

Fig. 4. Management Control as Integrative Force

and control functions, but the semantics problem is not the issue. It is necessary only that the distinguishing characteristics of the control function, as used herein, be recognized; for the body of the study presupposes this framework.

Major Sources of Material

This study made maximum use of primary source material for the formulation of a cogent factual framework that served as the basis of analysis. Secondary source material was used both to support study contentions, as appropriate, and to provide insight into alternative and differing views.

Primary Sources

Primary source material consisted predominantly of official plans, reports, studies, research documents, letters, memoranda for record, trip reports, minutes of meetings, fact sheets, staff studies, and speeches. Materials from both government files and industry files were utilized. Due to the national security sensitivity of the weapon system program, some pertinent material was classified in accordance with Executive Order 11652.[1] This limited direct usage to a "need-to-know" basis and precluded such information from inclusion in this study. While this restriction hampered the research activity slightly, it was not an insurmountable obstacle.

Secondary Source Material

Secondary source material consisted of the published works of known experts in the field of management control. Both texts and professional journals were examined and analyzed. This material was used either to collaborate conclusions drawn in this study or to demonstrate alternative conclusions that

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[1]U.S., President, Executive Order 11652, "Classification and Declassification of National Security Information and Material," 8 March 1972.

have been extracted from similar information. The basic intent in the use of this type of source material was to put this study in perspective with conventional wisdom.

Relationship to Similar Studies

This study represents an original and unique approach to the analysis of management control and differs in several particulars from major works on the subject that are currently available. First, this study utilizes a twenty-four-cell, three-dimensional matrix composed of a structured, functional array overlay on the project life cycle interposed against a decision hierarchy. Use of this technique permitted analysis of functional activity as it was impacted by status of the project in the life-cycle and the decision level. Critical selection of the matrix dimensions resulted in a balanced compartmentalization of typical project activity. Establishment of a management control base line against these activities will permit translation of individual cells or the total matrix structure to future large-scale endeavors. Additionally, it permitted demonstration of the effects of project life-cycle phase concurrency and the impact of changes in one phase on the remaining phases.

The development of a base line for integrated control that represents an adaptive and dynamic management posture is a second difference. It is not suggested (as it was under Scientific Management) that there is only "one best way" in which to accomplish a given objective. Neither, however, is it implied that the range of alternatives then available (given that the number is greater than one) is infinite. The thrust of this study is to demonstrate that management can and should have a base line for integrated control of complex projects. Further, the contention that the base line does accommodate project turbulence and typical dynamics will be explored.

Third, the specific analysis of the control function, operating through tools, techniques, and systems, as both a horizontal (functional) and vertical (hierarchic) integrative force in the management of large-scale endeavors is a departure from existing works. In this study, the concept of total integrated management control attaches to a theoretical framework of "pure integration" concerned with relating cost, schedule, and technical performance parameters to each other. This would permit qualified analysis of any one of the three parameters in terms of the other two and would relate all three in terms of total program or project activity. Analysis stresses the horizontal integration of functional activity, the vertical integration of hierarchic decision and organizational levels, the "problemistic search" (search prompted by the existence of a problem and aimed at problem resolution) and "opportunistic surveillance" (search activity not by a problem, but by the desire to avoid problems and seek opportunities).[1] The context of the analysis and not the issues suggests the tone of the difference between this study and other works.

In sum, this study is unique in several major respects. Its utility attaches to this uniqueness and the fact that the findings and conclusions may serve as guides in developing integrated control systems for future large-scale endeavors.

Organization of the Study

This study consists of eight chapters, including this introductory chapter. The organization of the material is interrelated with the methodology

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[1]James D. Thompson attributes the concept of "problemistic search" to Cyert and March and coins the terminology "opportunistic surveillance" himself in Organizations in Action (New York: McGraw-Hill Book Company, 1967), pp. 151-52.

of the study and stems from the use of the structured functional parameters in the analysis matrix. This format balances the need for analytical clarity with the natural sequential attractiveness of a chronological technique.

Chapter II synthesizes salient milestones in the evolution of management control from its early pragmatic origins to its present state. The emphasis of the chapter will be on twentieth-century achievements and contributions.

Chapter III is a historical account of the Safeguard program. The chapter traces the major milestones in the evolution of the program from its inception, emphasizing the organizational changes that paralleled system evolution. This background will enable the reader to gain deeper insight into why the management doctrine matured as it did.

The analysis matrix is fully developed in Chapter IV. The basic objective of the chapter is to construct the foundation for the subsequent analysis. A logical correlate to this objective is to provide for smooth transition from the introductory and prerequisite material to the body of the study.

Chapters V, VI, and VII address the structured functional phases of cost, schedule, and technical performance, respectively. The format of these three chapters is similar, but emphasis is on those factors critical to the pertinent analysis.

Finally, study summary and conclusions are presented in Chapter VIII. It is a synthesis of the study proper and an articulation of major conclusions. Appendices are utilized to present supportive secondary material.

CHAPTER II

MANAGEMENT CONTROL: SOME HISTORICAL MILESTONES

This chapter synthesizes milestones in the evolution of management control chronologically, from its pragmatic origins to its present state.[1] Management control as a distinguishable field of management is relatively new, but its origins are deeply rooted--not just in growth of the management discipline, but in the evolution of mankind itself. Control, in varying forms and degrees, is a necessary process in the fundamental functioning of family, church, government, military, academic, and business organizations. In essence, it is found throughout social, economic, and political systems and institutions. Significant historical contributions to management control techniques have come from many fields of endeavor and much of what is formally known today about management control has been derived from earlier theory and methodology.

Many of the individual theories and applications discussed in this paper are considered by modern scholars to be original and unique contributions to the field of management control. In some cases, contributions consisted primarily of

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[1]The course of management thought through the ages is frequently difficult to perceive due to the myriad of exogenous influences, the complex interrelationships of similar conceptual approaches, and the need to analyze contributions not only in light of historical perspective but also in the existing environment of their conception. A frame of reference serves to neutralize these many factors, thus permitting clearer definition and sharper focus. The following text was utilized for such a purpose in the research underlying preparation of this paper: Daniel A. Wren, The Evolution of Management Thought (New York: Ronald Press, 1972).

expanding an original concept or practice by extending its dimensions or by providing keener and more persuasive insight as a result of broader application or greater depth of analysis. Advancement of the state-of-the-art also occurred through the novel integration of specifically selected aspects of several theories or applications, often with a resultant synergistic effect. The substance of individual contributions often varied in magnitude, but viewed in perspective, these historical milestones form, underscore, and reinforce a continuously evolving body of knowledge.

It is difficult to determine consistently and conclusively the relative significance and merit of all individual contributions to management control. In the research effort associated with the development of this chapter, deliberate decisions had to be made regarding inclusion of germane information and exclusion of less relevant material. This is a subjective matter and the threshold of acceptance or rejection may vary with individual scholars. Because of the scope of the subject, this chapter is not a structuralized and institutionalized examination. The purpose is not encyclopedic conprehensiveness, but an intensive effort was made to include major contributions that had either significance to the time or were the foundation for later theory or application. In many cases, the material included fulfilled both conditions since the development of management in general and management control in particular has been an evolutionary process. Especially in recent years has our progress been built upon the foundation of prior thought. Many texts, articles, and papers were reviewed and were deemed to be primarily documentation of, rather than extension of, the body of knowledge relevant to management control. Reference to these less pertinent materials was omitted and emphasis placed on the more germane contributions.

Ancient Thought and Practice

In searching for the origins of management control, it is necessary to look beyond current terminology and conceptual boundaries of the field for such an envelop would be far too restrictive. It would reduce the primary search area to this century and eliminate from consideration earlier activities that form elements of a broader and historically more accurate picture. While it is difficult to determine the true beginnings of management control or, for that matter, the genesis of the management discipline itself, management control had its origins in the applied ingenuity of early man solving the problems of his day. In this sense, management control had no single, tangible, initial milestone, but a series of early milestones that are fragmentary and somewhat blurred by time and lack of detailed accounts of ancient man. The information that is available, however, points to the fact that control in various forms was in evidence in a number of early cultures.

Sumeria[1]

In the Sumerian civilization of approximately 5000 B.C. it was the responsibility of specified temple priests to manage the worldly goods and business functions of the religious institution. Taxes were levied on the people and paid in varying forms of tangible property, including livestock. Loans made by the religious organizations to its people were also repaid in like manner. These "manager" priests thus were in the position of not only having to keep track of income and expenditure items, but periodically to give an account of

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[1]This subsection is based largely on V. G. Childe, Man Makes Himself (New York: The New American Library, 1951), cited by Claude S. George, Jr., The History of Management Thought, 2d ed. (Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1972), pp. 3-4.

their stewardship to the chief priest. Accounting practices of the time, utilized by individuals for their own management purposes (the use of notched sticks as an example), were insufficient for the array of accounts controlled by the priest. Additionally, the accounts frequently survived the priest at his death, and it became difficult for successor manager priests to determine account status. Memory simply did not suffice under these complications of periodic audit and demise of the manager.

It was this need for inventory control that led to the development of an early system of writing by the Sumerian priests to record the multitude of individual transactions occasioned by the taxation and lending practices of the culture. This early recognition of the need for and desirability of management control served the day-to-day transactional requirements of the priest and permitted transition to another manager as the need arose.

Egypt

The Egyptian culture is frequently remembered primarily for its accomplishments in the construction of the pyramids and canals, but it was also a culture of "bureaucratic state administration."[1] The pyramids stand in silent testimony to the construction skills of the Egyptians and such mammoth undertakings undoubtedly required extensive control measures.[2] It is in the "bureaucratic state administration," however, that an equally important contribution was made.

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[1]Gross, The Managing of Organizations: The Administrative Struggle, p. 35.

[2]George, The History of Management Thought, pp. 4-5.

The state administrative structure was large and taxation widespread. Government bookkeeping grew to large proportions because of the extensiveness of the administrative structure, the number of employees on the payroll, and the fact that records were kept of many different activities throughout the state. As an example, records were kept on harvesting operations, wages paid, slaves, and worker performance. These latter records, relative to performance, were kept as marginal notes, in red, and contained information concerning the worker's absences, if he had been lazy, and finally his death. The clerks and scribes in Egypt enjoyed a high station in life, and government service was attractive for both free men and slaves. To be appointed as a writer or clerk to the Pharaoh was a high and desirable honor. In essence, the Pharaoh functioned as the head of a large business activity involving control of the waterways, taxation, and internal administrative concerns as early as perhaps 4000 B.C.[1]

Babylonia

The Babylonian civilization was approximately chronologically parallel to the Egyptian culture and dates back to 4000 B.C. It also demonstrated early recognition of the desirability of record-keeping. Whether the Egyptians and Babylonians developed their systems independently or one taught it to the other is unknown, but many of the control mechanisms and account classifications were similar.[2]

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[1]C. Bertil Nystromer, Four Thousand Years in the Office (Stockholm: National Office Management Association, 1940), reprinted in part by Edward C. Bursk, Donald T. Clark, and Ralph W. Hidy, eds., The World of Business, Vol. I (New York: Simon and Schuster, 1962), pp. 66-68.

[2]Ibid., p. 67.

About 2000 B.C., Hammurabi became King of Babylon and established a central government. He is probably most remembered for the code he developed for the dispensing of justice throughout the Empire. The code contained over three hundred separate entries and covered many facets of secular activity, including trade and business.[1]

Commercial control mechanisms were evidenced in the code by requirements for written and sealed receipts, contracts, and witnesses to transactions. Many forms of transactions such as loans, leases, and mortgages were covered by the code. As a consequence, there were many official documents in the form of clay tablets that were filed in a fashion similar to current index card systems. The bookkeeping system covered both credit and cash transactions and income and expenditure accounts. While not a double entry form of accounting, the system was used as a control technique and a method for periodically determining the profit and loss of business or individual transactions.[2]

The use of color coding for inventory control was evidenced some years later during the reign of Nebuchadnezzar (605-562 B.C.). As grain from the fields was harvested, it was placed in large earthenware containers and a colored reed placed in the seal of each. It was advantageous to differentiate containers by year of harvesting and each year was assigned a different color.[3]

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[1]Hammurabi, The Oldest Code of Laws in the World, translated by C. H. W. Jones (Edinburgh: T. and T. Clark, 1903), reprinted in part by Bursk, Clark, and Hidy, eds., The World of Business, p. 9.

[2]Nystromer, Four Thousand Years in the Office, pp. 64-66.

[3]L. P. Alford, Laws of Management Applied to Manufacturing (New York: Ronald Press, 1928), p. 37.

This simple yet serviceable means permitted easy identification of the age of the grain inventory lots. It demonstrates an early recognition of the effectiveness of color coding as a control technique.

China[1]

Two contributions of the Chinese culture deserve brief mention. The first, the Constitution of Chou, was basically a combined job descriptions catalog and standard operating procedure for the emperor's civil servants at all levels. In describing the responsibilities and powers of the prime minister, it defined his power in terms of control over the king's officers--the ultimate power being death, "...that controls their excessiveness."[2] Regulatory aspects relative to the position of prime minister dealt with internal administration of the governmental departments and included regulations concerning organization, functions, interdepartmental relationships, procedure, the appearance of permanency in the structure, control, punishment, and auditing. Finally, the constitution provided for methods by which the prime minister should govern the empire. This aspect covered such factors as control of ritual and worship, taxes and tributes, punishment and reward, and control of employment. This law was written about 1100 B.C. and displays a perceptive grasp of the need for and use of pervasive control processes both in the internal administrative and external governing functioning of the empire.

Approximately 600 years later the Chinese philosopher Mencius, in describing the wisdom required of a leader, urged the use of systems, procedures,

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[1]This subsection is based largely on George, The History of Management Thought, pp. 11-13.

[2]Ibid., p. 12.

and models generated by specialists. He advised that not only business concerns, but individual craftsmen as well, needed a system in order to succeed. He drew an analogy between the craftsman using a compass to inscribe a circle and the king using a system to govern the empire. He asserted that occasionally the skilled artisan could draw a circle without the use of a system, but that with a system or model even the unskilled could achieve the perfection of the specialist. Thus, Mencius cogently argued, the leader would be less perceptive than the craftsman to attempt to govern without a system as a model. The inherent simplicity of the analogy underscores the fundamental implications of using control processes developed by specialists.

Greece

The contributions of Socrates are manifest in many areas of thought, and Aristotle, by rejecting mysticism, has been given recognition as "the father of the scientific method."[1] Socrates recognized the universality of management in describing the expertise required in administration.[2] He spoke of control in the connotation of management or direction of organized units such as estates, choral groups, and armies. He emphasized that managerial skills were transferable and that those who understood how to apply them would be successful managers of both public and private affairs and that those who did not would fail in either. In Socrates' mind the difference between the management or control of public and private affairs differed only in magnitude.[3]

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[1] Wren, The Evolution of Management Thought, p. 17.

[2] Ibid., p. 16.

[3] Gross, The Managing of Organizations: The Administrative Struggle, p. 94.

Aristotle held views similar to those of Socrates concerning the universality of management between the private sector and the public sector of activity. Additionally, he sought true knowledge by questioning through reason, and "...this spirit of scientific inquiry would form a basis for scientific management."[1] From these two great philosophers came concepts that carry to this day.

India

Kautilya was an Indian statesman and vizier to King Chandragupta around 300 B.C. Like others that followed later in history, he wrote his Arthasastra (the oldest book in extant Sanskrit literature)[2] as a comprehensive account of general principles and specific rules concerning the governing of an empire's internal administration and foreign affairs.[3] It seems unorthodox to characterize Kautilya as "Machiavellian," yet this reference aptly describes his approach to administration and the tenor of his advice for "He was unscrupulous and treacherous, but never to his King."[4]

Kautilya was concerned with the difficulty of securing men of sufficient trustworthiness to serve the state with integrity. He saw this as a basic problem of administration, and his solution was one of extensive administrative control and performance assessment. As an example, he specified

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[1]Wren, The Evolution of Management Thought, p. 17.

[2]Will Durant, The Story of Civilization, Vol. I: Our Oriental Heritage (New York: Simon and Schuster, 1954), p. 443.

[3]Gross, The Managing of Organizations: The Administrative Struggle, p. 92.

[4]Durant, Our Oriental Heritage, pp. 441, 443.

daily analysis of employee results in terms of cost, time, and functions performed. Carelessness and error were to be dealt with harshly through fines and punishment. An even more elaborate part of his scheme, however, involved an extensive network of spies and covert attempts to compromise state officials. The spies were not only to secure information and report it to the king, but were also charged to make calculated and deliberate attempts at entrapment.[1] While the methods proposed may seem unduly harsh, there can be little doubt concerning the value that Kautilya placed on the performance measurement, feedback, and corrective action facets of administrative control.

Rome

The administrative structure of the Roman Empire attained vast proportions,[2] and the basic control mechanism of the state was its military strength. The geographic dispersion of the colonies presented problems initially, and the government sought to ease the burden by contracting out such public activities as collection of customs duties, tithes, and fees; mining operations; and provisioning of field forces of the Roman Army.[3] This system ultimately proved unsatisfactory and, under Augustus, public functions that had been contracted out reverted to internal state activity by making civil servants of the businessmen involved. This administrative reform proved highly successful.[4] It

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[1]Gross, The Managing of Organizations: The Administrative Struggle, pp. 102-3.

[2]Ibid., p. 34.

[3]Arnold J. Toynbee, "Thinking Ahead: Will Businessmen Be Civil Servants?" Harvard Business Review 36 (September-October 1958): 34.

[4]Ibid., p. 38.

is interesting to note that the proper balance between government "in-house" activity and contracted activity is still a matter of attention in the federal government.

Communication could have been a problem in control, but the "consular roads" aided communication and transport alike. The Roman road system has been described as "...the tenacles of Roman law, the members by which the mind of Rome became the will of the realm."[1]

Evidence is found in Roman civilization of guaranteed currency, an early corporate form of joint-stock companies operating under state control, strict state regulation of economic life coupled with liberal commercial policy, and a government of separated executive and legislative powers.[2]

The Roman Empire was the most advanced government the world had seen. It developed a system of municipalities and a communication and transport system of roads that were unexcelled in terms of speed of travel until the advent of the railroads.

Middle Ages and the Renaissance

Ancient man was predominantly reactive and his response to the environment demonstrated a pragmatic approach to coping with his problems. The means devised for record-keeping and inventory control are specific examples. Contributions to theory were limited and there is scant evidence to suggest any interchange of ideas or techniques between cultures. In great measure, control was equated to coercive power in large-scale organizations with complex administrative hierarchies.

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[1]Will Durant, The Story of Civilization, Vol. III: Caesar and Christ (New York: Simon and Schuster, 1954), p. 324.

[2]Ibid., pp. 79-80, 670.

Early man was handicapped by his cultural environment, by his limited ability to communicate, and by his methods of gathering, storing, and retrieving information. Management control is a varied and complex problem, and the quality and effectiveness of the control mechanism is related to the fidelity of the data[1] and the instrumental means of control. Early man was restricted both by the lack of high fidelity data and by the synthetic aids of control processes.

The Middle Ages began with the fall of the Roman Empire, and the outlook for civilization for the next eleven centuries was bleak. Conditions during this period were hostile and were marked by conflict and struggle. The primary need of the populace was survival. This need for self-preservation gave rise to the feudal system that lasted until approximately A.D. 1500. In return for protection by the landowner, the serf worked the soil and gave a share of his output and a significantly larger portion of his individual freedom to the feudal lord. This period was one of stagnation, with education all but forgotten, and intellectual life was centered on preparation for the hereafter. Original contributions to management thought were virtually nonexistent.[2]

The Renaissance ended the period of stagnation. Interest in trade was revived as a consequence of the desire for goods from the East, which was prompted by the Crusades; the restoration of political order quelled some of the hostility of earlier years. This stimulation of commerce produced new markets that became new cities and a revitalization of old cities that were given new

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[1]B. G. Schumacher, Computer Dynamics in Public Administration (Washington, D.C.: Spartan Books, 1967), p. 48.

[2]This contention is supported by both A. C. Littleton, Accounting Evolution to 1900 (New York: American Institute Publishing Co., Inc., 1933), p. 16, and Wren, The Evolution of Management Thought, pp. 19-20.

birth. Earlier concepts of property and money took on new and added significance beyond that of ancient times. The spirit of the Renaissance gave birth to the concept of the creation of capital through productive use of labor and resources.[1]

Double Entry Accounting

Ancient civilizations maintained bookkeeping records primarily in terms of receipts and expenditures, and they differentiated between cash and credit transactions. The system did not use double columns, and even precise placement of entries in single columns may have been more a penchant for neatness than a device for ease of computation.[2]

The wealth of the ancient world was static in the form of temples, palaces, and precious gems and metals, but the wealth of commerce was dynamically and productively employed in creating additional capital. It was this creation of capital that perhaps generated the final spark toward double entry accounting.[3]

Littleton described seven factors as necessary prerequisites to the inevitability of double entry accounting: the art of writing, arithmetic, private property, money, credit, commerce, and capital. These elements, activated by conducive social and economic factors, produced a methodology; i.e., double entry bookkeeping.[4] Probably the most conducive social factor was the

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[1]Littleton, Accounting Evolution to 1900, pp. 18-19, and Wren, The Evolution of Management Thought, pp. 20-21.

[2]G. E. M. de Ste. Croix, "Greek and Roman Accounting," in Studies in the History of Accounting, ed. by A. C. Littleton and B. S. Yamey (Homewood, Illinois: Richard D. Irwin, Inc., 1956), p. 14.

[3]Littleton, Accounting Evolution to 1900, p. 15.

[4]Ibid., pp. 12-13.

partnership form of business since it created the distinction between the firm and the owners.[1]

These prerequisite factors and the catalytic social and economic elements began their convergence as early as A.D. 1200 in the city-states of Italy, where capital formation was developing through trading and lending. Investment banking was found as early as A.D. 1171, when the merchants of Venice advanced gold to the government and were provided transferable credit in return. The existence of business partnerships as early as A.D. 1157 has been established from records of that period. Capital began accumulating in sizable amounts, and a crude form of commercial banking grew from a necessity for physical security of monetary assets.[2]

It appears that double entry bookkeeping developed simultaneously in a number of trading centers in Italy. Evidence as early as A.D. 1300 indicates that merchants were utilizing equity and expense accounts, which is only a thought away from mandatory use of debit and credit entries. As with many different types of systems, this last remaining hurdle was most likely overcome gradually through a process of trial and error as opposed to enunciation of specialized theory. Evidence of specific use of double entry bookkeeping occurred as early as A.D. 1390 in the records of Datini, a Pratese merchant-banker, although it is possible that it may have emerged even earlier.[3]

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[1]Raymond de Roover, "The Development of Accounting Prior to Luca Pacioli According to the Account Books of Medieval Merchants," in Studies in the History of Accounting, ed. by Littleton and Yamey, p. 115.

[2]Ibid.

[3]Cosmo Gordon, "The First English Books on Book-Keeping," in Studies in the History of Accounting, ed. by Littleton and Yamey, p. 202.

The earliest known written text on double entry bookkeeping was published in Venice in A.D. 1494. Written by Luca Pacioli, the Summa de Arithmetica, Geometrica, Proportioni et Proportionalita was the result of work over a thirty-year period. Truly one of the great classics, the text is not an original work (Pacioli did not claim it to be), but a collection of practices from many sources. Pacioli indicated that his primary source material was from the works of Leonardo da Pisa, who wrote in approximately A.D. 1200.[1] The text was translated into German, Bohemian, Russian, Dutch, and English. The first English text, Keeping the Reckoning Called Debtor and Creditor, by Hugh Oldcastle, was published in A.D. 1543 without acknowledgement of Pacioli.[2] Littleton suggests that a careful reading of the Summa will reveal "...how little basic change there has been in bookkeeping..." due to the simple and static nature of the principles involved.[3]

Management Control in Large Scale Production

The arsenal in Venice was founded in A.D. 1104. While its functions always included construction and arming of Venetian warships, its main mission was to serve as a munitions and naval stores depot. Initially it covered about eight acres, but additions in A.D. 1303 and A.D. 1325 increased its size to about 30 acres in order to increase its productive capacity. This need was prompted by a decision to concentrate galley building in the government shipyard. In addition, the arsenal was assigned the new function of maintaining a portion of the

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[1] R. Emmett Taylor, "Luca Pacioli," in Studies in the History of Accounting, ed. by Littleton and Yamey, pp. 179-80.

[2] Gordon, "The First English Books on Book-Keeping," p. 202.

[3] Littleton, Accounting Evolution to 1900, p. 77.

merchant marine fleet. The arsenal's mission then remained unchanged for the next one hundred and fifty years.[1]

Beginning in about A.D. 1470, the Venetians, spurred by the advance of the Turks, began the formation of a formidable naval fleet. The decision to arm 100 light galleys and 20 great galleys required addition to the arsenal, which doubled its size to approximately 60 acres of ground and water. At its zenith in the mid 1500s the Arsenal of Venice employed 1,000 to 2,000 men and had expenditures of 100,000 to 200,000 ducats annually.[2] This budget equates to approximately $2,250,000 to $4,500,000.[3]

The direct management of the arsenal was vested in "Commissioners of the Arsenal" responsible for mission activities and Lords of the Arsenal responsible for "...financial management, the collection of funds, the purchase of supplies, and the sending of munitions."[4] Two Commissioners acted as liaison between the arsenal and the Senate. Since the arsenal was considered the heart of the power of the state, the Senate and the secretaries of state participated directly in its management. This extensive and overlapping authority meant that no single individual or even a single group had full command authority or responsibility, but this system of control was by design and not by accident.[5]

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[1] Frederic C. Lane, Venetian Ships and Shipbuilders of the Renaissance (Baltimore: Johns Hopkins Press, 1934), pp. 129-31.

[2] Ibid., pp. 137-40, 146.

[3] The gold ducat contained 3.5 grams or 54 grains of gold, which equates to 0.1125 oz. (Troy weight). A ducat would equate to approximately $22.50, with gold at $200.00 per oz.

[4] Lane, Venetian Ships and Shipbuilders of the Renaissance, p. 143.

[5] Ibid., pp. 146-52.

The growth of the arsenal resulted in strict regulation of the accounting process. All records were consolidated in two journals and one ledger. One journal was kept by an accountant and the chief accountant entered items in the ledger from this journal. The second journal was kept by a Lord of the Arsenal and used periodically to check the ledger. The ledger was balanced annually, balances carried over to a new ledger, and the old books sent to the treasury for audit. Complete and accurate records were of primary concern.[1]

The system was sufficiently detailed that an accountant in 1564 determined that internal movement of lumber within the arsenal cost 500 ducats annually and that the clearing of wood kept in front of the slips (to permit launching of a ship) cost 1,200 ducats annually. This analysis ultimately led to revision of the casual methods used in storing lumber. It appears that completed items of inventory such as benches, oars, sáils, rigging, masts, rudders, and spars were controlled in a far more orderly and systematic fashion. These finished inventory items were arranged in order in designated warehouses, with the items to be issued last closest to the exit. The oarmakers' shop had an opening in the wall near the exit for issue of oars, one of the last items to be distributed to galleys being launched.[2]

Strict physical security of the arsenal was maintained. Visitors were not permitted and all workers were searched upon leaving. All materials leaving the arsenal required written authorization of the Lords and the fact of release and destination of the goods was recorded. In similar fashion, all material received was duly recorded.[3]

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[1] Ibid., pp. 153-55.

[2] Ibid., pp. 158-60, 175.

[3] Ibid., pp. 156-57, 193.

The Arsenal of Venice, in the sixteenth century, was perhaps the largest industrial facility of the time. It was efficient; it maintained physical, inventory, and visitor control; it had standards of quality for acceptance and rejection of raw and finished materials; and it maintained complete and accurate accounting records.[1] Its combination of accounting and inventory procedures, coupled with departmentalization of the construction process, permitted estimation of status of completion of each galley under construction and calculation of its cost when fully equipped and ready for service.[2] While no mention is made of the cost-effectiveness or performance measurement aspects of arsenal activity, its accomplishment of its mission was highly successful when measured by standards of the time.

Information in Management Control[3]

The availability of timely, accurate, and pertinent information is essential to the control function. Evidence of this fact was demonstrated by the Romans and their elaborate road system used for both transport and communication. In the fiercely competitive commerce of the sixteenth century, the timely availability of a different breed of information could, indeed, result in major advantage over competitors.

The Fugger family achieved prominence in central Europe with a diversity of interests including banking, mining, spice trading, and weaving,

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[1] Ibid., pp. 143-46, 153, 158-60, 193-95.

[2] Ibid., pp. 158-60.

[3] This subsection is based largely on Rodger Burlingame, Endless Frontiers: The Story of McGraw-Hill (New York: McGraw-Hill Book Company, Inc., 1959), pp. 13-15.

ranging geographically from China to Peru. With headquarters in Augsburg, it had agents in the larger cities such as London, Paris, Antwerp, and Venice. The geographic dispersion of its interests, the heavy competition from its business rivals, the political environment of war and international intrigue, and the existence of piracy made timely information concerning political and financial status imperative to continued success.

The House of Fugger developed the equivalent of a manual information system centralized in Augsburg and fed by satellite centers in the larger cities that were, in turn, subcenters receiving information from throughout the country. Input took the form of handwritten letters, submitted regularly, concerning critical issues of interest to the firm. The information contained in the letters was highly sensitive and dealt with local political conditions, activities of competitors (one letter in 1585 forwarded a complete inventory of the contents of ships outbound from India), information concerning prospective customers and their interests, and matters of calculated speculation.

Received in the "Golden Counting-House," as the headquarters in Augsburg was called, the newsletters were analyzed, data from various parts of the world compared, and conclusions drawn regarding appropriate action. Letters of instruction were then prepared and returned to the agents for implementation. While the techniques of information processing have improved in the twentieth century, the fundamental mechanics of the operation are not unlike those employed by the House of Fugger almost five hundred years ago.

Political Control

Niccolo Machiavelli (1469-1527) served for a number of years as a minor civil servant in the city-state of Florence. He was an idea-man and performed administrative work for the politicians of the government. He was adept at diplomacy and frequently was sent on diplomatic missions outside Florence. He was in a position to analyze power, and did so by observing "behind the scenes" activity. He was removed from office when the Medici family was restored to power and it was during this period of enforced inactivity that he wrote The Prince in 1513 in an unsuccessful attempt to regain the favor of the Medicis and thus reinstatement.[1]

Machiavelli took a dim view of the basic nature of man and made numerous references to man as "bad." On the assumption that men would not keep faith with the ruler, he argued that the ruler need not keep faith with them if it was against his own interests. He advocated deceit as required, the allusion of good qualities as favorable to actually possessing and observing them, and the ability to do evil if constrained in order to maintain control of the populace.[2] On internal administration, Machiavelli suggested that it was important for a prince to assert his authority by rewarding or punishing any extraordinary act of good or evil in a way that would be well publicized.[3]

Machiavelli equated control to power and felt that the ends always justified the means. Because of his writings, his name is now frequently synonymous with "unscrupulousness." But it is interesting to note that politics was Machiavelli's "bag" and he was an experienced political observer, ambassador, and administrator. The tone of his work was in keeping with the actual, but never openly admitted, practice of the times. In essence, he put into written form the real political spirit of his age, and this created more enemies for him

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[1] Niccolo Machiavelli, The Prince and the Discourses, trans. by Luigi Ricci, rev. by E. R. Vincent with an introduction by Max Lerner (New York: Random House, 1940), pp. xxv-xxviii.

[2] Ibid., pp. 63-68.

[3] Ibid., pp. 63-68, 82.

than ever.[1] Regardless of one's reaction to Machiavelli's precepts, his works stand as classic literature of the times.

Production Economies

In 1776, the great economist Adam Smith (1723-90) published his Wealth of Nations and thus established the "classical" school of economic thought.[2] Smith was one of the first to provide specific insight into the division of labor by recognizing three fundamental economic advantages from such practice: the development of dexterity and skill through repetitive performance of a single task, a savings of time by not having to switch from one activity to another, and the fact that the development of tools and machines seemed normally to follow when men concentrated on tasks of restricted scope. It is interesting to note that these were not hypotheses of a theorist, but conclusions based on empirical studies.[3]

Adam Smith's recognition of the existence of a basis for economies of production through division of labor accelerated the specialization of labor process and gave impetus to the factory system.[4] Adam Smith had a supply oriented view of macroeconomic theory based on an assumption that aggregate demand was dictated by aggregate supply. While his total view of economic theory was macro in scope, his analysis of the division of labor was a micro view of the production process.

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[1] Ibid., pp. xxviii, xxxii.

[2] Wren, The Evolution of Management Thought, p. 23.

[3] Elwood S. Buffa, Modern Production Management, 2d ed. (New York: John Wiley & Sons, Inc., 1965), p. 4.

[4] Ibid.

Period of Transition

The period of history just discussed began in despair and ended in the first stretchings of awakening. The Crusades revitalized interest in trade, the productive use of capital resulted in new business forms and a shift from barter economy, and the complexities of commerce urged improvement in control techniques. Improvements occurred, but these were largely the outgrowth of practice as opposed to development of pre-established theory. Transmittal of ideas and practices between cultures was still virtually non-existent, but the invention of the Gutenberg printing press in 1450 was to have a dramatic impact on the transmission of information.[1]

Many of the restrictions of ancient man continued through this period. Efficient control was still hampered by the lack of effective synthetic aids to the control process and information technology was nebulous at best.

The Industrial Revolution in England, spurred by the development of Watt's steam engine in 1765, marked a period of transition in the technology of man. It underscored the shift in emphasis from static technology involving instruments of little or no motion to dynamic technology characterized by energy converters.[2] It diminished his dependence on agriculture and opened the door to economic growth. The essence of the Industrial Revolution was the substitution of machine power for the prime movers of human, animal, and natural power, but two other revolutions also occurred simultaneously in England. The first was a

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[1]Burlingame, Endless Frontiers: The Story of McGraw-Hill, p. 23.

[2]Morris C. Leikind and Wyndham Miles, "The Nature of Science and Technology," in Science and Technology: Vital National Assets, eds. Ralph Sanders and Fred R. Brown (Washington, D.C.: Industrial College of the Armed Forces, 1966), pp. 7-8.

scientific revolution during which man began to shift from the Bible and look around him. This revolution broke with the idea of science for the sake of science and turned toward science for the sake of technology and advancement. The second was the agricultural revolution, in which land previously utilized for agricultural purposes was turned into pasture for the grazing of sheep. As wool grew in importance, enclosures of common land used for public farming were increasingly converted. This closing of farm land, coupled with improvements in farm machinery, forced farmers to seek other employment. It was this ready force that first began to fill the labor needs of the new factories.[1]

Early Factory System

The early factory system of the Industrial Revolution had its origins in the "domestic," or "cottage," or "putting-out" system of the Renaissance. Under this system, a merchant purchased raw materials and distributed them to individual workers or families. These in turn manufactured the product and sold it back to the merchant to recover value added. The merchant needed sufficient capital for the purchase of raw materials and finished goods; the workers needed sufficient capital for purchase of the tools of their trade. The factory system brought together capital, raw materials, tools of manufacturing, and workers; and separated ownership from management of the enterprise. Traditionally, the three elements of land, labor, and capital had been recognized as the factors of production. A French economist, Jean Baptiste Say (1767-1832), was the first to recognize management as an explicit fourth factor of production.[2]

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[1] Wren, The Evolution of Management Thought, pp. 36-38.

[2] Ibid., pp. 21, 42.

The problems presented by the factory system were unique in the history of man. The new manager could not rely on devotion, dogma, or military discipline as had his forefathers. Additionally, he had to compete in the market place and make a profit. These problems were made more complex by the fact that labor was unskilled, untrained, and undisciplined in relation to the rigors of factory production. The lack of knowledge on management methods and of codes of management behavior further compounded the problem.[1]

The growth of the factory system led to many new difficulties, not the least of which was the control of performance. The complexities of industrialization and organizational size precluded the manager's ability to personally supervise all activity. This is not to imply that personal observation of all operations had been the unanimous practice of management prior to this period, for it was not. The significance, however, was in the skill of the workman. Whereas the earlier workman was basically skilled in his particular craft, the workman in the early factory system was generally not well trained. The need for close observation to insure satisfactory performance and quality added to the continuing need for close supervision to insure physical security.[2]

The factory system resulted in some improvements in protection of materials and physical security, but quality control did not improve much over earlier systems. Control over raw materials and supplies was slack and manufacturing methods lacked standardization. These factors coupled with a lack of skilled workers often resulted in products of varying quality.[3] Financial control in the form of double entry bookkeeping was one of the more advanced

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[1] Ibid., pp. 43-50. [2] Ibid., pp. 54-55.

[3] George, The History of Management Thought, p. 53.

techniques of management control, but there is little evidence that the accounting function was utilized in decision-making in the early factory system.[1]

Textile Management

James Montgomery of Glasgow, Scotland, was "the" authority on textile mills of his times.[2] Writing in the 1830s, his works may be the first "management" text;[3] a significant milestone in history.

Montgomery's first advice to the mill manager was that he have a detailed knowledge of the business including how to regulate the speed of the machine, adjust the "draught" (i.e., pull or tension) of the machines, and make changes in the size of the yarn and quality of the fabric. Montgomery argued that without a thorough knowledge of the operation, the manager "...will not be so able to detect the deficiencies of others, and therefore be more liable to be taken advantage of."[4] He also recommended that the manager keep accurate records of cotton of unacceptable quality produced as a result of any alteration of process or technique, in order that the full import of such changes on profitability be ascertainable.

The advice on control of workers showed elements of both an economic and social nature. Montgomery discussed the use of fines as negative sanctions. He also stressed being "firm and decisive" but not "overbearing and tyrannical,"

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[1] Ibid.

[2] James Montgomery, The Carding and Spinning Master's Assistant; or, The Theory and Practice of Cotton Spinning (Glasgow: J. N. Niven, Jr., 1832), reprinted in part by James P. Baughman, ed., "James Montgomery on Factory Management, 1832," Business History Review 42 (Summer 1968): 219-26.

[3] Wren, The Evolution of Management Thought, p. 45.

[4] Montgomery, The Carding and Spinning Master's Assistant, p. 221.

"easy of access" without being "too familiar," and guarding both against "too much lenity" and "too much severity." He also suggested that male workers were more self-regulating in terms of both quality and quantity than female workers "...whom it is difficult to make sensible of their responsibility, and the evils resulting from carelessness on their part." Hence, female employees required constant supervision.[1]

Montgomery also provided keen insight into the very essence of control by any management definition in his advice that the manager be "...always on the alert to prevent rather than check faults, after they have taken place..."[2] thus underscoring the prospective and preventive aspects of control.

Railroad Management[3]

While the textile industry was growing and flourishing in the United States, it never reached the proportions of American railroads, which "...were truly America's first 'big business.'"[4]

Daniel C. McCallum (1815-78), a Scot who migrated to the United States and became general superintendent of the Erie Railroad in 1854, developed a macro system of management based on micro control mechanisms. His system included such micro control elements as "...detailed job descriptions, frequent and accurate reporting of performance, ...a clearly defined hierarchy of authority..., and the enforcement of personal responsibility and accountability

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[1] Ibid., pp. 224-26.

[2] Ibid., p. 226.

[3] This subsection is based largely on Wren, The Evolution of Management Thought, pp. 84-92.

[4] Ibid., p. 84.

throughout the organization."[1] He also drew up and published an organization chart of the railroad that, in addition to organizational relationships, depicted lines of communication for control reporting. In this connection, he utilized the telegraph facilities as an integral part of his communications network, thus exhibiting once again the necessity of information to control.

Henry Varnum Poor (1812-1905), editor of the American Railroad Journal, was impressed with McCallum's improvements in management of the Erie Railroad. Influenced by McCallum's internal operating procedures, Poor sought "broader principles" and a systemization of management. In so doing, he expanded McCallum's work particularly in the area of information and described a need for compiled financial data "...to analyze the present system and to provide a base for changes to improve service."[2]

It would appear that McCallum's system of control coupled with Poor's call for a "data base" lacked only the advent of automatic data processing techniques of the twentieth century to be transformed into a skeletal framework of systems requirements for an automated management information system.

Arsenal Management[3]

Captain Henry Metcalfe (1847-1917) graduated from the Military Academy at West Point, New York, in 1868 and was assigned to the Ordnance Department. In 1881 while stationed at Frankford Arsenal outside of

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[1] Ibid., p. 86. [2] Ibid., p. 90.

[3] This subsection is based largely on Henry C. Metcalfe, The Cost of Manufactures and the Administration of Workshops, Public and Private (New York: John Wiley and Sons, 1885), reprinted in part by Harwood F. Merrill, ed., Classics in Management (New York: American Management Association, 1960), pp. 46-56.

Philadelphia, Pennsylvania, he developed and installed a unique and highly effective control system. The system was devised as a method of controlling activity at the arsenal workshops, and its development resulted from the inconvenience of the existing system.

The system which Metcalfe developed was, in essence, a card system consisting of serialized order tickets for each activity in the workshop, material cards documenting activity against the work orders, and time cards for recording expended labor hours. It was in restricting the cards to a single entry each that the system developed its greatest potential. The cards were used to replace all regular transitory papers and records, with only permanent records, required by army regulations, remaining.

Metcalfe's system was used to control activity from the time an order was received by the workshops until the finished product was dispatched. His systematic use of cards for individual transactions also permitted cards to be combined through mechanical sorting. Metcalfe subsequently installed his system at other U.S. Army arsenals.

Conspectus of Additional Contributions

The emphasis of the Industrial Revolution was on technology rather than on management,[1] but the management control process continued its evolution.

John Stuart Mill (1806-78), an English economist, in addressing the cause of superior productivity, identified skill and knowledge of both workers and managers, economies of time and material, and "the general diffusion of

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[1]Wren, The Evolution of Management Thought, p. 56.

intelligence" as factors. He also deplored the "waste of wealth occasioned to society by human improbity" and the nonproductive but necessary effort involved in watching workmen as a result of this human failing.[1]

Robert Owen (1771-1858), an English entrepreneur, sought to change the conditions of the worker occasioned by industrialization and the specialization of labor by improving his environment from within the factory and through social reorganization.[2]

Charles Babbage (1792-1871), an English mathematical scientist, was the first to write about scientific management. He "...attempted to show the mutuality of interests between the worker and the factory owner somewhat similar to what Taylor was saying 75 years later..."[3] and was on the edge of probability theory in his thinking.[4] In 1822, Babbage developed a working "difference engine," the forerunner of the electronic data processer. As a scientist, however, he was concerned only with the underlying principles. He had no immediate or later intention of commercial application, and the machine was never completely finished.[5]

Early Modern Thought and Its Amplification

The Industrial Revolution led to the creation of the factory system that, in turn, compounded the demands on management. Primary attention was

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[1] John S. Mill, Principles of Political Economy, Vol. 1, 3d ed. (London: John W. Parker and Sons, 1852), pp. 131-35.

[2] Wren, The Evolution of Management Thought, p. 63.

[3] Ibid., p. 72.

[4] Ibid., pp. 68-72.

[5] Lyndall F. Urwick and E. F. L. Brech, The Making of Scientific Management, Vol. 1 (London: Management Publications Trust, 1949), pp. 21-22.

focused on solution of technology problems, and resolution of the parallel management control problems were secondary. Control was still thought of primarily in terms of physical security, but was expanded to include control of the manufacturing process. Double entry bookkeeping was slowly pointing the way to cost accounting and financial control, but the full import of these techniques for developing proper current and future costs was not recognized.

This section covers the first half of the twentieth century. Viewed from the perspective of technique and technology, it spans the period of scientific management to the advent of automatic data processing. This period was one of significant vertical growth in terms of theory and practice and of accelerated horizontal growth in terms of differentiation and specialization.

The Industrial Revolution had increased the actual and potential productivity of man to new heights and yet man was still not in complete control of the helm. The concentration of effort on industrial and productive technology with management techniques receiving only secondary emphasis resulted in the former outdistancing the latter, but full realization of the potential of the machine was a function of the management process. The task was one of integrating the new machinery of the Industrial Revolution into an anthropocentric environment.

During the first half of the twentieth century the pace of progress quickened and milestones were more closely spaced. Management began to come into its own and to exercise control with greater confidence and precision. The development of synthetic aids to management assumed new dimensions.

The control problems generated by the new industrialization were almost innumerable. Just as surely as necessity precipitates the need for invention, the conditions of the Industrial Revolution precipitated the need for systematic thinking.

Advent of Scientific Management

Frederick Winslow Taylor

Frederick Winslow Taylor (1856-1915), an American engineer, production man, executive, and consultant, is the recognized "father of scientific management." Taylor went to work at an early age, temporarily bypassing higher level education, and became familiar with the habits and environment of the worker. Realizing his limitations due to his lack of formal higher level education, he received a degree in mechanical engineering from Stevens Institute of Technology in Hoboken, New Jersey, in 1883, through correspondence study completed in only two and one half years. He also became president of the American Society of Mechanical Engineers in 1906.[1]

Taylor's quest for science in management was based on his conviction "...that management ought to be treated as an integrated whole." He wanted to find an answer to what he considered the fundamental question: "What is a fair day's work?"[2] In essence, Taylor sought "...to determine scientifically what the men ought to be able to do with their equipment and materials."[3]

Taylor's approach to management was originally termed "task management," and his basic motivation was to improve worker performance by showing

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[1] Wren, The Evolution of Management Thought, pp. 112-14, 133.

[2] L. M. Gilbreth and W. J. Jaffee, "Management's Past—A Guide to Its Future," in Fifty Years Progress in Management, ed. by Oliver J. Sizemore and Marshall Anderson (New York: American Society of Mechanical Engineers, 1960), p. 6.

[3] Wren, The Evolution of Management Thought, p. 116.

him how to perform more efficiently and effectively without injuring his physical being or his health. He utilized time study as a means of analyzing worker activities and then determined the best way to perform a job. His was a view of micro control at the worker level in its most elemental form.[1] It is interesting to note that Taylor mentions Henry Metcalfe's work at Frankford Arsenal in his text Shop Management. In discussing the system, Taylor said that it "...represents another such distinct advance in the art of management."[2]

Taylor emphasized the need for planning and rigorous control of tasks and called for the establishment of a special planning department. He listed seventeen leading functions for the department which included: complete analysis of all orders; balance of all materials, raw materials, stores, and finished parts; analysis of all inquiries for new work; cost of all items manufactured, with complete expense analysis and complete comparative costs on a monthly basis; information bureau (for all drawings, records, and reports); and control of system and plant, including a "tickler" follow-up.[3] His idea of the mission of such a department was summed in his statement: "The shop, and indeed the whole works, should be managed, not by the manager, superintendent, or foreman, but by the planning department."[4] It may be seen that many of the functions of the planning department would currently be considered functions of management control.[5]

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[1]Frederick W. Taylor, Shop Management (New York: Harper & Brothers Publishers, 1919), pp. 45-58. This text was first published in 1903 under the auspices of the American Society of Mechanical Engineers.

[2]Ibid., p. 202. [3]Ibid., pp. 64, 110-20.

[4]Ibid., p. 110.

[5]Harlow S. Person, "The Origin and Nature of Scientific Management," in Scientific Management in American Industry, ed. by Harlow S. Person (New York: Harper & Brothers Publishers, 1929), p. 5.

In 1929, the Taylor Society expressed the following principle of management control as consistent with Taylor's idea of scientific management:

> There must be established a systematic procedure, based on the defined standards, for the execution of work; a procedure which directs the researches, establishes and maintains the standards, initiates operations and controls work in process; which facilitates each specialized effort and coordinates all specialized efforts, to the end that the common objective may be achieved with a minimum of waste of human and material energies, and with a maximum of human welfare and contentment.[1]

The depth of perception in this principle exemplifies the spirit of Taylor's scientific management.

Taylor also discussed the principle of management by exception coming into use at the time. He argued that the manager should receive only summarized information covering all aspects of business and that even the summaries should be reviewed by an assistant before submission to the manager. All exceptions, both good and bad, to previously established standards or past averages were to be highlighted.[2]

The tap root of Taylor's concept lay in the need for "mental revolution" by both worker and management. The essence of the change was that the worker and management would stop arguing over the division of corporate surplus and work together in harmony to increase the surplus.[3] It is perhaps this precept that most clearly puts Taylor's management thought in its proper perspective.

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[1] Ibid., p. 11.

[2] Taylor, Shop Management, p. 126.

[3] Frederick W. Taylor, The Principles of Scientific Management, reissued as part of Frederick W. Taylor, Scientific Management (New York: Harper & Brothers Publishers, 1947), p. 10.

The advent of scientific management was an evolutionary process. Taylor did not invent scientific management as he himself testified,[1] and he acknowledged similar advanced work of others.[2] But he did synthesize and apply the concepts at a time when widespread industrial expansion was taking place. His work had a profound and lasting influence on modern management thought. Boddewyn synthesized Taylor's work on control with the observation: "His fundamental insight that control rests on measurement was simplicity itself."[3] Taylor's work represents one of our truly significant management milestones.

While Taylor had a number of close associates who assisted dramatically in the development of scientific management, three in particular made major contributions to the specific field of management control.

Harrington Emerson

Harrington Emerson (1853-1931) was a disciple of Taylor and one of the emerging group of "efficiency engineers."[4] His book, The Twelve Principles of Efficiency, outlined twelve principles for study and classification. His thrust was based on the premise that by knowing exactly actual status and comparing it to what ought to be, it would be possible to determine a direct relationship of efficiency. For Emerson, efficiency was necessary for the total organization

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[1] U.S., Congress, House, Special Committee, Hearings Before the Special Committee of the House of Representatives to Investigate the Taylor and Other Systems of Shop Management Under Authority of House Resolution 90, reprinted as part of Frederick W. Taylor, Scientific Management, pp. 5-6, 282.

[2] Taylor, Shop Management, pp. 201-2.

[3] J. Boddewyn, "Frederick Winslow Taylor Revisited," Journal of the Academy of Management 4 (August 1961): 100.

[4] Wren, The Evolution of Management Thought, p. 169.

from top to bottom. He clearly delineated the need for specific objectives; discipline; comparative records with reliable, immediate, and accurate information; and specific standards and schedules.[1]

His book is also of significance due to his suggested introduction of the concept of military staff into the industrial setting. He recognized the inevitability of line and staff conflict, and his proposed solution gave insight into his idea of executive control:

> For these clashes of line with line as to authority, of staff with staff as to knowledge and plans, for these clashes of each member of the line with each separate member of the staff, there is only one remedy--namely, the strong, governing and controlling executive, who need not be an expert in either staff or line, but who must have those qualities that fit him to direct, to harmonize, to convert a close parallelogram of forces into an open straight line along which all forces are summed in the same direction. Everywhere this executive ability is needed.[2]

His concept of managerial ability was reminiscent of that of Socrates in expression of the universality of management.

Frank Bunker Gilbreth

Frank Bunker Gilbreth (1868-1924) and Lillian Mollar Gilbreth (1878-1972) formed a rare husband and wife team in the annals of the history of management. Gilbreth admired Taylor, but worked in a field that he made his own, that of motion study. His wife was his constant companion "...whose work and record are inseparable from his."[3]

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[1]Harrington Emerson, The Twelve Principles of Efficiency (New York: Engineering Magazine Company, 1912), pp. 59, 135, 205, 261.

[2]Ibid., pp. 413-14.

[3]Urwick and Brech, The Making of Scientific Management, p. 126.

Frank Gilbreth's motion studies were a form of micro production control much in the manner of Taylor's time studies. His analysis of micro motion movements of workers was aimed at the elimination of avoidable effort. According to Gilbreth, "Motion-study, time-study, micromotion-study, fatigue-study, and cost-study are important measures of scientific management by which the efficiency of each function and subfunction is determined, tested, and checked."[1] Scientific management was management based on measurement.[2] Mrs. Gilbreth described it as an art of directing based upon a science of measurement. While she shared her husband's interest in motion study, she emphasized the relationship between psychology and management.[3]

Gilbreth also applied his call for elimination of needless motion to managers and executives in advising that "The personal work of the executive should consist as much as possible of making decisions and as little as possible of making motions."[4] He argues, therefore, that managers should utilize methods of graphic control based on the exception principle with predetermined "zones." Analysis of charts containing data within the zones was to be handled by lower level managers, with only those charts containing points outside the zone being sent to the executive. He also recommended that exceptionally large positive

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[1]Frank B. Gilbreth, Applied Motion Study (New York: Macmillan Company, 1919), p. 35.

[2]Ibid., pp. 3, 35, 44.

[3]L. M. Gilbreth, The Psychology of Management (New York: Macmillan Company, 1919), p. 6.

[4]Frank B. Gilbreth, "Graphical Control on the Exception Principle for Executives," American Society of Mechanical Engineers Transactions 38 (1916): 1213-19.

deviation evidencing unusual efficiency be recognized by the executive and that he take a personal interest in such cases.[1]

Henry Lawrence Gantt

Henry Lawrence Gantt (1861-1919), a mechanical engineer, was another of Taylor's disciples. Gantt was orthodox Taylor in his early career, but in his later life he began to develop more of his own thinking.[2] For Gantt, the human element was all important, and he was a forerunner in the developing idea of "industrial democracy." His contributions included such facets as task and bonus plans, training, and production control. While in some respects these and others were greater contributions in the formation of scientific management thinking, he is best remembered for the development of executive control charts and in particular for the type that bears his name.[3] Much of his original work is reprinted in a book edited by Rathe.[4]

Gantt was task and method oriented. He believed that task setting required knowledge, not guesswork--the ability to distinguish between fact and opinion. He also believed that methods were more important than results since if the proper methods were devised, the desired results would be obtained. These concepts, coupled with his stress on fair compensation, naturally led to accurate procurement of individual output, which Gantt put in graphic form.[5]

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[1] Ibid., pp. 1213, 1215, 1217-18.

[2] Wren, The Evolution of Management Thought, pp. 149, 156.

[3] Urwick and Brech, The Making of Scientific Management, pp. 71, 76-77.

[4] Alex W. Rathe, ed., Gantt on Management (New York: American Management Association and American Society of Mechanical Engineers, 1961).

[5] Henry L. Gantt, Industrial Leadership (New Haven: Yale University Press, 1916), pp. 57-58, 71, 62.

Gantt made his most memorable contribution in the form of the Gantt Chart while working as a consultant at Frankford Arsenal. It was while on this activity that Gantt revolutionized graphic scheduling techniques:

> We have all been wrong in scheduling on a basis of quantities; the essential element in the situation is time, and this should be the basis in laying out any programme [sic].[1]

The basic ingredient of the Gantt Chart was born with this unique concept.

A Gantt Chart depicts work scheduled and accomplished in relation to each other and in relation to time. On the chart itself, time is depicted by equal divisions of horizontal spacing (representing equal time increments) and work planned and completed by a simple combination of numerical data, solid lines of varying widths, and mnemonic symbols. Gantt Charts fall into three basic categories of Man and Machine Record Charts, Layout and Load Charts, and Progress Charts, with the latter being perhaps the best known.[2]

It was this technology and the relationship of scheduling on the basis of time that is traditionally credited as the foundation for subsequent developments such as production control boards and methods of network planning.

Of interest is the fact that prior to Gantt, but unknown to him, Karol Adamiecki (1866-1933) of Poland had developed a form of graphic aid called the "Harmonogram." It was in use in Poland in 1896 and was described for the first time in 1903,[3] but his work was not translated into English until 1974.[4]

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[1]Urwick and Brech, The Making of Scientific Management, p. 79.

[2]Wallace Clark, The Gantt Chart (New York: Ronald Press, 1923), pp. v, 5, 14-15, 17.

[3]Lyndall F. Urwick, ed., The Golden Book of Management (London: Newman Neame Limited, 1956), pp. 107-8.

[4]Edward R. Marsh, "The Harmonogram of Karol Adamiecki," paper presented before the Academy of Management Annual Meeting, Seattle, Washington, August 1974.

Conceptually, the various Harmonograms were utilized as work-flow network diagrams for the analysis of production processing and for recording status of work in process. They were actually more sophisticated than the Gantt Chart in that they depicted event priorities and the sequential aspects of work-flow, a technique of conceptualization not found in the Gantt methodology. Harmonograms, in fact, closely resemble current network planning techniques such as critical path and PERT networks.[1]

In this country as well, recognition to the necessity of establishing the sequence of operations in construction was evidenced in an article in Engineering Magazine in September, 1909.[2] In his article, Herbert F. Stimpson discussed the disparity between the emphasis placed on graphic aids in the form of blueprints and bills of material and the lack of systematic planning in the apportionment of time. He likened the situation to attempting to clothe a two-legged man with a pair of trousers with one leg intact (material) and the other leg missing (time). His solution to this dilemma was the use of equivalent graphic aids for estimated time, handled with the same care and precision as those for materials, broken down to each subordinate group, and with the relationship of times between subgroups identified. Stimpson argued that this was the direct cause of men being "blindly switched" from one operation to another, explained why some machines were consistently idle while others were continually overloaded, and that work was often delayed awaiting critically required materials.[3]

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[1]Ibid.

[2]Herbert F. Stimpson, "Graphical Helps for Apportioning Time in Constructive Operations," Engineering Magazine 37 (September 1909): 955-59.

[3]Ibid., pp. 955-57.

Stimpson summed his argument with this perceptive thought:

> We wish to know not only the time that will be necessary for the completion of the operation and of the entire work, but also the sequence in which each part and group must be begun in order that they may be combined at the proper times and in the proper sequence, so that the whole work may be finished at the time which is desirable or has been agreed upon.[1]

While Stimpson's article was not accompanied with illustrations, it is clear that he, like Adamiecki, demonstrated insight into concepts of prospective sequential flow and time analysis in construction where PERT, in later years, has been used effectively.

Graphic Methods of Analysis

Gantt provided the visual evidence of the logical appeal of charts for control purposes, and systematic thought paved the way for increased use and application of the graphic aid to management. Charts offered advantages in terms of demonstration through visual comparison with known frames of reference, conveyed trends more readily than columns of figures, and fostered computation and analytical analysis. During the early 1920s a host of texts appeared on the construction of graphs, and articles in periodicals covered graphic techniques applied to graphic statistics, accounting, advertising, analysis of costs, general business and financial data, inventory control, organization and management, personnel, planning, sales, and production control and scheduling.[2]

Willard C. Brinton, one of the pioneers in charting techniques,[3] devoted a chapter in his classic text Graphic Methods for Presenting Facts to

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[1] Ibid., pp. 958-59.

[2] Allan C. Haskell, Graphic Charts in Business (New York: Codex Book Company, Inc., 1922), pp. 1-5, 239-46.

[3] Karl G. Karsten, Charts and Graphs (New York: Prentice-Hall, Inc., 1923), p. ix.

the subject of "Records for the Executive."[1] In this chapter he provided keen insight into the value of centralized, summarized, integrated data and suggested the use of a card system with data filed both by department and by function. He outlined the procedures of how to establish a records room including responsibilities of room manager, security and retention of original records, limitation of access, methods of temporary and permanent visual display, procedures for obtaining copies of original records, and maintenance of timely data.[2] He suggested further that there was a danger in providing too much information to a manager of "small brain capacity." He said that such a man would use the tool as a means of unjustly criticizing his subordinates, thus ultimately drying up the basic flow of data from submanagers, who would regard the system "...as a new form of diabolical torture."[3]

Brinton's insight into information technology was limited only by the available synthetic aids. With this single addition, his description would read like the specification for one of our current control rooms. Even his warnings on the potential danger of too much information for narrow-minded managers has changed only through increases in magnitude.

Charts of all types were described by various authors. In a two part article appearing in Management and Administration, David B. Porter described both "historical" charts depicting after-the-fact data and "frequency" charts depicting the present and immediate future;[4] Arthur R. Burnet discussed the

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[1] Willard C. Brinton, Graphic Methods for Presenting Facts (New York: Engineering Magazine Company, 1914).

[2] Ibid., pp. 288-306.

[3] Ibid., p. 302.

[4] David B. Porter, "Application of Charts in Industry," Management and Administration, Part I, 7 (January 1924): 65-72, and Part II, 7 (March 1924): 329-36.

growing use of charts as management tools;[1] Wallace Clark discussed their use in forecasting and management by exception;[2] and William C. Marshall integrated the mathematical and business aspects of a graphic representation.[3]

The breakeven chart[4] also came into being during this period. While not referring to it as a breakeven chart, Henry Hess described the basic concept in 1903[5] and then refined it in a series of articles the following year.[6] Hess recognized the value of the technique as a control device. In later years the concept was further developed by C. E. Knoeppel[7] and Walter Rautenstrauch.[8]

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[1]Arthur R. Burnet, "Charts as Management Tools," Management and Administration 9 (January 1925): 55-58.

[2]Wallace Clark, "Effective Control of Future Results," Management and Administration 7 (February 1924): 179-82.

[3]William C. Marshall, Graphical Methods for Schools, Colleges, Statisticians, Engineers and Executives (New York: McGraw-Hill Book Company, 1921).

[4]An analytic technique for studying the relationships among fixed and variable costs, sales, and profit.

[5]Henry Hess, "Manufacturing: Capital, Costs, Profits and Dividends," Engineering Magazine 26 (December 1903): 367-79.

[6]Henry Hess, "Wage-Paying Methods from the View-Point of the Workman," Engineering Magazine 27 (April 1904): 27-35; "Wage-Paying Methods from the View-Point of the Employer," Engineering Magazine 27 (May 1904): 172-86; and "Wage-Paying Methods from the View-Point of Invested Capital," Engineering Magazine 27 (June 1904): 409-16.

[7]See for example: C. E. Knoeppel, Managing for Profit (New York: McGraw-Hill Book Company, Inc., 1937).

[8]See for example: Walter Rautenstrauch and Raymond Villers, The Economics of Industrial Management (New York: Funk & Wagnalls Company, 1949) and Walter Rautenstrauch and Raymond Villers, Budgetary Control (New York: Funk & Wagnalls Company, 1968).

More recent improvements include integration of breakeven analysis with linear programming.[1]

Continued Emphasis on Scientific Management

The scientific management method influenced many writers and practitioners of the time, as is evident from their work. The purpose of this subsection is to summarize the concepts of some of the additional influential writers of the times.

Alexander Hamilton Church

Alexander Hamilton Church (1866-1936), a lecturer and author, was concerned with conditions of industrial confusion and disorder.[2] He criticized scientific management on the basis that in its rush to "apply" it neglected the necessity to "construct," and he believed that the former had been mistaken for the latter. His book, The Science and Practice of Management, was written to consolidate the regulative principles of management.[3]

Church summarized control as "...the organ concerned with duties, responsibilities, and the exercise and limitation of initiative" (original italicized).[4] He also stated that control was the function of the "boss," and that it varied depending upon the complexity of the operation.[5]

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[1] R. H. Parker, Management Accounting: An Historical Perspective (New York: Augustus M. Kelly, Publishers, 1969), p. 72.

[2] Joseph A. Litterer, "Alexander Hamilton Church and the Development of Modern Management," Business History Review 35 (Summer 1961): 212.

[3] A. Hamilton Church, The Science and Practice of Management (New York: Engineering Magazine Company, 1914).

[4] Ibid., p. 77. [5] Ibid., pp. 30-31.

One of Church's contributions was to write Volume I of The Cumulative Loose-Leaf Business Encyclopedia.[1] This volume contained an extensive discussion on the subject of control. Of particular interest is Church's discussion on the use of schedule control boards. He described the need for time estimates, sequencing of interrelated activities, and identification of "steps" in the process. His illustration and description strongly suggest that his "steps" were, by modern standards, milestones and his control board, a milestone chart.[2] This is one of the earliest narrative and graphic references made to a technique similar to modern milestone charting techniques.

Church was one of the earliest writers to look at the total managerial process[3] and to recognize the salient factors of management control.[4]

Leon Pratt Alford

Leon Pratt Alford (1877-1942), engineer, editor, and writer, was also concerned with the implications of scientific management. He coauthored an article with Church in 1910 in which they attempted to formulate a basis for an art of management somewhat in counteraction to the implied "science" of management under Taylor. The authors defined broad principles of the systematic use of experience, the economic control of effort, and the promotion

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[1] A. Hamilton Church, "The Executive" and "Business Administration," The Cumulative Loose-Leaf Business Encyclopedia, Vol. 1 (Philadelphia: John C. Winston Company, 1928).

[2] Ibid., pp. 183-85.

[3] Litterer, "Alexander Hamilton Church and the Development of Modern Management," p. 275.

[4] Giglioni and Bedeian, "A Conspectus of Management Control Theory: 1900-1972," p. 294.

of personal effectiveness. Under the economic control of effort they stated: "Most of the discussions about management are, in fact, discussions about various methods and degrees of controlling effort and fixing its regard;"[1] a broad but comprehensive definition of control.

In his text Laws of Management Applied to Manufacturing, Alford continued his desire to formulate principles and he enumerated some fifty laws of management. In his later text Principles of Industrial Management,[2] he expanded the meaning of control to include not only the commonly understood considerations of direct, govern, influence, restrain, but also added the facets of determining objectives, program and plan to be adopted, leadership, and unification.[3]

Further Definitions and Approaches

In addition to Church and Alford, other authors offered individual views on management control. Hugo Diemer called for clearly defined departmental lines.[4] John Lee wrote on the implications of a growing trend toward industrial democracy whereby workers were becoming interested in administrative questions previously the sole domain of the manager. In this environment, autocratic management would no longer be effective and the

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[1]Alexander H. Church and L. P. Alford, "The Principles of Management," American Machinest 36 (May 30, 1912), reprinted in Merril, ed., Classics in Management.

[2]L. P. Alford, Principles of Industrial Management (New York: Ronald Press Company, 1940).

[3]Ibid., p. 164.

[4]Hugo Diemer, Factory Organization and Administration (New York: McGraw-Hill Book Company, 1910), pp. 38-39, 45.

manager, therefore, must be "...exquisitely sensitive to the thoughts and feelings of the worker."[1] For Lee this suggested an art of new administration where the administrator "...will realize that his control must be rather radiation than domination."[2] Lee also suggested that management by exception necessitated use of summarized data by the manager, with his comments on reports annotated and returned to subordinates to avoid the danger of "dead data."[3] Benjamin A. Franklin approached the subject of costs and cost reports from the viewpoint of the executive in order to demonstrate the invaluability of cost data as an aid to management control. He clearly recognized the managerial benefits of a predictive cost system, and the fact that executive indifference would weaken the effectiveness of a cost system.[4] Henry P. Dutton grouped all of the operations and functions of industrial manufacturing into the four categories of design, supply, control, and operation.[5] Control called for a system for issuing orders, follow-up, and checking results with the supervision function resting with "...the executive who exercises the final control function."[6] In a later text Dutton defined management control as consisting of supervision, program

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[1]John Lee, Management: A Study of Industrial Organization (London: Sir Isaac Pitman & Sons, Ltd., 1921), p. 4.

[2]Ibid., p. 10.

[3]Ibid., pp. 4, 10, 35.

[4]Benjamin A. Franklin, Cost Reports for Executives as a Means of Plant Control (New York: Engineering Magazine Company, 1913), pp. 28, 143.

[5]Henry P. Dutton, Factory Management (New York: Macmillan Co., 1924), p. 5.

[6]Ibid., p. 7.

control, quality control, and control of expenditure.[1] Webster Robinson identified eight fundamentals of business organization, the sixth of which was control. He defined control as "...that fundamental of organization which comprises the means of providing the manager and the executives of an organization with continuous, prompt, and accurate information concerning the efficiency of operation, what the business is doing, what it has done in the past, and what it can be expected to do in the future."[2] He also described a system of control as that which "...collects the details of operation, segregates them, combines them, and classifies them into a form suitable for use."[3] Erwin Schell wrote from the viewpoint of the executive and saw the administrators or executives as determining policy and guiding and controlling the total enterprise.[4] T. G. Rose described a theory and system of higher control for the manager as "...a monthly survey of the functional activities of a commercial undertaking, carried out from the business, technical, trading, and financial viewpoints, and based upon direct trend comparison between the position at the moment and the position at the last financial year."[5]

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[1] Henry P. Dutton, Business Organization and Management (Chicago: A. W. Shaw Company, 1927); pp. 24-25.

[2] Webster Robinson, Fundamentals of Business Organization (New York: McGraw-Hill Book Company, Inc., 1925), p. 147.

[3] Ibid.

[4] Erwin H. Schell, The Technique of Executive Control (New York: McGraw-Hill Book Company, Inc., 1924), p. 5.

[5] T. G. Rose, Higher Control in Management, 4th ed. (London: Sir Issac Pitman & Sons, Ltd., 1947), p. 61.

Four Individualists

Much of the written work on management during the first half of the twentieth century focused on, or was largely influenced by, the scientific management movement. Four individuals, however, stand out as not exactly fitting this mold and all made significant contributions to the theory of management. Two were Europeans whose work was not immediately recognized in the United States, and two were native Americans with ideas of their own.

Henri Fayol

Henri Fayol (1841-1925), a highly successful French administrator and executive, originated the first theory of administration.[1] He had a long and successful business career. His historic work, General and Industrial Management[2] (published in France in 1916 and first translated into English in 1930), was the result of analysis of his own duties and responsibilities as a top executive.[3] Fayol identified fourteen principles of management that he had most frequently applied in his own activities. These principles were neither exhaustive nor rigid, but were intended to demonstrate the conditions or ground rules of the management process and were adaptable to circumstances. Of interest was Fayol's description of the management process, in which he identified five elements: planning, organizing, command, coordination, and control.[4] As defined,

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[1] Wren, The Evolution of Management Thought, p. 209.

[2] Henri Fayol, General and Industrial Management, trans. by Constance Storrs (London: Sir Isaac Pitman & Sons, Ltd., 1949).

[3] Urwick and Brech, The Making of Scientific Management, pp. 40, 44.

[4] Henri Fayol, General and Industrial Management, pp. 19, 41, 43, 53, 97, 103, 107.

"...control consists in verifying whether everything occurs in conformity with the plan adopted, the instructions issued and principles established."[1] For Fayol, control permeated all elements of the undertaking including personnel, execution of plans, quality, financial activities, security, and information.[2] Control was to be timely and had as its objective "...to point out weaknesses and errors in order to rectify them and prevent recurrence."[3] Some years later Fayol described the integrative effect of control on the other four elements by saying that control "...tends to stimulate planning, to simplify and strengthen organization, to increase the efficiency of command and to facilitate co-ordination [sic]."[4]

Max Weber

Max Weber (1864-1920), a German sociologist, wrote extensively in a scientific sense in the social field. He distinguished between managers who were at the same time owners, and pure owners outside the management structure who exercised a wide degree of control over the managers by virtue of their control over financing and credit. For Weber, the separation of ownership and management was rational and permitted managers to be selected on the basis of qualifications of profitability. Weber identified three pure types of managerial authority as rational-legal, traditional, and charismatic, recognizing that the "pure" or ideal types were seldom found in history.[5] Under rational-legal

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[1] Ibid., p. 107. [2] Ibid., pp. 107-8. [3] Ibid., p. 107.

[4] Henri Fayol, "The Administrative Theory in the State," in Papers on the Science of Administration, trans. by Sarah Greer, ed. by Luther Gulick and L. Urwick, 2d ed. (New York: Institute of Public Administration, 1947), p. 103.

[5] Max Weber, The Theory of Social and Economic Organization, trans. by A. M. Henderson and Talcott Parsons (Glencoe, Illinois: Free Press, 1947), pp. 4, 7, 248-49, 328-29.

authority, there existed "...complete separation of the property belonging to the organization, which is controlled within the sphere of the office, and the personal property of the official, which is available for his own private uses."[1] He believed that "The purest type of exercise of legal authority is that which employs a bureaucratic administrative staff."[2] Weber described ten criteria for the administrative staff under a single "supreme authority." The last one contains the essence of his concepts of control for the individual official: "He is subject to strict and systematic discipline and control in the conduct of his office."[3]

Mary Parker Follett

Much of the written work on management in the United States during the first half of the twentieth century focused on (or was largely influenced by) the scientific management movement. There was a growing concern, however, for the social side of man in industry. This was reflected in the work of Mayo and Roethlisberger, based predominantly on their activities at the Hawthorne Plant of the Western Electric Company in Chicago, Illinois, beginning in 1924. Although the work did not become well recognized until the 1930s, it had an impact on management thinking. Mary Follett was a contemporary of Taylor's, but philosophically she belonged to the social man era, and her work is representative of the human relations movement.[4]

Mary Parker Follett (1868-1933), political scientist and philosopher, was primarily interested in the phychological basis of human activity and group

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[1] Ibid., p. 331. [2] Ibid., p. 333. [3] Ibid., p. 334.

[4] Wren, The Evolution of Management Thought, pp. 275, 300.

interaction.[1] She briefly defined control as "...power exercised as means toward a specific end..." but added that power and strength were "...not always synonymous."[2] She went on to suggest that power-with (co-active) was to be desired to power-over (coercive).[3] Follett called for "fact-control" rather than "man-control" and "correlation of control" rather than a "superimposed control." The situational environment generated collective control, based on fact and self-control of the individuals concerned. Control, then, was based on a philosophy of coordination and integration, not on compromise and abandonment. In this context, the object of organization was control, and subelement viewpoints were to be reconciled with each other and integrated into a composite and complementary over-all point of view. In essence, for Follett, control was a "self-generating process" of "collective self-control"[4] reflective of current management-by-objectives thinking.

Chester Irving Barnard

Chester Irving Barnard (1886-1961), an executive of American Telephone and Telegraph, had a significant impact upon management theory, particularly with regard to organizational theory and human relations thinking. His total volume of written work was small, but he is quoted frequently.[5]

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[1]Urwick and Brech, The Making of Scientific Management, p. 48.

[2]Mary P. Follett, Dynamic Administration: The Collected Papers of Mary Parker Follett, ed. by Henry C. Metcalf and L. Urwick (New York: Harper & Brothers Publishers, 1940), p. 99.

[3]Ibid., p. 101.

[4]Mary P. Follett, "The Process of Control," in Papers on the Science of Administration, ed. by Gulick and Urwick, pp. 161-69.

[5]William B. Wolf, "Chester I. Barnard," Journal of the Academy of Management 4 (December 1961): 167.

Sociologists frequently consider Weber as the "father of oranizational theory," but for many management theorists and practitioners that title belongs to Barnard.

In his classic The Functions of the Executive,[1] Barnard developed his theory of organization. He described formal organization as "...that kind of cooperation among men that is conscious, deliberate, purposeful."[2] For Barnard, control "...relates directly, and in conscious application chiefly, to the work of the organization as a whole rather than to the work of the executives as such."[3] Deeper insight into this definition may be gained by Barnard's unique concept of authority. In his mind, the test of whether an order had authority was based on whether or not it was accepted and carried out. In other words, the basis of authority did not reside in the "persons of authority" or the order-giver, but rather in the person to whom the order was directed or order-receiver. This concept was, at the time, in direct opposition to conventional wisdom.[4]

Last of the Period

In closing this discussion of the first fifty years of this century, two additional individuals deserve mention: Lyndall Urwick and Ralph Davis. While their work actually occurred in both this and the period covered by the next section, it seems appropriate to include their work of the period as the final note to the first half of the 1900s.

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[1]Chester I. Barnard, The Functions of the Executive (Cambridge, Massachusetts: Harvard University Press, 1938).

[2]Ibid., p. 4.

[3]Ibid., p. 223.

[4]Ibid., p. 163.

Lyndall Fownes Urwick

Lyndall Fownes Urwick (1891-) was a prolific writer in his own right and also coedited a number of classic texts in management.[1]

Urwick was perhaps the first to author a set of control principles. By his definition, control was "...concerned with the reaction of persons and materials to the decisions of direction, with the measurement of such reactions in terms of space, time, and quantity, and with methods of securing that the results of such reactions shall be in line with those contemplated by direction."[2] The five principles to be observed in exercising control over activities were the principles of responsibility, evidence, uniformity, comparison, and utility.[3] In a later text, he defined the principles of control as the principles of uniformity, comparison, utility, and exception.[4] He also provided a definition of control as: "To control means to see that everything is done in accordance with the rules which have been laid down and the instructions which have been given."[5] This definition he ascribed to Fayol's aspects of administration.

Ralph Currier Davis

Ralph Currier Davis (1894-), an engineer and educator, in his text The Principles of Factory Organization and Management, defined control in an individual environment as "...the instruction and guidance of the organization and

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[1]Wren, The Evolution of Management Thought, p. 357.

[2]Lyndall F. Urwick, "Principles of Direction and Control," in Dictionary of Industrial Administration, Vol. 1, ed. by John Lee (London: Sir Isaac Pitman and Sons, 1928), p. 163.

[3]Ibid., p. 179.

[4]Lyndall F. Urwick, The Elements of Administration (New York: Harper & Row, Publishers, 1943), pp. 107-12.

[5]Ibid., p. 122.

the direction and regulation of its activities."[1] The process of control involved the four steps of "...the predetermination of reasonable accomplishment, the issuance of definite and complete written instructions, the analysis of reports and the comparison of actual and predetermined accomplishments to determine the cause of variations, and the recognition of responsibility for final results."[2] In what amounted to a second edition of this text (with a revised title) he defined planning, organizing, and controlling as the three organic functions of the executive. He defined control as "...the regulation of activities in accordance with the requirements of a business plan, to the end that the final objectives of a project may be achieved properly."[3] Control was considered as consisting of the three phases of assurance of proper performance, coordination, and removal of obstacles preventing execution.[4]

Recent Initiatives

The Industrial Revolution started in England, spread to the United States, and created the impetus for new thinking about management. This early emphasis on industrial technology resulted in significant strides being made in the development of the technical method of achieving or producing goods and services. At the same time, however, it did so partially at the expense of the human element of the factors of production. It became management's role to

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[1] Ralph C. Davis, The Principles of Factory Organization and Management (New York: Harper and Brothers, Publishers, 1928), p. 84.

[2] Ibid.

[3] Ralph C. Davis, Industrial Organization and Management, rev. ed. (New York: Harper and Brothers, Publishers, 1940), p. 22.

[4] Ibid., pp. 35-36.

integrate the capital and human elements into a harmonious, productive, and efficient whole, with all forces moving toward the same objective.

The first concerted effort in this direction was the application of systematic thought to the technical problems of industry. The scientific management movement was concerned primarily with the establishment of standards, measurement of performance, and the advancement of technology. There was also a growing call for a broader and more humanistic look at the management process. The control function was not an explicit element of the management process for many of the early human relationists. Hugo Munsterberg (1863-1916), the father of industrial psychology,[1] worked to "...strengthen the bridge between scientific management and industrial efficiency..."[2] through the study of psychological man.[3] George Elton Mayo (1880-1949) and Fritz Roethlisberger began the inquiry into the human aspect of the management process with their famous Hawthorne research activity.[4] The work of these two researchers contributed significantly to the human relations school of management thought.[5] The work of Follett and Barnard, previously mentioned, contained nuggets of the human relations philosophy. Of primary importance from a management control standpoint is the fact that these early thoughts would contribute to the concept of self-control in later years.

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[1]Wren, The Evolution of Management Thought, p. 197.

[2]Richard M. Hodgetts, Management: Theory, Process, and Practice (Philadelphia: W. B. Saunders Company, 1975), p. 66.

[3]Ibid., pp. 66-67.

[4]An excellent digest of the Hawthorne studies and criticisms may be found in Wren, The Evolution of Management Thought, pp. 275-99, 370-81.

[5]Ibid., pp. 278-79.

The years since World War II have been years of extraordinary growth in the size, scope, and complexity of business organizations. The population of the United States continued to increase, productivity steadily increased, and the variety of manufactured commodities mushroomed. This period witnessed reinforced emphasis on task and functional specialization, growth in employment, large proliferation of organizational elements and expanded diversification, increased geographic dispersion, and amplified concern regarding scarcity of productive resources. It was a period of accelerated growth of management control theory and practice. The period witnessed introduction of commercial electronic data processing, perhaps the single most significant synthetic aid to management control in history.

The Years Just Preceding Automation: Conspectus of Major Contributions

In 1951, Ralph Davis produced a new text, The Fundamentals of Top Management,[1] in which he reflected a transition from the industrial orientation of his earlier works to one more closely attuned to administration. His purpose was to present a "...fundamental statement of business objectives, policies, and general methods that govern the solution of basic business problems."[2]

Davis defined control "...as the function of constraining and regulating activities that enter into the accomplishment of an objective."[3] He further developed this thesis by describing eight control functions that normally occurred in sequence. The first four were concerned with "preliminary control" or the

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[1] Ralph C. Davis, The Fundamentals of Top Management (New York: Harper & Row, 1951).

[2] Ibid., p. xix. [3] Ibid., p. 663.

time period prior to execution of a given activity. The second four were more normally associated with "concurrent control" or the time period of execution of activity. The eight functions were: (1) routine planning, (2) scheduling, (3) preparation, (4) dispatching, (5) direction, (6) supervision, (7) comparison, and (8) corrective action. Having identified functions (1)-(4) as "preliminary" and functions (5)-(8) as "concurrent," he further associated the functions organizationally by stating that the functions of (5) direction, (6) supervision, and (8) corrective action were basically line organization functions while the remainder were predominantly staff organization functions.[1]

This analysis of control functions and identification in terms of the status of project activity represented one of the most penetrating and comprehensive treatments of the control function to that time. The text is a milestone in the evolution of management control.

Also published in 1951, Administrative Action: The Techniques of Organization and Management by William H. Newman[2] presented a principles and techniques approach to administration. He defined the process of administration as consisting of the five elements of planning, organizing, assembling resources, directing, and controlling. Newman defined control as "...assuring that the performance conforms to plan."[3] Control was dependent for its effectiveness on the other elements of administration. Newman further defined three steps essential to the control process: setting standards at

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[1]Ibid., pp. 407, 663, 698.

[2]William H. Newman, Administrative Action: The Techniques of Organization and Management (Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1951).

[3]Ibid., p. 407.

strategic points, checking and reporting on performance, and taking corrective action. He also emphasized that control only became truly effective when implemented on an individual responsibility basis.

Earlier, in 1945, Marshall E. Dimock called for efficiency through the application of precise and quantitative units in measuring performance, by reducing functions into their individual parts. Carrying this theme forward, he defined control as "...the analysis of present performance, in the light of fixed goals and standards, in order to determine the extent to which accomplishment measures up to executive orders and expectations."[1] He called for careful analysis and full responsibility and accountability of individuals so that supervision could be strengthened if necessary and plans perfected for the future. His most concise description of control was in his reference to the process as the "check up."[2] In a later text, Dimock stressed that "When the emphasis is on the means of control rather than on its results, the effect may be a proliferation of paperwork."[3]

George R. Terry's text, Principles of Management, was first published in 1953 and a sixth edition was published in 1972.[4] Terry was the first author to use the specific title of Principles of Management.[5] Terry defines controlling as "...determining what is being accomplished, that is, evaluating the performance

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[1]Marshall E. Dimock, The Executive in Action (New York: Harper & Brothers, 1945), p. 217.

[2]Ibid., pp. 145, 217.

[3]Marshall E. Dimock, Administrative Vitality (New York: Harper & Brothers, 1959), p. 91.

[4]George R. Terry, Principles of Management, 6th ed. (Homewood, Illinois: Richard D. Irwin, Inc., 1972).

[5]Wren, The Evolution of Management Thought, p. 410.

and, if necessary, applying corrective measures so that the performance takes place according to plans."[1]

Koontz and O'Donnell's "principles" text appeared first in 1955[2] and in its sixth edition in 1976.[3] Koontz and O'Donnell demonstrate a high level of sensitivity to the proactive nature of control in their discussion on "feedforward" control.[4] Simply stated, feedforward control is a system of control that informs managers, "...in time to take corrective action, that problems will occur if they do not do something about them now."[5]

In an article in The Journal of the Academy of Management Koontz outlined four principles of control as the principles of strategic point control, organizational suitability, future controls, and direct control.[6] The basic purpose of the article was a suggestion that more attention be directed to management fundamentals and, as the title of the article suggested, the four principles were a preliminary statement. In a subsequent article in 1959, in the California Management Review, Koontz amplified the same plea and enumerated five principles of control: assurance of objectives, efficiency of control, control

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[1] Terry, Principles of Management, p. 535.

[2] Harold Koontz and Cyril J. O'Donnell, Principles of Management: An Analysis of Managerial Functions (New York: McGraw-Hill Book Company, 1955).

[3] Harold Koontz and Cyril J. O'Donnell, Management: A Systems and Contingency Analysis of Managerial Functions, 6th ed. (New York: McGraw-Hill Book Company, 1976).

[4] Ibid., pp. 646-52. See also: Harold Koontz and Robert W. Bradspies, "Managing Through Feedforward Control," Business Horizons 15 (June 1972): 25-36.

[5] Koontz and O'Donnell, Management: A Systems and Contingency Analysis of Managerial Functions, p. 646.

[6] Koontz, "A Preliminary Statement of Principles of Planning and Control," pp. 57-59.

responsibility, future controls, and direct control.[1] Both articles reflected conviction that control could best be analyzed through three general categories of control: nature and purpose, structure, and process explanation. The second article reflected additional contemplation and some revision of thinking concerning principles from the earlier article.

Advent of Automation

In the late 1950s a new synthetic aid to management was becoming commercially available to managers and businessmen; it signaled a revolution in the technology of management control. For some, puppy love developed into a mature romance; for others, it faded rapidly into disillusionment. No matter the reaction, the age of electronic data processing was born. In its infancy it suffered the same growing pains that befall many new ideas or technologies, but it is maturing slowly and is considered to be one of the most momentous occasions in management history. Electronic data processing provided vigorous encouragement to the pursuit of intensified management control.

As management control requirements grew more complex and the need for faster response more acute, the problems of data manipulation became more severe. Utilizing electronic data processing, it was possible to accelerate the retrieval and manipulation functions, and data processing began to take on the form of a science rather than an art, although the art has not disappeared.[2]

It was during this period that the systems management concepts of operations research and quantitative methods began to blossom. In large

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[1]Koontz, "Management Control: A Suggested Formulation of Principles."

[2]William C. Wall, Jr., Systems Management in the Urban Environment, Monograph 19 (Norman, Oklahoma: Bureau for Business and Economic Research, University of Oklahoma, August 1973), p. 4.

measure, these were products of military-aerospace management concepts as military and space engineers, scientists and managers, recognized the awesome tasks of management control that confronted them.[1] The environment of large-scale systems is perhaps best illustrated by a statement made by James E. Webb, former administrator of the National Aeronautics and Space Administration, in his book Space Age Management: The Large-Scale Approach.[2] In describing the management complexities and critical need for anthropocentricism in large-scale endeavors, he likened the effort to the early task of the Wright brothers:

> ...from a management standpoint the situation is not unlike that faced by the Wright brothers when they decided that to achieve both the speed needed for takeoff and the necessary three-dimensional control, they had to couple a human pilot with his senses and muscles to a system of coordinated machine controls. The separate elements of control had to be brought into a system that enabled the pilot to relate what he could see and what he could feel to what he needed to do. Only thus could he maintain flying speed and maneuver his vehicle to overcome the hazards of air currents and turbulence he encountered, but which he could not predict or assess in advance."[3]

The day of automated control systems requiring a new relationship between man and machine had been born.

The Age of Automation

For perhaps the first time in history, management found itself in the position of having a synthetic aid in advance of practical theory for its use. Here was a tool developed not for management per se, but for scientific endeavor. The challenge then for management was to harness this new heuristic and cybernetic tool and integrate it into evolving management control practice.

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[1] Ibid.

[2] James E. Webb, Space Age Management: The Large-Scale Approach (New York: McGraw-Hill Book Company, 1969).

[3] Ibid., p. 9.

Network Planning

One of the most familiar new applications in management control was the development of various network planning techniques. A Line of Balance (LOB) technique was developed in 1941 by George Fouch of Goodyear Aircraft, as a graphic form of depicting the essential processes of production from receipt of raw materials to completion of the product against a planned time-frame. It utilized the exception principle and depicted only the most important aspects of the process. In 1955, the E. I. DuPont de Nemours Company and Univac Division of the then Remington Rand Corporation joined together in an attempt to apply the new data-processing technology to problems of plant maintenance. This resulted in the development of what is now known as the Critical Path Method (CPM) of schedule control. The CPM is basically a method of integrating the sequencing and timing factors of a process and computing schedules that depict possible time and cost variation in the process.[1]

The Program Evaluation and Review Technique (PERT) was introduced in 1958. It was developed by the U.S. Navy in a joint effort with Booz-Allen & Hamilton and Lockheed Aircraft Corporation in an effort to effect drastic reduction in the estimated deployment schedule of the Polaris Ballistic Missile. The effort was successful for PERT is credited with having achieved a large reduction in the Polaris development program schedule.[2] PERT is similar to CPM in concept, but it differs in the methodology utilized in the determination of time estimate probabilities.

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[1]Thomas V. Sobczak, "Network Planning, The Continuing Evolution," Academy of Management Proceedings: Annual Meeting (Boston, Massachusetts, December 27-28, 1963), pp. 96-105.

[2]Harry F. Evarts, Introduction to PERT (Boston: Allyn and Bacon, Inc., 1964), p. 1.

Extensions of these three basic networking techniques (LOB, CPM, and PERT) have evolved in all directions; such systems as PERT/COST, third generation PERT/LOB, LESS (Least Cost Estimating and Scheduling), PACT (Production Analysis Control Technique), SCANS (Scheduling, Control, and Automation by Network Systems), and many others have appeared. All are dependent upon computer processing.

Management Information Systems

This brief account of the rapid growth of networking techniques is illustrative of the growth in many areas. Specialized systems in budgeting, cost accounting, financial management, procurement, quality control, personnel administration, marketing, inventory control, and a host of others have been developed to take advantage of the tremendous potential offered by electronic data processing.

The rapid shift to development of real-time and required-time large-scale integrated management control systems began about 1955-60. The general intent of most of these systems was to integrate the control function in order to provide management with accurate, timely, relevant, and summarized information across the total spectrum of corporate interest. An added feature was often an attempt to provide an impact prediction capability that would assess future actions, determine probable impact, and provide rational alternative courses of action across the entire spectrum of functional activity. Cybernetic systems based on the exception principle were also developed and, in some cases, the computer system automatically prepared source data to be reviewed manually and inserted at a later date as updated input.

Emphasis was also placed on new methods of integrating and controlling cost and schedule data in the military/aerospace arena. Introduction of the Planning, Programming, and Budgeting System (PPBS) by the Department of Defense in the early 1960s was an example of an effort to provide:

> "...for an orderly progression from national security objectives, through strategy, through the development of force requirements, through the derivation of force structure and programs under specified fiscal constraints to budget preparations, execution and review, and resource allocation.[1]

The development of performance measurement techniques such as Cost/Schedule Control Systems Criteria (C/SCSC) by the Departments of the Air Force, the Army, and the Navy in 1972 also represented the high priority placed on improved management. This system was designed primarily in an effort to secure more comprehensive management control of prime contractor activity in the major acquisition contracts by insuring that contractor management systems were sound. C/SCSC was not designed as a universal plug-in system, but as a definition upon which to evaluate contractor management control systems and the establishment of criteria that such systems had to meet.[2]

The approach of specifying control systems criteria rather than control systems meant that contractors could use their internal systems for reporting to the government if their system met the established criteria. This was a significant departure from past practice where the government specified the use of specific control and/or reporting systems. This earlier practice frequently resulted in a contractor operating two systems--his own and the one specified by the government. The move to C/SCSC was a prudent one.

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[1]U.S., Department of the Army, The Army Planning, Programming, and Budgeting System, Army Regulation No. 1-1 (Washington, D.C., October 1973), p. 1-1.

[2]U.S., Departments of the Air Force, the Army, and the Navy, Cost/Schedule Control Systems Criteria (Joint Implementation Guide), Pamphlet AFSCP/AFLCP 173-5, AMCP 37-5, NAVMAT P5240 (Washington, D.C.: Government Printing Office, 31 March 1972), pp. 1-1 - 1-2.

Conspectus of Additional Major Contributions

Although cited in Chapter I in the discussion on definitional considerations, the major works of Anthony,[1] Newman,[2] Mockler,[3] and Drucker[4] must be cited again to establish chronological integrity. Each of these writers has added to the body of knowledge referred to in this study as management control.

Additionally, other authors have suggested varying views on the topic. Jerome introduced the concept of executive control as "...some sort of systematic effort to compare current performance to a predetermined plan or objective, presumably in order to take any remedial actions required."[5] Vardaman and Halterman established a relationship between communication, management control, and the manager in suggesting a framework for improving organizational operations.[6] Eilon stressed the central role of control in the management task and the importance of feedback.[7] Strong and Smith provided a systems view and defined control as "...a function through which the executive is

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[1] Anthony, Planning and Control Systems: A Framework for Analysis. See also Robert N. Anthony and Regina Herzlinger, Management Control in Nonprofit Organizations (Homewood, Illinois: Richard D. Irwin, Inc., 1975).

[2] Newman, Constructive Control: Design and Use of Control Systems.

[3] Mockler, The Management Control Process. See Also Robert J. Mockler, Information Systems for Management (Columbus, Ohio: Charles E. Merrill Publishing Co., 1974).

[4] Drucker, Management: Tasks, Responsibilities, Practices.

[5] William Travers Jerome III, Executive Control: The Catalyst (New York: John Wiley & Sons, Inc., 1961), p. 24.

[6] George T. Vardaman and Carroll C. Halterman, Managerial Control Through Communication (New York: John Wiley & Sons, Inc., 1968).

[7] Samuel Eilon, Management Control (London: Macmillan and Co., Ltd., 1971).

able to identify change, discover its causes, and provide decisive action in order to maintain a state of equilibrium within the system for which he has managerial responsibility and authority."[1] Stokes also looked at control from a systems viewpoint and suggested various control system approaches for a variety of management tasks and business situations.[2] Boyce emphasized the essentials of management control in typical business and management applications. He demonstrated his conviction of the compelling value of visual aids to control through the liberal use of exemplary illustrations in his text.[3] More recently, Cleland and King have expressed a philosophy associated with the elements of control in the project management context[4] while Johnson, Kast, and Rosenzweig have expanded the systems view.[5]

Recent initiatives have been characterized by increased vertical and horizontal growth of theory; by renewed effort in the continuing search for fundamentals in management and establishment of a conceptual framework; by the advent of high speed data processing; and by the emergence of large-scale, complex, integrated management control systems. Managers, machines, and systems are converging and forming new relationships as theorists and practitioners continue the search for management logic.

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[1]Earl P. Strong and Robert D. Smith, Management Control Models (New York: Holt, Rinehart and Winston, 1968), p. 2.

[2]Paul M. Stokes, A Total Systems Approach to Management Control (New York: American Management Association, Inc., 1968).

[3]R. O. Boyce, Integrated Managerial Controls (New York: American Elsevier Publishing Company, Inc., 1968).

[4]Cleland and King, Systems Analysis and Project Management, pp. 324-40.

[5]Johnson, Kast, and Rosenzweig, The Theory and Management of Systems, pp. 73-92.

Emerging Patterns

Management theory and practice have undergone significant change in recent years. This is particularly evident in the management of United States national defense activities.[1] Evolving technology, especially since the late 1940s and early 1950s, has led to weaponry and peripheral equipment of increasing complexity. Additionally, weapons came to be "systems" involving not just individual components of hardware, but integrated items of total weaponry; support and maintenance equipment; real estate for deployment sites; selection, training, and care of operating and maintenance personnel; repair parts; preparation of technical documentation; and development and implementation of military doctrinal relationships between companion strategic and tactical offensive and defensive military weapons.[2] The systems concept was more than a planning convenience; it became a "way of thinking" about the management process.[3]

The following paragraphs of this section briefly describe some emerging patterns in current management control thought with emphasis on the total systems concept.

Tools and Techniques

While many individual tools and techniques have been developed to cope with modern management problems, reference to three generic families

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[1] Kast and Rosenzweig, Management in the Space Age, pp. 43-57.

[2] Baumgartner, The Lonely Warriors: Case for the Military-Industrial Complex, pp. 128-29.

[3] Cleland and Dellinger, "Changing Patterns in Management Theory," p. 2.

should satisfactorily establish the requisite historical base. These three families of tools and techniques are compatible with the examination parameters identified with the PPL analysis matrix in Chapter I.

Cost Control

This family is frequently identified by a number of different titles, and there is wide variation in the control activities discussed. Other words commonly associated with this specific parameter are "budget" or "budgetary," "finance" or "financial," and combinations thereof. Budgetary, financial, or cost control systems are among the most common found in business.[1]

Having their roots in accounting systems, cost control tools and techniques are usually designed to satisfy particular financial management needs. As an example, Alain Enthoven stressed, in 1966, that, ideally, the purpose of a budget is to "...convert goals, programs, and priorities into monetary terms following rational economic analysis and decision on the optimum means of accomplishing an agency's objectives."[2] He adds that "...budgeting is an important device for the review and control of activities of the component parts of an organization, to the end that overall purposes and not parochial ones are served."[3] Enthoven also notes that while the Congress has historically used its power to authorize and appropriate funds as a lever with the executive branch, the use of the systematic budget process as a "positive instrument" of economic analysis and decision making is relatively new.[4]

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[1] Mockler, The Management Control Process, p. 85.

[2] Alain C. Enthoven, "Introduction," in A Modern Design for Defense Decision: A McNamara-Hitch-Enthoven Anthology, ed. by Samuel A. Tucker (Washington, D.C.: Industrial College of the Armed Forces, 1966), p. 1.

[3] Ibid. [4] Ibid.

Anthony and Herzlinger suggest that the federal government's continued reliance upon the accounting technique of obligation and expenditure (focus of purchasing and liabilities incurred respectively) denies it the preferred method of accrual accounting (emphasis on resource consumption). They argue also that general use of the obligation and expenditure technique eliminates the disciplines imposed by basic double entry accounting.[1]

The Congressional Budget and Impoundment Control Act of 1974 (Public Law 93-344) represents an attempt to bring major reform to the federal budget process. Among other reforms, it established new committees on the budget in both houses of Congress, established a timetable for the Congressional budget process, provided for improvements in the information to be included in the President's budget submissions to the Congress, and improved review and analysis procedures. While it is too early to determine the full impact of the Act, it may cause significant change in day-to-day operations within the Department of Defense.[2]

One point is abundantly clear: fiscal responsibility is being stressed at the operating level within the Department of Defense. Severe penalties are assessed at the level of the individual or individuals knowingly taking any action resulting in any overdistribution, overobligation, or overexpenditure of funds in any fiscal appropriation or a subdivision of a fiscal appropriation. Additionally, management actions involving accidental accounting, clerical, recording or

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[1] Anthony and Herzlinger, Management Control in Non-profit Organizations, pp. 53-54.

[2] James A. Francis, "The Congressional Budget and Impoundment Control Act of 1974: Implications for Program Managers," Defense Systems Management Review 1 (Winter 1976): 1-24.

reporting errors that lead to actual overobligation and overexpenditure are considered violations of regulations.[1]

Schedule Control

The schedule control family of tools and techniques derives much of its current state of development from the early contributions of the scientific management movement and, more recently, from the activity in network planning. Additionally, many of the quantitative models of operations research and operations management have constructive application as tools and techniques in the schedule control parameter.

Just as money is the common denominator in cost control, time is the common denominator in schedule control. The value of a common denominator is readily apparent when the inherent integrative properties of such a feature are considered. This point is illustrated by Hodgetts in his opening discussion on time-event analyses:

> Some of the most successful approaches to control have been attained through techniques that permit the manager to see how all the segments of the project interrelate; evaluate overall progress; and identify and take early corrective action on problem areas.[2]

Hodgetts suggests that the Gantt Chart is one of the earliest techniques of time-event analysis and that later and more sophisticated techniques are based on these early principles.[3]

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[1] U.S., Department of the Army, Executive Handbook for Financial Management (Fort Benjamin Harrison, Indiana: U.S. Army Institute of Administration, April 1976), pp. 3-2 - 3-5. See also U.S., Department of the Army, Financial Administration: Administrative Control of Appropriated Funds, Army Regulation No. 37-20, Change 1 (Washington, D.C., 24 June 1969).

[2] Hodgetts, Management: Theory, Process, and Practice, p. 204.

[3] Ibid.

Technical Performance Control

Technical performance is a generic term applying to those dimensions not falling clearly in the cost or schedule categories, that may be used for controlling project progress. Included are such dimensions as product design specifications, product improvement programs, product assurance and test requirements, operational readiness status of deployed systems, and reliability and maintainability status and trends.

Where project cost and schedule control have common denominators of money and time respectively, technical performance has no such single common trait. Cleland and King, discussing technical performance in concert with cost and schedule standards, describe it as "...one of the least understood of the standards."[1] They provide further insight into the nature of the technical performance parameter by suggesting that it be quantified "...in terms of system weight, speed capability, etc., ..."[2] and monitored over time. It is clear that weight and speed have no readily apparent common trait.

Martin refers to this parameter as "product performance" and defines the purpose of measurement as giving "...a continuing estimate during the execution of a research or development program as to whether the performance goals of the project end product will be met."[3] He concludes that "Control of product performance should follow the best practice for the product or in the industry."[4]

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[1]Cleland and King, Systems Analysis and Project Management, p. 329.

[2]Ibid.

[3]Charles C. Martin, Project Management: How to Make It Work (New York: AMACOM, 1976), p. 189.

[4]Ibid., p. 192.

Chestnut also differentiates between cost, time, and "system performance" as factors for judging the worth of systems.[1] Discussing re-entry vehicle technical performance, Chestnut suggests that "Because of the importance of successful completion of the desired mission, system performance is considered a primary factor in the judgement of the system."[2] In a later text stressing the problems confronted by systems engineers, Chestnut discusses the use of ratios or "figures of merit" as performance indices in non-dimensional form as a means of relating performance of similar systems. The use of ratios thus would eliminate masking caused by the size or number of variables.[3]

Integrated Management Control

Integrated management control is compatible with systems theory. It views management control as a system to examine, analyze, and explain project performance factors in terms of their total influence in large-scale complex endeavors, to search for constructive patterns and trends, and to suggest meaningful relationships and interdependences. Mockler describes integrated control in broad terms as a "...scientific discipline...which has its own systematically organized set of principles and processes to guide the manager in handling all types of business control situations."[4] This definition clearly and deliberately breaks with the traditional focus on financial and monetary

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[1] Harold Chestnut, Systems Engineering Tools (New York: John Wiley & Sons, Inc., 1965), pp. 57-58.

[2] Ibid., p. 57.

[3] Harold Chestnut, Systems Engineering Methods (New York: John Wiley & Sons, Inc., 1967), pp. 145-46.

[4] Mockler, The Management Control Process, pp. vii-viii.

systems.[1] It stresses a broader, more comprehensive, more pervasive view, one calculated to bring maximum exposure to the topic.

In Mockler's view, the science of management control is not yet fully developed. He suggests, however, that a higher level of maturity may be achieved more rapidly and with less lost motion, if those theorists and practitioners working to advance the science of management build on prior works.[2] It is this task to which this study is dedicated.

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[1] Ibid., p. viii. [2] Ibid., p. 345.

CHAPTER III

A HISTORY OF BMD MISSION AND MANAGEMENT

The deployment of the Safeguard BMD System at the Stanley R. Mickelson Safeguard Complex, Nekoma, North Dakota, represented the visible culmination of the most massive, complex defensive weapon project ever undertaken by the U.S. Army.[1] It was the tangible product of more than two decades of ballistic missile defense (BMD) research, development, test and evaluation activity by an Army-Industry team of unprecedented proportions.[2] It has been suggested by Augustine[3] that this vigorous activity on the Safeguard program may have motivated the U.S.S.R. to join with the United States in the Antiballistic Missile (ABM) treaty and the interim offensive weapons agreements.[4]

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[1]At the acceptance ceremony, where the Safeguard System was turned over to the U.S. Army by the Safeguard prime contractor, the Honorable Norman R. Augustine, then Assistant Secretary of the Army (Research and Development) referred to Safeguard as "...one of the most massive, complex undertakings in military history." Norman R. Augustine, address at the Safeguard System Acceptance Ceremony, U.S. Army Safeguard Command, Nekoma, North Dakota, 27 September 1974.

[2]U.S., Army Ballistic Missile Defense Systems Command, Safeguard: Ballistic Missile Defense, (Huntsville, Alabama, n.d.) p. inside front cover.

[3]Augustine address, 27 September 1974.

[4]For a concise description of these two major agreements and discussion of the Strategic Arms Limitation Talks (also known as SALT), of which they are products, see Lincoln P. Bloomfield and Irirangi C. Bloomfield, "Arms

Initiated by a small study effort in 1955,[1] the project progressed through a series of critical technological and management phases until, in December 1975, the Congress directed the Department of Defense (DoD) to provide the House and Senate Committees on Appropriations a report of plans to deactivate and terminate the Safeguard complex in North Dakota. The intent of the Joint Senate/House Conference action was to close the complex, except for the perimeter acquisition radar (PAR) and ancillary equipment, in a manner calculated to insure that no future funding would be required unless directly associated with completion of dismantlement and disposal of Safeguard facilities.[2] Initiated in the House, the Congressional action directing termination of operation of the Safeguard System (less the PAR) was officially completed by virtue of the fiscal year (FY) 1976-7T[3] DoD Appropriations Bill which became public law on February 9, 1976.[4] This cessation of Safeguard operation, depending

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Control," 1975 Yearbook: Collier's Encyclopedia Yearbook Covering The Year 1974 (New York: Macmillan Educational Corporation and P. F. Collier, Inc., 1974), pp. 72-81.

[1]U.S., Department of the Army, Ballistic Missile Defense (BMD) Management Study (U), Vol. II, Study Report (U) (CONFIDENTIAL), (Washington, D.C., 1 September 1972), p. II-1.

[2]U.S.,Congress, Senate, debate on Kennedy Amendment on H.R. 9861, Department of Defense Appropriations, 1976, 94th Cong., 1st sess., 18 November 1975, Congressional Record, pp. S20314-S20320.

[3]Through June, 1976, the U.S. fiscal year (FY) ran from July 1 through June 30 each year preceding the calendar year by six months. As an example, the first half of FY 76 coincided with the last half of calendar year (CY) 1975, while the second half of FY 76 coincided with the first half of CY 1976. In CY 1976, however, the fiscal year was changed to run from October 1 through September 30; thus each year preceded the calendar year by only three months. The transition period occurred in the third quarter of CY 1976 or July 1, 1976, through September 30, 1976. This period is referred to as FY 7T. Thus, FY 77 covers the period October 1, 1976, through September 30, 1977.

[4]U.S., Congress, House, H.R. 9861 Pub. L. 94-212 (9 February 1976; 90 Stat. 153), Federal Register 41, No. 31, 13 February 1976, p. ii.

upon one's mental persuasion, signaled either a strident defeat of strong BMD advocacy or a resounding triumph for détente.[1]

This chapter is devoted to a synthesized history of BMD mission and management, from the first formal feasibility study in 1955 through the Safeguard termination decision. The complexity of technical and strategic considerations, the intensity of Congressional and public interest in the effort, and the dynamic nature of national BMD policy have had a profound effect on the BMD mission and on the management considerations and philosophy attaching to the accomplishment of that mission. While United States BMD activity has been subject to a number of significant and influential factors, six key decisions marked the course of Safeguard progression. Chronologically, these decisions were: (1) the decision to study anti-missile missile feasibility in 1955; (2) appointment of a system manager in 1966; (3) the Sentinel decision in 1967; (4) the Safeguard decision in 1969; (5) the ABM Treaty in 1972; and (6) the system termination action in 1975-76. The brief program history that follows focuses on these six key factors and emphasizes the interaction of management techniques and initiatives with the evolving mission.

Anti-Missile Missile Feasibility[2]

The development of an effective BMD capability using ABM technology has aptly been described by the scientific community as "hitting a bullet

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[1]For an interesting observation on the demise of Safeguard see Nick Lamberto, "How the U.S. Lost a $5.6 Billion Poker Hand," Des Moines Sunday Register, September 4, 1977, pp. 4-7.

[2]The term "anti-missile missile" was originally used in conjunction with early U.S. Army activity. This term was generally replaced by the more accurate term "antiballistic missile." Both of these terms, however, technically refer to the missile major item only of a BMD system. BMD is a broader term

with a bullet."[1] Such an undertaking in 1955 represented a formidable challenge to the air defense development community, and many scientists believed the task impossible.[2]

Early Activity

The formal study by the Department of the Army of the feasibility of defending against the Intercontinental Ballistic Missile (ICBM) began as an analysis of a super air-breathing (but high altitude) class of targets as the primary objective, with the ICBM target as a concommitant correlate.[3] This original emphasis, however, was rapidly reoriented, and defense against the ICBM became the principle concern with total consideration open to a wide range of targets.[4]

Genesis

In March, 1955, the Ordnance and Missile Laboratories located at Redstone Arsenal, Alabama, awarded an eighteen month study contract in the amount of $1.65 million to the Bell Laboratories, Whippany, New Jersey, for the study of defense against postulated future air threats including ICBM's.[5] In June of that same year, the emphasis of the study was directed to the ICBM threat at the request of the Army.[6]

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that encompasses the total program, including hardware items (interceptors, radars, command, control and communications components, etc.), software items (drawings, technical manuals, field manuals, tactical computer software, etc.), site facilities, personnel, and services (project management, operator and maintenance training test and evaluation, etc.). Chronologically and technically appropriate and correct terminology is used in this study.

[1]U.S., Army Ballistic Missile Defense Systems Command, Project History (Whippany, New Jersey: Bell Laboratories, October 1975), p. I-11.

[2]Ibid. [3]Ibid., p. I-1. [4]Ibid.

[5]Ibid., p. I-2. [6]Ibid., p. I-1.

This initiation of Army BMD effort followed the development of the highly successful Nike-Ajax missile system which was deployed in urban areas to defend against bomber aircraft attacks. Ajax's equally impressive successor, Nike-Hercules, emerged as an operational antiaircraft system in 1958.[1]

Designated the Nike II[2] Study, funding for BMD feasibility was to embrace not only the engineering study effort, but also exploratory hardware development in areas deemed critical to successful development of the Nike II system.[3]

During this same time-frame the Department of the Air Force was also concerned with an ABM capability. In this period, the mission of the Army was characterized as "terminal" defense while that of the Air Force was defined as "area defense." While the rivalry was intense, the BMD mission subsequently was assigned solely to the Army.[4] This assignment of the ABM strategic mission to the Army was consistent with its traditional role of providing ground-based defense against attack from the air.

Early anti-missile missile activity was managed by the Ordnance Missile Laboratory (OML), Redstone Arsenal, Alabama. Created as a mission agency or line organization in 1952, OML was responsible for planning, directing, performing, and coordinating research, development, and product engineering

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[1]U.S., Department of the Army, BMD Management Study, Vol. II, p. II-1.

[2]System nomenclature in the Nike family was solidified in late 1956 as follows: Nike I was changed to Nike-Ajax, Nike B to Nike-Hercules, and Nike II to Nike-Zeus. These changes were announced in: U.S., Department of the Army, Circular No. 700-22 (Washington, D.C., 15 November 1956).

[3]U.S., Army Ballistic Missile Defense Systems Command, Project History, p. I-2.

[4]Ibid., p. I-15.

within the fields of guided missiles, JATOs and rockets. Additionally, OML was assigned responsibility for maintaining a position of leadership in scientific and engineering activities within the same fields.[1]

On December 22, 1955, the Department of the Army formally announced the establishment of the U.S. Army Ballistic Missile Agency (ABMA) as an independent activity at Redstone Arsenal, but reporting directly to the Chief of Ordnance, Washington, D.C. The new agency was to be effective February 1, 1956.[2] The primary mission of ABMA was to bring focus and emphasis to a family of ballistic missiles.[3] The establishment of ABMA was carefully designed to preclude technical mission conflict with Redstone Arsenal.[4] It was during this period that Redstone Arsenal began to achieve national and world-wide prominence. While the establishment of ABMA did not materially affect the mission of OML with regard to its anti-missile missile work, it precipitated unprecedented continuous national interest in Redstone Arsenal and its activities.[5]

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[1]U.S., Department of the Army, Semiannual Historical Summary: 1 January 1953-30 June 1953 (Huntsville, Alabama: Redstone Arsenal, n.d.), p. 128.

[2]U.S., Department of the Army, General Orders No. 68 (Washington, D.C., 22 December 1955).

[3]U.S., Department of the Army, Historical Summary: 1 Jul 1955-31 Dec 1955, Vol. I (Huntsville, Alabama: Redstone Arsenal, n.d.), p. 4.

[4]U.S., Department of the Army, Historical Summary: 1 Jan 1956-31 Jul 1956, Vol. I (Huntsville, Alabama: Redstone Arsenal, n.d.), p. 6.

[5]U.S., Army Ordnance Missile Command, Historical Summary: 1 Jan 1958-30 Jun 1958 (Redstone Arsenal, Alabama, n.d.), p. 1.

Feasibility Study Results

The product of the Army Nike II Study was a new, forward-looking, surface-to-air guided-missile system capable of engaging target threats (specifically the ICBM) postulated for the 1960-70 time-frame. The study, completed in October, 1956, concluded that an anti-missile missile system was feasible against the specifically defined threats. The study also provided a phased development and production program which, if fully funded and implemented as planned, would have attained an operational system capability in late 1962.[1] This milestone would finally be met thirteen years later following accomplishment of many technological advancements, much spirited and strident debate, and a program approaching $6 billion.[2] The total approved Safeguard program is depicted in Table 1.

As a result of the Army study, the phased development of the Nike-Zeus system was initiated in November, 1956.[3]

Nike-Zeus

During the continuing development of Nike-Zeus, the National Security Council assigned the highest national priority to the program. The management of the system within the office of the Chief of Ordnance, Department of the Army, gradually became more sophisticated and progressively more centralized.[4]

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[1]U.S., Department of the Army, BMD Management Study, Vol. II, p. II-3.

[2]Program figure cited is through 31 March 1977, as depicted in BMDPO Form 68, "Continued Management Integration and Control of BMD Costs," Action No. BMD 3-47, 31 March 1977.

[3]U.S., Department of the Army, BMD Management Study, Vol. II, p. II-3.

[4]Ibid.

TABLE 1

SUMMARY OF SAFEGUARD APPROVED PROGRAM
FISCAL YEARS 1968 – 1977, INCLUSIVE
(Dollars in Millions as of December 1976)

FISCAL YEAR	DEVELOPMENT	INVESTMENT	OPERATING	TOTAL
1968	$ 383.5	$ 184.7	$ 10.0	$ 578.2
1969	311.1	512.5	37.2	860.8
1970	399.0	447.7	35.0	881.7
1971	361.8	845.4	54.3	1,261.5
1972	296.0	637.0	74.1	1,007.1
1973	299.2	272.0	71.2	642.4
1974	176.1	130.4	65.6	372.1
1975	33.1	3.0	70.5	106.6
1976	0.	1.9	83.8	85.7
197T	0.	0.	17.6	17.6
1977	0.	4.2	26.7	30.9
TOTAL	$2,259.8	$3,038.8	$546.0	$5,844.6

SOURCE: COMPILED FROM U.S., DEPARTMENT OF THE ARMY, BMDPO FORM 68, 'CONTINUED MANAGEMENT INTEGRATION AND CONTROL OF BMD COSTS,' ACTION NO. BMD 3–47, 31 MARCH 1977 AND RCS–BMDPM–8, 'BMD PROGRAM STATUS,' REPORT NO. J1004R9, 31 DECEMBER 1976, BOTH DOCUMENTS FROM BALLISTIC MISSILE DEFENSE ORGANIZATION FILES, WASHINGTON, D.C.

Redstone Anti-Missile
Missile Systems Office

In October, 1957, the Redstone Anti-Missile Missile Systems Office (RAMMSO) was established at Redstone Arsenal to bring intensive management to the project in response to the increasing urgency given the anti-missile missile program by higher headquarters.[1] Formed from a small anti-missile missile office established in OML in December, 1956, RAMMSO was attached directly to the Office of the Commanding General[2] and was, in effect, the first formal project office for BMD activity.

Although the Nike-Zeus project had already reached the development stage and was progressing satisfactorily, the urgency of the ballistic missile threat demanded that the normal course of development, procurement and production, and deployment be abandoned in favor of an accelerated program with a high degree of concurrency or overlapping of major program phases. This required conceptual changes in normal management methods in order to integrate the many diverse functional activities and provide for smooth establishment of a BMD system in minimum time.[3] Accordingly, the RAMMSO mission was clearly delineated to reflect its role of program control in matrix overlay with supporting arsenal functional mission organizations, other government agencies, and prime contractors. Initially staffed with five Army officers

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[1]U.S., Department of the Army, Historical Summary: 1 Jul 1957-31 Dec 1957, Vol. II (Redstone Arsenal, Alabama, n.d.), p. 151.

[2]U.S., Army Ordnance Missile Command, Historical Summary: 1 Jan 1958-30 Jun 1958, p. 6.

[3]U.S., Department of the Army, Historical Summary: 1 Jul 1957-31 Dec 1957, Vol. II, p. 151.

and nineteen civilians, RAMMSO had an authorization of sixteen military and twenty-four civilians by the end of 1957.[1]

U.S. Army Rocket and Guided Missile Agency

In March, 1958, the Secretary of the Army announced the establishment of the U.S. Army Ordnance Missile Command (AOMC) at Redstone Arsenal, effective March 31, 1958.[2] Major organizational elements of AOMC included ABMA; the Jet Propulsion Laboratory at Pasadena, California; the White Sands Proving Ground (renamed White Sands Missile Range one month later); and the Redstone Arsenal.[3] The U.S. Army Rocket and Guided Missile Agency (ARGMA) was activated as a fifth subordinate element of AOMC, effective April 1, 1958.[4] The primary intention of the sweeping reorganization was to establish a unified command under single direction, coupled with administrative streamlining, to manage the entire Army rocket and guided missile effort and assigned portions of the national space program.[5]

The establishment of ARGMA erased Redstone Arsenal's identity as a commodity arsenal for rockets and guided missiles. All of the Redstone

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[1] Ibid.

[2] U.S., Army Ordnance Missile Command, Historical Summary: 1 Jan 1958-30 Jun 1958, p. 1.

[3] U.S., Department of the Army, General Orders No. 12 (Washington, D.C., 28 March 1958).

[4] U.S., Army Ordnance Missile Command, General Orders No. 6 (Redstone Arsenal, Alabama, 1 April 1958).

[5] U.S., Department of Defense, "Army Ordnance Missile Command Established at Huntsville, Alabama," News Release No. 263-58 (Washington, D.C.: Office of Public Information, 20 March 1958).

technical mission and organization remaining from the establishment of ABMA, including the RAMMSO mission, went to ARGMA.[1] ARGMA was functionally organized. A complement of mission divisions performed specific functions for a number of weapon systems, however, project orientation was used wherever feasible within the mission divisions.[2] As an example, when RAMMSO was abolished shortly after the establishment of ARGMA,[3] research and development activities pertaining to the anti-missile missile effort were transferred to the Anti-Missile Missile Branch within the Research & Development Division.[4]

From its inception, ARGMA operated under a prime contractor concept involving technical control and coordination by ARGMA of development work actually performed by industrial contractors.[5] This early ARGMA philosophy of heavy reliance on private industry was to remain a cardinal management principle in BMD activity.[6] The management objectives of the research and development programs conducted by AOMC were "First, to control

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[1]U.S., Army Ordnance Missile Command, Historical Summary: 1 Jan 1958-30 Jun 1958, p. 5.

[2]U.S., Army Ordnance Missile Command, Historical Summary: 1 April 1958-30 June 1958 (Redstone Arsenal, Alabama: U.S. Army Rocket & Guided Missile Agency, 21 October 1958), p. 26.

[3]U.S., Army Rocket & Guided Missile Agency, General Orders No. 5 (Redstone Arsenal, Alabama, 11 April 1958).

[4]U.S., Army Ordnance Missile Command, Historical Summary: 1 April 1958-30 June 1958, pp. 25, 64.

[5]Ibid., p. 27.

[6]Two excellent contemporary articles on the subject of the use of private enterprise in weapon system procurement are J. Sterling Livingston, "Decision Making in Weapons Development," Harvard Business Review 36 (January-February 1958): 127-36 and J. Sterling Livingston, "Weapon System Contracting," Harvard Business Review 37 (July-August 1959): 83-92.

the degree to which the state of the art was pushed in any given project; second, to project an accurate time schedule for the development, production, and deployment of a program; and, third, to apply available funds and manage the program with optimum efficiency."[1]

The commodity management procedure involving functional orientation made effective management control and internal coordination of mission effort difficult. While the commodity management concept provided formal guidelines for determining the division of primary interest based on specified transition points in the life cycle of the system, the need for centralized technical management control was recognized.[2] For Nike-Zeus this meant the establishment in February, 1960, of a Deputy Commander, ARGMA, for Ballistic Missile and Space Defense with full responsibility for the Nike-Zeus program.[3] This Deputy Commander was delegated authority for Nike-Zeus to: "Issue in his own name directives and instructions to all ordnance agencies engaged in the execution of support actions and services."[4] The title was subsequently changed to Project Director for Ballistic Missile and Space Defense.[5] The responsibilities assigned this first genuine BMD project administrator were prophetic of a management trend toward continuing centralization of BMD activity.

The sensitivity of the BMD effort to the balance of world power was succinctly stated by the then Chief of Staff of the Army when, referring to the Nike-Zeus, he stated:

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[1] U.S., Army Ordnance Missile Command, History of Headquarters, U.S. Army Ordnance Missile Command: 1 January-30 June 1959 (Redstone Arsenal, Alabama, 1 November 1959), p. 4.

[2] U.S., Army Ordnance Missile Command, Historical Summary: 1 Jan 1960-30 Jun 1960 (Redstone Arsenal, Alabama: 19 October 1960), pp. 15-19.

[3] Ibid., p. 3. [4] Ibid., p. 4. [5] Ibid., p. 5.

> It would be reassuring to know that it is the only anti-missile missile system in the world which has advanced so far. It takes little imagination to picture our predicament if the Soviets were to develop an effective anti-missile defense before we do.[1]

This logic, in fact, subsequently underscored the negotiations with the U.S.S.R. that led to the ABM treaty mentioned earlier in this chapter.

During this period the program continued to progress technically and the development effort remained on schedule. Significant technology advancements were achieved in many of the major elements of the system.[2]

Nike-Zeus Project Office

The organizational structure of ARGMA remained essentially stable until December, 1961, when the major elements of AOMC were realigned to consolidate the activities of ABMA, ARGMA, and AOMC headquarters in accordance with Department of the Army direction.[3] An organization chart of the period depicts a Deputy Commanding General for Ballistic Missiles (basically ABMA systems) and a Deputy Commanding General for Guided Missiles (basically ARGMA systems). Each had a number of project offices reporting directly to him including a Nike-Zeus Project Office organizationally aligned under the Deputy Commanding General for Guided Missiles. Major functional elements reported directly to the Commanding General.[4] Matrix management had arrived at AOMC. The major mission of the Zeus and other project managers was to

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[1]Speech by General George H. Decker, Chief of Staff, U.S. Army, before the National Press Club Luncheon, Washington, D.C., 15 December 1960.

[2]John G. Zierdt, "Nike-Zeus: Our Developing Missile Killer, Army Information Digest 15 (December 1960): 2-11.

[3]U.S., Army Ordnance Missile Command, Organizational Manual (Interim) (Redstone Arsenal, Alabama, 26 January 1962), p. 1.

[4]Ibid., p. 1.

"...assure most effective management of assigned weapon system."[1] Project managers were given "...maximum responsibility and broadest possible authority..." in keeping with this comprehensive mission.[2] The disestablishment of ABMA and ARGMA in December, 1961, finally solidified the trend toward a unified organization for Army missiles and rockets which had been initiated more than three years earlier. The days of AOMC by that name were also numbered; during an Army-wide reorganization, the Army Missile Command (MICOM) supplanted the AOMC in August, 1962.[3]

The Army Missile Command was officially established at Redstone Arsenal as a subordinate element of the Army Materiel Command (AMC), Washington, D.C., in May, 1962. It did not become operational until three months later with the final transfer of assets such as personnel, records, files, property, and equipment of the old AOMC to MICOM.[4] In the reorganization the Nike-Zeus Project Office remained intact. The Zeus Project Manager, together with one other project,[5] were attached to MICOM for administrative support, but each reported directly to the Commanding General of the Army Materiel Command.[6]

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[1] Ibid., p. 380-5. [2] Ibid.

[3] U.S., Army Ordnance Missile Command, History of the Headquarters, Army Ordnance Missile Command: 1 January-30 June 1962 (Redstone Arsenal, Alabama, 15 November 1962), p. 1.

[4] U.S., Army Missile Command, Annual Historical Summary: 1 July 1962-30 June 1963, Vol. I (Redstone Arsenal, Alabama, 1 October 1963), p. 2.

[5] The Field Army Ballistic Missile Defense System (FABMDS).

[6] U.S., Army Missile Command, Annual Historical Summary: 1 July 1962-30 June 1963, Vol. I, p. 5.

The project management concept continued to mature,[1] and the vertical project management concept recognized the project manager as "...the single individual responsible for accomplishing the objectives of his assigned program."[2] Project managers had the authority to direct support elements of MICOM and also supervised large staffs organic to their own offices. Technical direction of program activity covered such gross functional areas as system design, research and development, procurement, production, quality engineering, reliability, system test, maintenance engineering, and program resource management.[3]

The real additional cost of the matrix form of management was the subject of a study at MICOM in August, 1963. The study concluded that the project management concept at MICOM added costs of $5.7 million and 434 personnel over straight functional management. The Commanding General, MICOM, however, concluded:

> Although from the standpoint of internal operating costs it would appear that considerable money and manpower could be saved by reversion to the functional concept, I feel that the concentrated attention to individual systems under the project management concept is effecting savings in money and time on our contracts which far outweigh the increased internal costs.[4]

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[1]Informed, authoritative, contemporary descriptions of early Army project management concepts may be found in Fremont E. Kast and James E. Rosenzweig, eds., Science, Technology, and Management (New York: McGraw-Hill Book Company, Inc., 1963), pp. 90-128; Frank S. Besson, Jr., "General Besson Highlights Project Manager Duties Under Reorganization," Data 8 (June 1963): 13-17; and Francis J. McMorrow, "General McMorrow Outlines Missile Command Organization and Functions," Data 8 (June 1963): 19-22.

[2]U.S., Army Missile Command, Annual Historical Summary: 1 July 1962-30 June 1963, Vol. I, p. 6.

[3]Ibid.

[4]U.S., Army Missile Command, Annual Historical Summary: 1 July 1963-30 June 1964 (Redstone Arsenal, Alabama, 2 November 1964), p. 27.

This early endorsement of the project concept was indicative of the high esteem in which this management technique was held in the Army, particularly with regard to the Zeus Project. During this time-frame, the Zeus Project Office was authorized a total of 279 personnel.[1]

Production Planning

A significant milestone in the evolution of strategic defensive forces was reached in July, 1962, when a Zeus missile, launched from the Kwajalein Test Site in the Marshall Islands in the Central Pacific Ocean, intercepted and theoretically destroyed an incoming ICBM nose cone (the ICBM payload) hurled into trajectory by an Air Force Atlas missile launched from Vandenberg Air Force Base, California.[2]

Production planning for Nike-Zeus had reached a stage of maturity that permitted the Secretary of Defense to approve, in September, 1962, the first two phases of a three-phase plan for production and deployment of Nike-Zeus. Despite the success of the test program, however, the Nike-Zeus system was limited in capability. The slow, mechanically slewed radars were limited in their capacity to search and track, and the Zeus missile itself responded too slowly to be launched and still intercept a hostile ICBM after the ICBM had re-entered the atmosphere. When confronted with a sophisticated attack, incorporating penetration aids (decoy warheads) or a great number of actual warheads, the defensive Zeus could be target saturated or numerically overwhelmed.[3]

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[1] Ibid., p. 15.

[2] U.S., Department of the Army, BMD Management Study, Vol. II, p. II-3.

[3] Ibid.

The Secretary of Defense reversed his earlier production decision in January, 1963, and stated that the existing Nike-Zeus would not be produced or deployed. He indicated further that the Nike-Zeus program was to be reoriented toward a new system approach and that no decision had been made as to the eventual production and deployment of the new system which was designated Nike-X.[1] Concurrently, the need for an active BMD continued to be argued in the technical periodicals.[2]

Nike-X System Manager

Early in 1963 the Secretary of Defense directed that the Army commence, with the highest priority, to develop an advanced concept, Nike-X.[3] The new approach was to include more versatile and higher traffic-handling capacity radars and data processors and a missile capable of being launched after a hostile projectile had re-entered the atmosphere and still achieve destructive intercept.[4]

Nike-X

Nike-X, by definition, was not a single system concept. Unlike its predecessor, Nike-Zeus, it was more a generic term embracing "...a number of

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[1] Ibid.

[2] See, for example, John G. Zierdt, "Defense in Nuclear War," Ordnance 47 (January-February 1963): 418-21; C. A. Warren, "Nike-Zeus," Bell Laboratories Record 41 (March 1963): 78-86; Strom Thurmond, "The Gap in Ballistic Missile Defense," Data 8 (June 1963): 42-45; and "BMD in Perspective," Data 8 (June 1963): 7-11.

[3] An interesting comparison of Nike-Zeus and Nike-X is made by the then project manager in Ivey O. Drewry, Jr., "Project Officer Evaluates Zeus and Nike-X," Data 8 (June 1963): 24-27.

[4] An authoritative description of this missile may be found in Ivey O. Drewry, Jr., "Hot Rod Missile," Army Information Digest 20 (May 1965): 22-26.

studies and exploratory developments aimed at leading from the then outmoded Nike-Zeus to the next generation ABM system."[1] In terms of technological lineage, Nike-X represented the fourth-generation Nike. It would build on the accumulated scientific and engineering knowledge derived from Ajax, Hercules, and Zeus.[2]

Nike-X Project Office

The project office mission remained essentially unchanged during 1963, although the Nike-X decision meant significant technical redirection of the program. In fact, the office was not renamed the Nike-X Project Office until February, 1964.[3]

The Nike-X Project Manager continued to report to the Commanding General of the Army Materiel Command, Washington, D.C. Additionally, a direct contracting capability with authority to negotiate and execute Nike-X contractors was established within the project office.[4] In July, 1964, an additional organizational change occurred as the Nike-X Project Office assumed responsibility for operating and managing the Kwajalein complex and redesignated it the Kwajalein Test Site.[5] The project manager summarized his mission

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[1] U.S., Army Ballistic Missile Defense Systems Command, Project History, p. 2-1.

[2] Ivey O. Drewry, Jr., "The Brand Name is Nike-X," Army 14 (February 1964): 53.

[3] U.S., Army Materiel Command, General Orders No. 4 (Washington, D.C., 30 January 1964).

[4] "Col. Drewry Confident Nike-X Fills ABM Need," Data 9 (June 1964): 29.

[5] U.S., Army Materiel Command, Annual Historical Summary: 1 July 1963-30 June 1964 (Redstone Arsenal, Alabama: Nike-X Project Office, 10 August 1964), p. 1.

succinctly when, in addressing the possible future deployment decision of Nike-X, he wrote:

> Our job at the project management office is to summon all the technical competence available to build the best system possible and to provide those in authority with the best information possible upon which to base such a decision. These tasks are being executed under the highest priority.[1]

If contract dollar amount is any indication of the magnitude of this job--and it undoubtedly is--the Nike-X program achieved distinction in September, 1964, when the largest single contract awarded in Army history was signed with the Western Electric Company in the amount of $309,664,200.[2] Spanning a one year period, the contract covered testing of Nike-X equipment at White Sands Missile Range, New Mexico; Kwajalein Test Site; and other smaller test sites. While certainly the largest of contracts at that time, it was only one of many under the purview of the project office.[3]

Deployment Planning

Deployment of an active BMD, specifically Nike-X, continued to be the subject of techno-military defense policy articles in a variety of periodicals.[4]

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[1] Ivey O. Drewry, Jr., "Nike-X: New Look in ICBM Defense," Ordnance 49 (November-December 1964): 281.

[2] U.S., Army Materiel Command, Annual Historical Summary: 1 July 1964-30 June 1965 (Redstone Arsenal, Alabama: Nike-X Project Office, 27 July 1965), p. 1.

[3] Ibid.

[4] See, for example: James Trainor, "Nike-X Fate Keyed to DoD Study," Missiles and Rockets 14 (18 May 1964): 14-15; James Trainor, "Missile Site Radar Paces Nike-X," Missiles and Rockets 14 (25 May 1964): 14-15; "Ballistic Missile Defense: The $20 Billion Question," Data 9 (June 1964): 9-11; Freeman J. Dyson, "Defense Against Ballistic Missiles," Bulletin of the Atomic Scientists 20 (June 1964): 12-18; Jerome B. Wiesner and Herbert F. York, "National Security and the Nuclear-Test Ban," Scientific American 211 (October 1964): 27-35; and George A. W. Boehm, "Countdown for Nike-X," Fortune (November 1965): 132-37, 192, 194, 196, 198, 200.

The issue was rapidly becoming more public and opposing viewpoints were brought into sharper focus. The first major signs of significant opposition to missile defense began to appear in the 1963-64 time-frame.[1] The "ABM controversy," so long waged in the relative quiet of the executive branch of government, was about to erupt into public view.

In January, 1965, a comprehensive organizational plan for Army support of Nike-X production and deployment was prepared by the project office.[2] This plan, with minor modification, would become the basic blueprint for the establishment and organization of the Army element formed some three years later to manage BMD deployment.[3] Additionally, a Nike-X System Manager Charter was completed in September, 1965, in preparation for a deployment decision. Approved by the Chief of Staff of the Army, it was forwarded to the Secretary of the Army, but the charter was not acted upon.[4]

In October of that same year, the results of an Army study based on the postulated future People's Republic of China ballistic missile threat was presented to the Secretary of the Army and the Secretary of Defense. The study recommended a twenty-five-city defense of the United States, but in December the Secretary of Defense deferred production activities for at least one year.[5]

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[1]Benson D. Adams, Ballistic Missile Defense (New York: American Elsevier Publishing Company, Inc., 1971), p. 92.

[2]U.S., Army Materiel Command, Organizational Plan for U.S. Army Support of Nike-X Deployment.

[3]U.S., Department of the Army, BMD Management Study, Vol. II, p. II-4.

[4]Ibid. [5]Ibid.

This was done to permit more time for analysis and study of alternate deployment models.[1]

Achievement of System Management Status

In September, 1966, the ever-expanding program achieved new prominence with the appointment of the Chief of Research and Development as the Nike-X System Manager (in addition to his other duties) under the direct command jurisdiction of the Army Chief of Staff. This change raised management of Nike-X one level higher in the Army hierarchy. It was the only major project in the Army to achieve such status. Simultaneously, the Nike-X System Office was established in Washington, D.C., effective October 15, 1966, to function as the staff of the System Manager. The Nike-X System Manager assumed operational control of the Nike-X Project Office at Redstone Arsenal, but command jurisdiction remained the responsibility of the Army Materiel Command.[2] The principle mission of the System Office was to "...direct and control the approved development program and to do the necessary planning to implement any production decision made by the Secretary of Defense."[3] In November, 1966, the Nike-X Engineering/Service Test Office was established at White Sands Missile Range as a subordinate element of the System Office.[4] Under the System Office, the main role of the Nike-X Project Office was to

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[1] An interesting analysis of why this particular decision was made may be found in "Why the Nike-X Was Not Ordered into Production," Armed Forces Management 12 (March 1966): 91-92, 94, 96.

[2] U.S., Nike-X System Office, Annual Historical Summary: 1 July 1966-30 June 1967 (Redstone Arsenal, Alabama: Nike-X Project Office, 27 July 1967), p. 3.

[3] Ibid. [4] Ibid.

provide the primary technical and contractual interface between DoD components and the weapon system contractor structure.[1] The Nike-X Project Office was the central technical arm of the System Manager and continued its mission for managing development and test activity and production and deployment planning.[2]

The magnitude of the Nike-X program is difficult to describe in words, but the flavor of its scope may be captured by describing a few of its more unusual facets. In terms of funds expended, the BMD effort had cost the government $2.5 billion since its inception in 1955. In terms of the industrial contractor structure, approximately three thousand American firms were producing goods and services used in the program. In physical terms, the principal radar approached the height of a ten-story building above the ground, but a critical component of the radar was a dime-sized electronic device of which literally millions were required. The program required such diverse components as a one-hundred-ton permanent magnet and microminiature electronic circuitry so small that assembly had to be accomplished under high-power microscopes.[3] Certainly the largest program ever undertaken by the Army, Nike-X became the fulcrum of the BMD deployment decision.

Deployment Precursor

The appointment of a System Manager was a precursor of the deployment decision. It further centralized management of the Nike-X program

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[1] Ibid., p. 4.

[2] U.S., Army Materiel Command, Organization and Management Manual Nike-X Regulation No. 10-1 (Redstone Arsenal, Alabama: Nike-X Project Office, 30 June 1967), pp. i, 2.

[3] U.S., Nike-X System Office, Annual Historical Summary: 1 July 1966-30 June 1967, p. i.

and was a milestone in the history of BMD effort. In December, 1966, the System Manager developed a Nike-X deployment model directed against a potential threat through the 1970s from both the People's Republic of China and the U.S.S.R. The model was presented to the Secretary of Defense and approved for planning purposes. In July of the following year, the Secretary of Defense was again briefed on several deployment concepts. He directed that a thirty-day study be made of the evolving People's Republic of China threat. It was this direction and the subsequent study that set the stage for the forthcoming production and deployment decision.[1]

Sentinel Decision

The third major milestone in the evolution of United States BMD activity was the Sentinel deployment decision.

Dr. Harold Brown, former DoD Director of Defense Research and Engineering, writing on military forces planning, suggested:

> We must be wise enough to manage the interaction between weapons development and defense policy so that our weapons are always responsive to policy and our policy is based on a full consideration of the options made available by technology.[2]

While development of Nike-X was pushed without a deployment decision,[3] technology and strategy, weapon and policy, finally coincided in 1967 with the announcement of the decision to proceed with a limited ABM deployment.[4]

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[1]U.S., Department of the Army, BMD Management Study, Vol. II, p. II-5.

[2]Harold Brown, "Planning Our Military Forces," Foreign Affairs 45 (January 1967): 290.

[3]Ibid., p. 284.

[4]Robert S. McNamara, Address by the Secretary of Defense (DoD News Release No. 868-67) before the United Press International Editors and Publishers, San Francisco, California, 18 September 1967.

Sentinel

The Secretary of Defense, in a prepared news release, announced the approval of the name "Sentinel" for the Chinese-oriented ABM system at a news conference early in November.[1] He also outlined the framework of the organization responsible for Sentinel's development and deployment, but noted that Nike-X activity would continue separately. The mission would be continued research and development on systems designed to protect population centers against large-scale attacks.[2]

Deployment Decision

In an exclusive interview one week following the deployment announcement, the Secretary of Defense elaborated on the terminology "limited," or (as it was also referred to) "light," BMD deployment. He indicated that the Sentinel mission was first, an area defense of the United States population against the kind of attack the Chinese Communists might be capable of in the 1970s; second, point defense of ICBM underground silos against Soviet attack; and third, protection against accidental launch of a nuclear armed missile by anyone possessing the capability.[3] In early November, 1967, excellent statements were provided by DoD to the Joint Committee on Atomic Energy

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[1] Robert S. McNamara, News Conference of the Secretary of Defense (DoD News Release No. 1059-67) at the Pentagon, Washington, D.C., 3 November 1967.

[2] Ibid.

[3] "Defense Fantasy Now Come True," Life, September 29, 1967, pp. 28A-28C.

outlining the rationale behind the decision, the technical features of the system, and the implications of the deployment.[1]

The deployment decision fanned the heat of the "ABM debate." As one author has suggested, the ABM controversy was unique "...in its openness and duration, the public's awareness of it, the role of non-governmental participants and their influence on the decision makers, and the role Congress played."[2] Senator Strom Thurmond, staunch advocate, referred to the ABM as "...a vital component of our national security..."[3] and called the decision "...one of the most significant U.S. Military decisions of the decade."[4] Dr. Jerome B. Wiesner, an opponent, stated his belief that "...a really effective anti-missile system is [not] remotely possible..." and suggested that the decision "...could be as wrong and have as serious domestic and international consequences as the disastrous conclusion...that a few military advisors and some weapons could lead to an early victory for South Vietnam's forces."[5] These polemic views on the deployment decision are representative of the ABM debate rhetoric of the period.

Organization and Management

With the deployment announcement, the Army moved rapidly to implement the new organization designed to manage the Sentinel program. Of

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[1]U.S., Congress, Joint Committee on Atomic Energy, Scope, Magnitude, and Implications of the United States Antiballistic Missile Program Hearings, pp. 6-17, 44-47.

[2]Adams, Ballistic Missile Defense, p. xi.

[3]Strom Thrumond, "ABM: Lessening the Threat of Nuclear Blackmail," Data 12 (October 1967): 11.

[4]Ibid., p. 10.

[5]Jerome B. Wiesner, "The Case Against an Antiballistic Missile System," Look, November 28, 1967, p. 26.

paramount importance to this effort was the appointment of a Sentinel System Manager (SENSM), reporting directly to the Chief of Staff of the Army, with responsibility for over-all management of the total Sentinel program.[1] The SENSM was provided a broad charter that called for the organization of Sentinel dedicated elements including a System Office (SENSO) located in Washington, D.C.; a System Command (SENSCOM) located in Huntsville, Alabama; and a System Evaluation Agency (SENSEA) located at White Sands Missile Range, New Mexico.[2] Each of the equivalent organizations within the old Nike-X System Office structure was discontinued and its personnel and resources transferred to form the nucleus of the corresponding new element. In addition to the SENSM's command authority over these dedicated organizations, he was given staff supervision over all Army staff elements and participating organizations[3] and operational control of Sentinel-committed elements of other Army major commands in the planned deployment.[4] At no time in the history of the Army had a single system-dedicated individual been given such authority and responsibility for a program.[5]

The Sentinel System Organization, as defined by the Sentinel System Charter, included only the dedicated organizations under the direct command of

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[1]Stanley R. Resor, Secretary of the Army, "Sentinel System Charter," Memorandum for Chief of Staff, U.S. Army, 3 November 1967, Ballistic Missile Defense Organization Files, Washington, D.C.

[2]U.S., Department of the Army, General Orders No. 48.

[3]Ibid.

[4]U.S., Department of the Army, BMD Management Study, Vol. II, p. II-5.

[5]Ibid.

the SENSM. The SENSO constituted the immediate staff of the SENSM. Established as an element of the Office of the Chief of Staff of the Army, its mission was to assist the SENSM in the discharge of his responsibilities. The SENSCOM was organized as the design agency of the Sentinel System Organization. The mission of this element included the development, acquisition, and installation of the weapon system. Additionally, management of the Kwajalein Test Site (organizationally attached to Headquarters, Department of the Army) was assigned to the Commander, SENSCOM. The SENSEA was established to provide an independent (i.e., independent of the SENSCOM) evaluation and assessment program, through direct testing or active participation in design agency testing, responsive to Army Air Defense Command (the combat user of the system) requirements.[1] Left unsettled by the charter was the responsibility for continued development of a BMD capability against large-scale attack. This mission remained temporarily with the Chief of Research and Development, Department of the Army, as part of the Nike-X program.[2]

In addition to its primary mission as the field command of the Sentinel System Organization responsible for system development, acquisition, and installation, the SENSCOM was also assigned the lead role in major program management activities. Specifically, SENSCOM was assigned lead responsibility for financial management and for receipt and distribution of Sentinel funds and program authority; accomplishment of the configuration management program; accomplishment of the product assurance program; and development,

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[1]Resor, "Sentinel System Charter," Memorandum.

[2]Ibid.

implementation, and operation of the Sentinel management information system.[1] The assignment of program management primacy to SENSCOM had two significant aspects. First, it put SENSCOM at the focus of all program activity; second, it removed the development of the total management control system from the direct supervision of the SENSM. These two factors were to have subtle downstream influences on management control activities.

Following the decision to deploy the Sentinel system and the establishment of the Sentinel System Organization, a series of high-level conferences was held within the Army and between the Army and DoD. As a result, the Army planned to create the Advanced Ballistic Missile Defense Agency (ABMDA) with the mission to: develop modifications to the planned deployment that might be necessary to extend the effective life of Sentinel, develop concepts and technology that could provide a defense against more sophisticated threats, and provide data that would aid the development and evaluation of United States offensive penetration capability. ABMDA was officially established in March, 1968, in Washington, D.C., as a separate element reporting to the Chief of Research and Development, Department of the Army. In June, 1968, the Nike-X Development Office was formed with personnel from the SENSCOM Advanced Development Directorate and a cadre of personnel from the Army Missile Command. Under the command jurisdiction of the ABMDA, the Nike-X Development Office was colocated with SENSCOM to facilitate interfacing of programs. This office was subsequently redesignated as the

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[1] U.S., Army Sentinel System Command, Organization and Management Manual, SENSCOM Regulation No. 10-1 (Huntsville, Alabama, 6 May 1968), pp. 4-5.

Advanced Ballistic Missile Defense Agency-Huntsville (ABMDA-H) in May, 1969.[1] Thus, the question left unsettled by the Sentinel charter was resolved.

Also of significance during this period was the establishment of two Sentinel committed organizations in Huntsville, Alabama. The U.S. Army Engineer Division, Huntsville, was established in October, 1967, under the direct command of the Chief of Engineers, Washington, D.C.[2] The mission of this group was to provide real estate services and to execute the Sentinel construction program involving developmental, training, support, and tactical facilities.[3] The Sentinel Logistics Command was established in April, 1968, as a major subordinate command of the U.S. Army Materiel Command, Washington, D.C. The sole mission of the new command was to provide logistical support to the Sentinel system including all aspects of inventory management and maintenance engineering.[4] Formed initially in Washington, D.C., the new logistics command moved to Huntsville, Alabama, in August, 1968.[5]

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[1]U.S., Army Safeguard System Command, "Nike-X Development has New Name, Same Mission," News Release 69-5-1 (Huntsville, Alabama: Information Office, 7 May 1969).

[2]U.S., Department of the Army, Office of the Chief of Engineers, General Orders No. 17 (Washington, D.C., 9 October 1967).

[3]Alfred D. Starbird, Sentinel System Manager, "Sentinel System Deployment Task Assignment - Chief of Engineers," letter CSSSO-OP to Chief of Engineers, 23 April 1968, Ballistic Missile Defense Organization Files, Washington, D.C.

[4]U.S., Army Missile Command, News Release (Redstone Arsenal, Alabama: Information Office, 1 July 1968).

[5]U.S., Army Sentinel Logistics Command, News Release (Huntsville, Alabama: Information Office, 20 August 1968).

Early planning depicted Sentinel as a seventeen-site program.[1] The DoD announced the first ten geographical areas to be surveyed as possible site locations in November, 1967.[2] Selection of the potential locations was based primarily on tactical and technical considerations. These considerations included both the fulfillment of the immediate objectives of area defense and preservation of the option for point defense of strategic forces.[3] In May, 1968, three more potential sites were announced by the DoD;[4] two additional sites were announced in November, 1968,[5] for a total of fifteen sites publicly announced.

Sentinel Review

A matter of technical, political, and civic debate before the deployment decision, the implementation of the Sentinel program ignited a new wave of public and Congressional sentiment.[6] Central to the technical debate was the basic question of whether Sentinel was a militarily effective weapon or would be obsolete when deployed. At the core of the political issue was the

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[1]U.S., Department of the Army, BMD Management Study, Vol. II, p. II-2.

[2]U.S., Department of Defense, "Sentinel System Potential Sites to be Surveyed," News Release No. 1088-67 (Washington, D.C.: Office of Assistant Secretary of Defense, 20 November 1967).

[3]U.S., Army Sentinel System Command, Summary of the Sentinel Program: FY 68 (Huntsville, Alabama, n.d.), p. 4.

[4]U.S., Army Sentinel System Command, News Release (Huntsville, Alabama: Information Office, 27 May 1968).

[5]U.S., Department of Defense, News Release (Washington, D.C., 13 November 1968).

[6]An excellent account of this controversy during the life of the Sentinel Program (September, 1967-March, 1969) may be found in Adams Ballistic Missile Defense, pp. 177-97.

question of whether Sentinel was, in fact, a "thin" defense solely against the Chinese Communists or constituted the basis of a potential "thick" defense against the U.S.S.R. Civic concern focused on ecological, property value, and locale endangerment considerations. Professional groups joined with civic groups to express their adverse reaction to deployment of an ABM system.[1]

Resistance to the Sentinel system peaked in early 1969, with Boston, Seattle, and Chicago being the most active areas. In one two-week period in February, 1969, more than twenty-three hundred pieces of ABM related correspondence reached Washington with a ratio of twenty to one against Sentinel.[2]

Finally, in February, 1969, by order of the Secretary of Defense, all site acquisitions and construction activities were suspended on Sentinel pending a Presidential review of the program and its deployment.[3] This review subsequently led to the fourth major decision in United States BMD effort: the reorientation of the program to Safeguard.

Safeguard Decision

The DoD analyzed four basic alternatives as possible resolutions of the BMD issue: (1) a thick defense designed to protect major population centers; (2) continuation of the existing Sentinel program; (3) modification of Sentinel to improve point defense of strategic forces and provide some population protection without attempting heavy defense of major cities; or (4) cancellation of Sentinel

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[1]U.S., Army Safeguard System Command, Summary of Sentinel/Safeguard Program Progress: FY 69 (Huntsville, Alabama, n.d.), p. 2.

[2]Ibid. [3]Ibid.

and continuation of research and development only. The analysis also reaffirmed the technical feasibility of existing Sentinel components.[1]

Safeguard

In March, 1969, the President announced the reorientation of the ABM program with a revised deployment plan. Referring to the new program as "a safeguard program," the primary defensive mission changed from an area defense of major population centers to point defense of United States strategic deterrent forces.[2]

Reorientation Decision

The reoriented BMD program[3] had three basic objectives: (1) protection of the United States deterrent system; (2) defense against any ICBM attack by the People's Republic of China that could be postulated through 1979; and (3) safeguard against any irrational or accidental attack of less than massive magnitude. Since protection of major cities was not an objective, BMD sites were to be placed away from major cities.[4]

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[1]Statement by Deputy Secretary of Defense David Packard, News Release No. 190-69 (Washington, D.C.: Office of Assistant Secretary of Defense, 14 March 1969).

[2]Richard M. Nixon, President of the United States (Press Conference No. 4), at the White House, Washington, D.C., 14 March 1969.

[3]An excellent, authoritative presentation of the Administration's rationale for the Safeguard decision may be found in U.S., Congress, House, Committee on Appropriations, Safeguard Antiballistic Missile System. Hearings, before the subcommittees on Department of Defense and on Military Construction, 91st Cong., 1st sess., 1969. A contemporary evaluation by critics of Safeguard may be found in Abram Chayes and Jerome B. Wiesner, eds., ABM: An Evaluation of the Decision to Deploy an Antiballistic Missile System, (New York: Harper & Row, 1969). An essentially friendly examination may be found in Johan J. Holst and William Schneider, Jr., eds., Why ABM? Policy Issues in the Missile Defense Controversy (New York: Pergamon Press, 1969).

[4]Ibid.

An element of the decision that differed markedly from the Sentinel program involved the deployment schedule and a requirement for annual program reviews. In discussing this point, the President stated:

> The Sentinel system called for a fixed deployment schedule. I believe that because of a number of reasons, we should have a phased system. That is why, on an annual basis, the new Safeguard system will be reviewed, and the review may bring about changes in the system...[1]

The President pointed out that the annual evaluations would be based on three major points: (1) the magnitude of the offensive threat, (2) status of arms control talks, and (3) technological progress in the development of BMD componentry.[2]

The revised deployment plan dropped the number of potential sites from seventeen to twelve. Sites were to be authorized incrementally based on the annual evaluations with only two sites initially authorized. Of the original seventeen sites selected for deployment, five remained unchanged and seven new sites were identified regionally.[3] The change in mission prompted a name change, and Sentinel was renamed "Safeguard."[4]

One partisan writer, in discussing the announced decision, stated that it "...represents an astute matching of the threat with feasible technology--packaged in language designed to disarm those opposed to any ABM deployment."[5] This observation hardly proved to be valid for, some three months later,

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[1]Ibid. [2]Ibid.

[3]U.S., Army Safeguard System Command, Summary: FY 69, p. 3.

[4]U.S., Department of the Army, General Orders No. 18 (Washington, D.C., 25 March 1969).

[5]Walter Andrews, "Sentinel to Defend ICBM Sites," Armed Forces Journal 106 (22 March 1969): 18.

an advocatory professional journal suggested that the modified program was "fighting for its life" and was the most ardent topic of discussion in the political and scientific communities since the decision to develop the hydrogen bomb.[1]

The controversy was also an issue of intense debate in the Congress. Many weeks of Congressional committee hearings and over a month of floor debate in the Senate preceded the vote on the Administration's proposed Safeguard program for FY 1970.[2] The importance of the issue is aptly illustrated by the opening remarks of Congressman George H. Mahon, Chairman, Subcommittee on Department of Defense of the House Committee on Appropriations, at a special hearing on Safeguard:

> There are many weapon systems for which funding is proposed in the fiscal 1970 budget which are quite important and significant to our military posture and strategy. The ABM is probably one of the most important from this point of view of its effect on relative military strength and strategy of the major powers. The system relates to the defense capability which it offers the United States. We need a proper balance between offensive and defensive weapons if we are to achieve optimum deterrence. It is clear that the proposed deployment of the ABM system known as Safeguard is one of the most important questions to come before the Government in years. It is important militarily, it is important economically, it is important from the political standpoint.[3]

Referred to in one professional journal as the "ABM Hassle,"[4] the controversy peaked on the Senate floor on August 6, 1969, when the Safeguard

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[1]Leon Booth, "Missiles and Astronautics: Attack on the Sentinel," Ordnance 53 (May-June 1969): 554.

[2]U.S., Army Safeguard System Command, Summary of the Safeguard Program: FY 70 (Huntsville, Alabama, n.d.), p. 1. See also R. James Woolsey, "Chipping Away at the Bargains," in Arms, Defense Policy, and Arms Control, ed. by Franklin A. Long and George W. Rathjens (New York: W. W. Norton & Company, Inc., 1976), pp. 175-85.

[3]U.S., Congress, House, Committee on Appropriations, Safeguard Antiballistic Missile System. Hearings, p. 2.

[4]"ABM Hassle Starts," Armed Forces Journal 106 (12 July 1969): 11.

authorization came before the Senate for approval. After months of intense debate, the Senate endorsed President Nixon's proposal to deploy Safeguard by two votes.[1] A bipartisan amendment to permit continued research and development, but to bar deployment and site acquisition was defeated by a 51 against, 49 for, vote.[2] Actually somewhat of an anticlimax, this critical amendment would not even have come to a vote had not an earlier amendment to bar Safeguard, but permit other antimissile research, been defeated by a 50 to 50 tie vote.[3] This was perhaps the most dramatic vote in the Senate in many decades.[4] As the passage of time has revealed, this was merely a temporary endorsement of BMD deployment activities.

Organization and Management

The program name change resulted in all dedicated organizational elements being redesignated Safeguard. As an example, the Sentinel System

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[1]This one Senate session did not, by itself, mean victory for the Administration's BMD program since both houses must independently approve an Authorization Bill and, subsequently, an Appropriation Bill. But the vote did spell endorsement for that fiscal year because the session represented BMD opponents' greatest concentration of strength for the year. Pertinent portions of the debate may be found in U.S., Congress, Senate, Authorization of Appropriations for FY 70 for military procurement, research and development, and for the construction of missile test facilities in Kwajalein Missile Range, and Reserve Component Strength, 91st Cong., 1st sess., 6 August 1969, Congressional Record 115: S9235-S9283, S9306-S9308, S9312-S9315.

[2]U.S., Department of the Army, BMD Management Study, Vol. II, p. II-7.

[3]U.S., Army Safeguard System Command, Summary: FY 70, p. 1.

[4]A concise and accurate account of this series of votes may be found in "ABM: A Senate Divided," Armed Forces Journal 106 (16 August 1969): 14-15. An excellent presentation of the BMD issue through the time of the Safeguard decision as viewed by an opponent may be found in Ralph E. Lapp, "From Nike to Safeguard: A Biography of the ABM," New York Times Magazine, May 4, 1969, pp. 28-30, 32, 121.

Manager was redesignated the Safeguard System Manager.[1] Organizational structures and major management missions remained unchanged for all Safeguard System Organizations.

The initial Safeguard deployment plan consisted of two planned sites in the vicinity of two offensive weapon bases. The first site was in the Grand Forks Air Force Base, North Dakota, area, and the second in the Malmstrom Air Force Base, Montana area. Each of these locations were to be complete sites with a full complement of equipment.[2]

At this point in the program evolution, a unique turn of events occurred involving the prime contractor. In October, 1969, the Executive Vice President of the Western Electric Company met with the Safeguard System Manager to discuss ways of limiting and preferably reducing the company's total commitment to the program as other contractors became technically qualified over a period of years. This was unique in that few prime contractors seek to reduce their participation in the weapon system acquisition process. In response, the Army expressed a willingness to work toward an arrangement to limit the prime's commitment.[3] In so doing, the Army re-emphasized its strong concern that the prime contractor:

> ...maintain major responsibilities for the Safeguard system integrity and integration in conformity with Army technical objectives. The

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[1]U.S., Department of the Army, General Orders No. 18.

[2]U.S., Army Safeguard System Command, Summary of Program Progress Through FY 71 (Huntsville, Alabama, n.d.), p. xiii.

[3]Stanley R. Resor, Secretary of the Army, letter to Mr. Arthur P. Clow, Executive Vice President, Western Electric Company, 29 January 1970, Ballistic Missile Defense Organization Files, Washington, D.C.

> continuation of these responsibilities, in addition to reducing system performance risks, is also necessary to protect the Government against unacceptable schedule slippage and cost increases.[1]

This problem ultimately resolved itself through continued reduction in the program and an automatic lessening of Western Electric Company's commitment to the BMD effort.

Presidential Reviews

The annual Presidential Reviews of the Safeguard program became the basis for the Administration's BMD budget submissions. In addition to this top-level personal review by the President, the BMD program continued to be the subject of intense review in the Congress as well.

First Annual Review

Early in 1970, the Secretary of Defense announced the results of the first annual Presidential review of the Safeguard program. Appearing before the Appropriations Committee, Secretary Laird presented the Administration's plan to seek authority in the FY 1971 budget to add one site for the defense of strategic offensive forces to the two previously authorized and to begin advanced planning for five additional sites.[2] In October of the same year, Congress authorized only the one additional site for offensive weapon defense (for a total of three authorized) and advanced planning for a fourth site.[3]

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[1] Ibid.

[2] U.S., Congress, House, Committee on Appropriations, Department of Defense Appropriations for 1971. Hearings, before a subcommittee of the Committee on Appropriations, 91st Cong., 2d sess., 25 February 1970, pp. 318-21.

[3] U.S., Army Safeguard System Command, Summary FY 71, p. xiii.

An important secondary issue in the Safeguard dilemma was the January, 1971, announcement of an expanded mission for the Safeguard System Manager. The culmination of continuing analysis of Safeguard capabilities and numerous studies conducted by the Army for defense of United States strategic offensive missiles, the expanded mission concerned the initiation of a new program of development. The program was designed to augment Safeguard during the last half of the 1970s in response to a more sophisticated threat in the form of improved U.S.S.R. technology.[1] First designated as Hardsite Defense,[2] the program was later redesignated the Site Defense Program and still later the System Technology Program.[3]

Second Annual Review

In March, 1971, the Secretary of Defense announced the President's decision to request authorization to continue deployment of Safeguard at the three previously authorized sites and initiate steps toward deployment of a fourth site.[4] In November, however, Congress further limited Safeguard by authorizing continuing deployment only at two sites and advanced preparation at two additional sites.[5] Although the number of sites authorized remained

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[1] Ibid., pp. xv-xvi.

[2] U.S., Army Safeguard System Command, General Orders No. 4 (Huntsville, Alabama, 12 February 1971).

[3] The System Technology Program and its predecessors are not of specific interest in this study. Brief reference is made here in the interest of historical integrity.

[4] U.S., Department of the Army, BMD Management Study, Vol. II, p. II-10.

[5] U.S., Army Safeguard System Command, Summary of Program Progress Through FY 72 (Huntsville, Alabama, n.d.), p. xiv.

constant with the previous year's program of four sites, the action resulted in the shift of one site from the "deployment authorized" category to the "advanced preparation only" category--a remission to a less advanced status of site activation activity.

Congressional resistance was beginning, once again, to mount to pivotal proportions and diplomatic gains had been made by the United States at the Strategic Arms Limitation Talks (SALT) with the U.S.S.R. It was in this environment that the fifth major decision in United States BMD activity, the signing of the ABM Treaty, occurred.

ABM Treaty

The bilateral SALT between the United States and the U.S.S.R. was initiated formally in Helsinki, Poland, in 1969.[1] After some three years of negotiations, President Nixon signed the treaty between the United States of America and the Union of Soviet Socialist Republics on the Limitation of Anti-Ballistic Missile Systems[2] on May 26, 1972. While rather broad in scope, but with far reaching consequences to the United States BMD effort, it specifically limited ABM deployment to only two sites: within a 150 kilometer radius of an ICBM launch complex and of the national capital.[3] For Safeguard, this equated to the existing site at Grand Forks, North Dakota, and a potential National Command Authority (NCA) site within the Washington, D.C., area. Thus, the

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[1] SALT pertains not only to defensive weapons, but offensive weapons as well. The ABM Treaty was merely an initial milestone, the first agreement, in the continuing SALT dialogue. One of the better accounts of early SALT activities may be found in John Newhouse, Cold Dawn: The Story of SALT (New York: Holt, Rinehart, and Winston, 1973).

[2] It is more commonly known as the "ABM Treaty."

[3] Newhouse, Cold Dawn, p. 274.

"bargaining chip" attributes of Safeguard were realized at SALT.[1] Noting some of Safeguard's critics' citations of the system's weaknesses, Newhouse emphasized this point in stating:

> To the Russians, the Sentinel-Safeguard components--radars and missiles alike--were not only far more sophisticated than their own, but a base on which the Americans might build something that would actually work.[2]

As will be shown in succeeding paragraphs, the United States Congress was less impressed with Safeguard's potential utility.

Continuing Redefinition

The ABM Treaty precipitated a number of actions within the BMD community. While the administration continued to press the Safeguard issue, the passage of time has underscored the significance of the ABM Treaty to the Safeguard program. It was the preface to the continuing reduction in the scope and magnitude of the total project and formal recognition that ABM was falling into increasingly greater disfavor.

ABM Decision

In consonance with the provisions of the treaty, the Secretary of Defense directed the Army to continue the Grand Forks deployment but suspend construction and advanced preparation activity at all other sites. Further, the Army was directed to initiate planning to cancel the twelve-site program, but initiate planning to deploy Safeguard at the NCA.[3]

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[1] Ibid., p. 156.

[2] Ibid., p. 157.

[3] U.S., Army Safeguard System Command, Summary of Program Progress Through FY 72, p. xvii.

At this time, the Army also initiated planning for two major reviews designed to define and propose alternatives for the future BMD program, taking cognizance of the impact of SALT on the continuing ABM program. One of the reviews was to be primarily technical in nature and was designated as a System Design Review (SDR). The SDR was to be under the aegis of the Safeguard System Manager. The second review, the BMD Management Study, was under the direction of a specially appointed brigadier general from outside of the BMD community. The BMD Management Study was to examine the organization and management of the total BMD effort as an independent but parallel comprehensive Army-wide management review.[1]

In August, 1972, shortly after both BMD reviews were underway, the Senate, by a vote of 88 to 2, agreed to a resolution of ratification of the ABM Treaty. Thus, the fifth major decision in BMD activity was conclusively made by the United States.

BMD Management Study

The BMD Management Study was directed by the Secretary of the Army on July 10, 1972.[2] Its purpose was twofold: to guide the Army in "...any necessary revisions in our current assignment of responsibilities and functions for matters related to ballistic missile defense..."[3] and to formulate alternatives

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[1] Ibid. See also R. L. Johnson, Assistant Secretary of the Army (Research and Development), "Army BMD Under SALT Limitations," Memorandum for Safeguard System Manager, 23 August 1972, Ballistic Missile Defense Organization Files, Washington, D.C.

[2] Robert F. Froehlke, Secretary of the Army, letter to Brigadier General Hal E. Hallgren, 10 July 1972, Ballistic Missile Defense Organization Files, Washington, D.C.

[3] Ibid.

"...in organization and procedures that would give the most effective overall management program to meet the Army's ballistic missile defense missions."[1]

The BMD Management Study consumed approximately one hundred fifty direct man-months of effort in a three-month period. The final report was submitted to the Secretary of the Army in September, 1972.[2] It encompassed a comprehensive examination of the total Army BMD management organization and philosophy and addressed a number of potential organizational structures and system management concepts. The final report postulated three alternative management structures calculated to provide sufficient differences to offer meaningful choices. Additionally, the study report documented actions that could be taken immediately to effect economies without pre-empting the final choice as to organizational structure.[3]

Concurrently, the SDR, completed in October, 1972, suggested a number of specific recommendations in the areas of deployment objectives, appropriate funding levels, and concepts of operation.[4]

Both the SDR and the BMD Management Study were reviewed by the Secretary of the Army, and he found them to be "compatible and reinforcing."[5]

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[1] Ibid.

[2] Hal E. Hallgren, Brigadier General, USA, Director, BMD Management Study, "Ballistic Missile Defense Management Study-1972," Memorandum DACS-BD for Secretary of the Army, 8 September 1972, Ballistic Missile Defense Organization Files, Washington, D.C.

[3] Ibid.

[4] U.S., Army Safeguard System Command, Summary of the Safeguard Program FY 73 (Huntsville, Alabama, n.d.), p. 2.

[5] Robert F. Froehlke, Secretary of the Army, "Directed Actions Related to Ballistic Missile Defense Management," Memorandum for Safeguard System Manager, 26 October 1972, Ballistic Missile Defense Organization Files, Washington, D.C.

As a consequence of these two studies, the Secretary directed the Safeguard System Manager to develop a plan of action for major reorganization of BMD activity.[1]

Initial Impact

The most immediate management impact of the ABM treaty had been the imposition of a military and civilian employment ceiling. Based on the number of individuals actually on the payroll as of May 30, 1972, the ceiling applied to all Safeguard manpower spaces[2] and anticipated the manpower reductions to come.[3] Additionally, in October, 1972, the U.S. Army Safeguard System Command announced that it had terminated major portions of its prime contract activities and had directed the principal prime contractor to also terminate major portions of its subcontracts.[4] The Army had recommended completion of the work and stockpiling of the hardware items in case an NCA site should ultimately be approved, but Congress rejected this notion.[5]

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[1] Ibid.

[2] Employment levels in Safeguard were managed by issuance of manpower spaces by category; i.e., military (made up of officer, warrant officer, and enlisted personnel) spaces and civilian spaces. Each space represented authorization to hire one individual.

[3] Safeguard System Manager, "ABM Development and Deployment Programs," Message 302148Z May 72, to Commanding General, U.S. Army Safeguard System Command, 30 May 1972, Ballistic Missile Defense Organization Files, Washington, D.C.

[4] U.S., Army Safeguard System Command, "USASAFSCOM Terminates Contracts," News Release 72-10-1 (Huntsville, Alabama: Information Office, 3 October 1972).

[5] Ibid.

In the meantime, the Safeguard facility at Grand Forks, North Dakota, was symbolically activated by appropriate military ceremonies in November, 1972, thus becoming the Army's newest military post.[1] Planning at that time called for the site to be transferred to the Army Air Defense Command as an operational BMD site in early 1975.[2]

Organization and Management

Pursuant to the instructions of the Secretary of the Army,[3] the Safeguard System Manager directed the major elements of the Safeguard System Organization to develop a three-phase time-sequenced reorganization plan to be implemented in the FY 1973 through FY 1975 time-frame. The plan was to stress reduction of organizational layering, overhead, and duplication through consolidation and realignment of necessary functions. Organization and management alternatives were to be attuned to the austerity being applied to the Army in general and the BMD community in particular.[4]

The major thrust of the total realignment was to bring the Safeguard System Organization into line with a one- to two-site program. The mission had not changed significantly at this point, but the scope, magnitude, and emphasis of

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[1] U.S., Army Safeguard System Site Activation Command, News Release 7224 (Langdon, North Dakota, 9 November 1972).

[2] Ibid.

[3] Froehlke Memorandum for the Safeguard System Manager, 26 October 1972.

[4] Walter P. Leber, Lieutenant General, USA, Safeguard System Manager, "Ballistic Missile Defense Management," letter to Commanding General, U.S. Army Safeguard System Command, 31 October 1972, and Safeguard System Manager, "SAFSO Review of SAFSCOM TDA," Message 131450Z Dec 72, to Commanding General, U.S. Army Missile Command, 13 December 1972, Ballistic Missile Defense Organization Files, Washington, D.C.

the program had changed dramatically. The action was one of retrenchment and retraction coupled with a reduction of personnel.

In terms of major organizational elements, the Safeguard System Office retained its major functions, but reduced the number of employees. The Safeguard Logistics Command combined with the Safeguard System Command, with the latter absorbing the mission and resources of the former.[1] This action prompted a reorganization within the Safeguard System Command to accommodate a new mission.[2] Subsequent to the merger, the military and civilian strength of the resultant organization was drastically reduced.[3] The missions of the Safeguard System Evaluation Agency, the Advanced Ballistic Missile Defense Agency, and the U.S. Army Engineer Division, Huntsville, were not materially impacted, but Safeguard-sponsored activity was generally reduced in scope and magnitude.

In April, 1973, the Secretary of Defense crystalized BMD guidance of the time as: (1) a one-site deployment with the objectives of providing defense of retaliatory forces and obtaining operational experience; (2) planning for application of Site Defense Technology for an NCA site; (3) preservation of options for further deployments,; and (4) continued investigation of new or

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[1]U.S., Army Materiel Command, General Orders No. 3 (Washington, D.C., 4 January 1973).

[2]U.S., Army Safeguard System Command, General Orders No. 1 (Huntsville, Alabama, 15 January 1973).

[3]U.S., Army Safeguard System Command, USASAFSCOM Reorganization Plan (FOUO), Vol. II: Reorganization Concept (Huntsville, Alabama, 15 December 1972).

improved system concepts and technological capability within the limitations of the ABM Treaty and SALT.[1]

Thus, with the drastic reduction in the number of deployed sites planned, the advent of the Site Defense Program, and a continued emphasis on retention of a basic BMD technology advancement capability, it was inevitable that the management philosophy would undergo substantial change commensurate with the organizational changes.

Termination Precursor

It should have been abundantly evident that the end was in sight for Safeguard. The U.S. emphasis at the SALT had been to further reduce ABM deployments, and on July 3, 1974, President Nixon signed a Protocol to the ABM Treaty limiting both the United States and the U.S.S.R. to only one ABM site each.[2] In transmitting the Protocol to the Senate for ratification, President Ford emphasized his belief that it would, "...as an integral part of the Treaty, contribute to the reduction of international tension."[3] The Protocol was subsequently ratified by the Senate on November 10, 1975.[4]

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[1] Elliot L. Richardson, Secretary of Defense, "Ballistic Missile Defense Guidance," Memorandum for Secretary of the Army, 3 April 1973, Ballistic Missile Defense Organization Files, Washington, D.C.

[2] U.S., President, _Protocol to the Treaty with the Union of Soviet Socialist Republics on the Limitation of Anti-Ballistic Missile Systems. Message,_ from the President of the United States Transmitting the Treaty Between the United States of America and Union of Soviet Socialist Republics on the Limitation of Anti-Ballistic Missile Systems, Signed in Moscow on July 3, 1974 (Washington, D.C.: Government Printing Office, 19 September 1974).

[3] _Ibid._

[4] U.S., Congress, Senate, Ratification of Protocol, 94th Cong., 1st sess., 10 November 1975, _Congressional Record_, p. S19557.

Still, an aura of optimism for BMD in general persisted during 1974. The scheduled equipment readiness date (ERD) demonstrating the satisfactory interoperability of all tactical equipment at the Grand Forks site had been met in October, 1974; the Site Defense Program was continuing to emphasize improvements in subsystems and components; and the technology advancement aspect of BMD remained undiminished.[1]

In mid-1974, the BMD activity could be catagorized into three principal areas. First, the Safeguard site at Grand Forks, North Dakota, nearing completion was still assigned the mission to protect a portion of the land-based deterrent force and to provide experience in the actual operation and test of a deployed tactical site. Second, the Site Defense Program was viewed as an orderly development of the next generation BMD system. Finally, the advanced technology program (the special province of the Advanced Ballistic Missile Defense Agency) represented a vigorous research effort embracing all technology of BMD.[2]

Additionally, the Deputy Secretary of Defense, in the same memorandum, announced the realignment of BMD activity under a single Program Manager.[3] In a broad, sweeping move to centralize BMD management, all BMD effort, including the ABMDA advanced technology effort and the Kwajalein

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[1]U.S., Congress, Senate, Committee on Appropriations, Department of Defense Appropriations for Fiscal Year 1976. Hearings, before the Defense Subcommittee, 94th Cong., 1st sess., 12 February 1975, pp. 107-9.

[2]W. P. Clements, Jr., Deputy Secretary of Defense, "Reorganization of Army Ballistic Missile Defense Structure," Memorandum for Secretary of the Army, 26 March 1974, Ballistic Missile Defense Organization Files, Washsington, D.C.

[3]Ibid.

Missile Range, was placed under a BMD Program Manager. Implemented in May, 1974, the restructuring resulted in significant organization and allied name changes. The Safeguard System Manager was redesignated the BMD Program Manager (BMDPM), while the Safeguard System Organization was redesignated the BMD Organization (BMDO). The Safeguard System Office was renamed the BMD Systems Office, and the Safeguard System Command was redesignated the BMD Systems Command (BMDSCOM). The ABMDA, Washington, D.C., was deactivated and the ABMDA, Huntsville, Alabama, was placed under command of the BMDPM and redesignated the BMD Advanced Technology Center (BMDATC). The resources of the Safeguard Evaluation Agency (SAFSEA) were transferred to the U.S. Army Training and Doctrine Command, redesignated, and assigned a new non-BMD related mission. All BMD activity was consolidated for the first time under a single program manager reporting directly to the Chief of Staff of the Army.[1]

Perhaps one of the most succinct analyses of the impact of the ABM Treaty on Safeguard was made by Rathjens. Writing on arms control, Rathjens cited the fact that treaties can impact weapons acquisition as one of the traditional arguments for negotiations. As he put it:

> ...agreements can foreclose significant weapons development or procurement. The ABM treaty is usually cited as an example of this.[2]

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[1]U.S., Army Ballistic Missile Defense Systems Command, Ballistic Missile Defense Program Summary: FY 74 (Huntsville, Alabama, n.d.), pp. x-xi. See also U.S., Department of the Army, General Orders No. 12 (Washington, D.C., 22 May 1974).

[2]George W. Rathjens, "Changing Perspectives on Arms Control," in Long and Rathjens, eds., Arms, Defense Policy, and Arms Control, p. 204.

While Congressional and public pressures were also highly influential, it seems a reasonable argument that the ABM Treaty had a profound affect upon the Safeguard program.

Termination and Deactivation

In presenting the proposed defense budget for FY 1977, the Secretary of Defense addressed the Safeguard portion of BMD by stating simply:

> In accordance with FY 76 Congressional direction, operation of the Safeguard system has been terminated. The Missile Site Radar is being deactivated and the interceptor missiles and warheads are being removed. The Perimeter Acquisition Radar (PAR) will remain fully operational in support of the NORAD warning and attack assessment mission. The PAR will provide more accurate information on the numbers of attacking RV's and their targets than is available from other warning systems.[1]

Stated in other words, the only operative vestige of the Safeguard system to remain would be the perimeter acquisition radar.

The Decision

The decision to close the Safeguard complex, with the exception of the PAR, was made by Congress and implemented by the Army. It signaled a definite shift in United States BMD policy away from deployment and operation back to research and development. It was also the sixth and final milestone in the evolution of the Safeguard program.

Congressional Action

The essence of the Congressional action to terminate the Safeguard program was addressed at the outset of this chapter. Little more needs to be

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[1] U.S., Congress, Senate, Committee on Appropriations, Department of Defense Appropriations for Fiscal Year 1977. Hearings, before the Defense Subcommittee, 94th Cong., 2d sess., 2 February 1976, p. 85.

added here. Exercising its power through the defense appropriations process, the Congress insured that no future Safeguard funding would be required unless directly associated with the PAR or the completion of dismantlement and disposal of the remainder of the facility. The intent of the Congressional action was impressively clear.

Immediate Impact

On February 10, 1976, the day following the enactment of the FY 76 and FY 7T DoD Appropriations Bill into Public Law, the Joint Chiefs of Staff directed that the operation of the radars at the Safeguard complex be terminated immediately and that the missiles be disarmed. This direction ended the ten-month operational status that had commenced in April, 1975, with achievement of the initial operating capability. This decision was not unexpected by the Army, and plans already existed for deactivation of the operational facility. In fact, initial planning addressing a number of different operational alternatives and deactivation concepts had begun in 1973. Refined and updated periodically to conform with possible Congressional direction, planning included a proposal for transfer of the PAR to the U.S. Air Force.[1]

Becoming tactically operational in December, 1976, the PAR was operationally linked to NORAD in January, 1977. Operational command of the PAR was assigned to the Aerospace Defense Command at Colorado Springs, Colorado. Command of the PAR, less operational command, was retained by the U.S. Army Ballistic Missile Defense Systems Command, Huntsville, Alabama.[2]

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[1]U.S., Army Ballistic Missile Defense Systems Command, Proposed Army Input: PAR Transfer Plan (PARTP), Draft Revision No. 1 (Huntsville, Alabama: PAR Management Office, 4 February 1977).

[2]Ibid., p. 3.

In accordance with the direction of the Secretary of Defense, the transfer of the PAR from the U.S. Army to the U.S. Air Force was completed in September, 1977. The transfer included complete assignment of responsibility for control, operation, and maintenance of the radar to the Air Force, thus terminating Army involvement totally.[1] The ceremony marking the official transfer came ten years and two weeks after the original deployment decision.[2]

Management Response

BMD management response to the Congressional decision manifested itself in two ways: first in program terms, and second in terms of organizational changes. Both topics are briefly discussed.

Program

From a program standpoint, deactivation of the Safeguard BMD facilities became the principal activity following the termination and deactivation decision. Equipment disposition occurred quickly, with the majority of the equipment being transferred to DoD agencies. Missile warhead removal was completed in April, 1976, and remaining items of ordnance were removed by October, 1976. The missile inventory, although dismantled and removed, was placed in storage. Support facilities were disposed of, with final disposition of all facilities and equipment completed in late 1977.[3]

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[1] Ibid., p. 1.

[2] For a brief description of the transfer ceremony see "Radar Transferred," Huntsville (Alabama) Rocket, October 5, 1977, p. 24.

[3] Briefing by L. N. Hightower, Director, Safeguard Project Office, U.S. Army Ballistic Missile Defense Systems Command, at the Annual Manager's Meeting, Huntington Beach, California, 4-5 November 1976.

Organization and Management

In mid-1976, a major organizational change occurred when the Commander, U.S. Army Ballistic Missile Defense Systems Command, was designated to serve also as the BMD Program Manager.[1] With duty station in Huntsville, Alabama, the assignment of the same individual to occupy both positions signaled a further retrenchment of BMD organization, in keeping with the reduced scope of BMD activity. At the time of his appointment, the new BMD Program Manager was specifically charged with continued examination of possible BMD organization improvements.[2] A summary of the evolution of United States BMD activity is depicted at Figure 5.

Epilogue

Certainly the total story of BMD is not complete at this writing. Conceived as an anti-missile missile feasibility program in 1955, it continues as a much matured and technologically advanced pursuit of "exploratory research and advanced development in BMD technology."[3] It continues also as the accomplishment of "research, development, and support of BMD systems."[4] The venture into BMD deployment by the United States represented a transition of the

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[1]Norman R. Augustine, Acting Secretary of the Army "Ballistic Missile Defense (BMD) Program Manager," Memorandum for Chief of Staff, United States Army, 6 August 1976, Ballistic Missile Defense Organization Files, Washington, D.C.

[2]Ibid.

[3]U.S., Ballistic Missile Defense Advanced Technology Center, Organization and Management Manual (Huntsville, Alabama, 30 October 1975), p. 3.

[4]U.S., Army Ballistic Missile Defense Systems Command, Organization and Management Manual, BMDSCOM Regulation No. 10-1 (Huntsville, Alabama, 10 December 1976), p. 3.

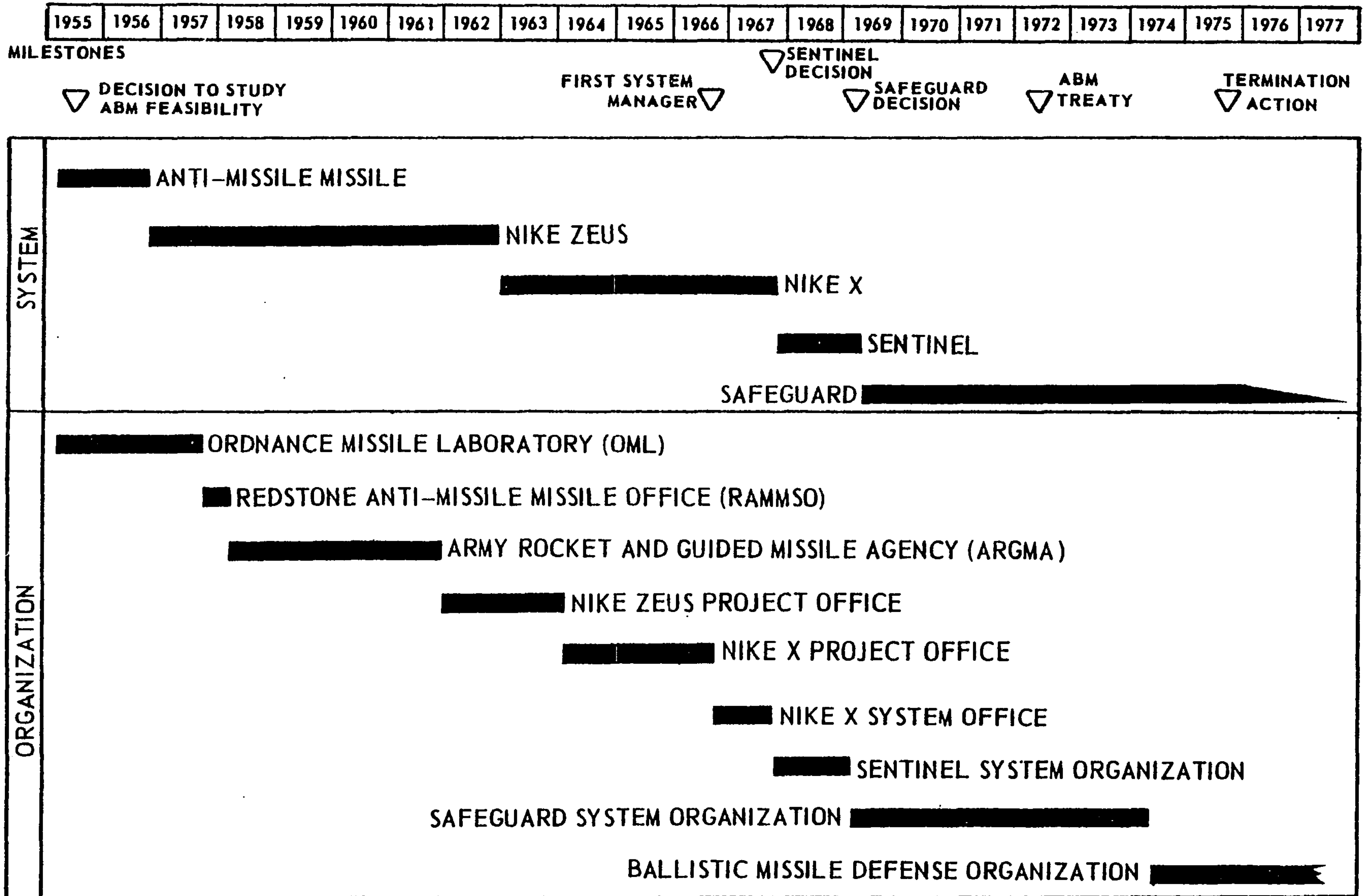

Fig. 5. Summary Evolution of United States BMD Activity

main-stream thrust from paper technology and controlled tests to system production and operational capability. It also initiated a period of prominence for BMD in strategic planning. Paper technology was shunted to a siding to play a parallel, but secondary role in United States BMD activity. The termination and deactivation of BMD deployment represented a remission of BMD effort to its original objectives and a de-emphasizing of BMD as a conspicuous element of United States strategic planning. For purposes of this study, the Safeguard BMD program stands as a unique specimen for examination and analysis of large-scale, complex endeavors.

CHAPTER IV

THE PARAMETER-PHASE-LEVEL (PPL) ANALYSIS MATRIX

Having formed the frame of reference of this study in the preceding three chapters, attention is focused in this chapter on the formulation of the PPL analysis matrix. The objectives are to construct the matrix, to define precisely its dimensions, and to explore the manner of its application in this study.

Many of the specifics discussed are peculiar to large-scale complex endeavors in general and military weapon systems in particular. The concepts, however, have a wider application so care has been taken to provide notional insight as well as specific meaning. In this way, a broader view of the PPL analysis matrix is projected. Furthermore, specificity here permits greater preciseness in the analytical treatment of later chapters.

Conceptual Foundation

The three dimension matrix is ideally suited to the analytic requirements of this study. Use of the matrix provides a vehicle for: (1) stressing the unitary wholeness of a system, (2) subdividing a large-scale endeavor into its major constituent parts, (3) permitting portrayal of interdependences among the parts being examined and among the parts and the whole or system, and (4) potential restructuring of the matrix following subdivision and examination in a form different from the original. The notional approach to the PPL analysis matrix was discussed in Chapter I; the matrix is described in detail in succeeding paragraphs.

Parameters

The basic premise of the parameter dimension of the PPL analysis matrix is to capture those elements of program activity essential to determination of project status. In other words, the performance parameters encompass those elements or characteristics of program activity that, when measured and analyzed, provide insight into the health, status, and progress of the program. Characteristics that must be assessed in order to determine program accomplishments and success will vary with the program. In the private sector these characteristics might include market position, return on investment, profit, quality, deliveries, productivity, organizational development, social responsibility, corporate growth, and a host of other parameters. In the public sector these characteristics might include inflation rates, unemployment rates, budget deficits, cost overruns, schedule slippages, customer satisfaction or dissatisfaction, teacher-student ratios, crime rate, cost-of-living indices, changes in GNP, and many others.

Batten suggests that characteristics to be measured for a project must include all resources of men, money, materials, time, and space.[1] This categorization does not specifically spell out achievement of technical performance, although it is inherent in Batten's thoughts on materials. Brandon and Gray specify people, time, money, equipment, and quality as key variables in project

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[1] J. D. Batten, Tough Minded Management (New York: American Management Association, 1963), pp. 85-93.

progression.[1] Martin discusses the broad categories of product performance, schedule status, and costs versus budgets as project variables.[2] In general, the characteristics to be measured are a function of the goals and plans of the organization;[3] i.e., the key variables that are at the disposal of the program manager.

For purposes of this study, the three principal weapon system performance parameters of cost, schedule, and technical performance were selected. As generic variables, these three parameters are common to complex weapon systems[4] and, by definition, include all major weapon system program characteristics critical to project progression. Consequently, they provide a meaningful, constructive, and comprehensive array of key variables or critical project control parameters. The parameter dimension of the PPL analysis matrix is depicted in Figure 6.

Cost Parameter

The cost parameter refers to the monetary resources budgeted, funded, and expended in the execution of the project or program. While the program manager normally treats the cost parameter as if it had only a monetary dimension, it does, in fact, also represent all those assets that may be purchased with money. In other words, the cost parameter is also a surrogate for all

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[1] Dick H. Brandon and Max Gray, Project Control Standards (Princeton, New Jersey: Brandon/Systems Press, Inc., 1970), p. 41.

[2] Martin, Project Management: How to Make It Work, p. 218.

[3] Johnson, Kast, and Rosenzweig, The Theory and Management of Systems, p. 83.

[4] Cleland and King, Systems Analysis and Project Management, pp. 191-92.

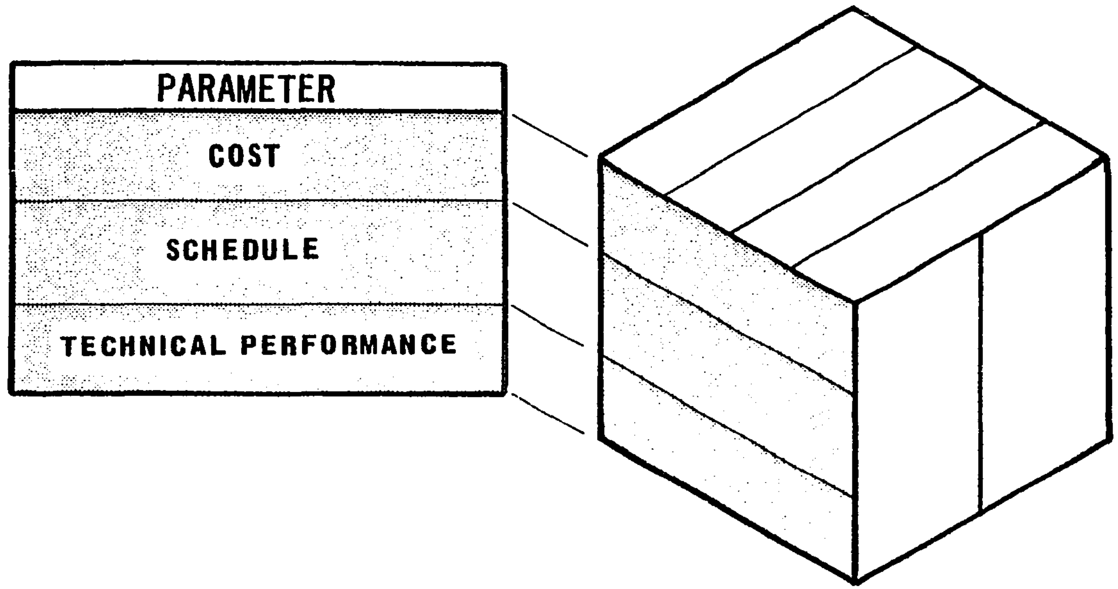

Fig. 6. Parameter Dimension of PPL Analysis Matrix

resources such as people, materials, buildings and facilities, equipment, and other goods and services that may be allocated to only one alternative or option at a time.[1]

It should be evident at this point that the term "cost" is not being used in an accounting sense. As Anthony so aptly states:

> ...the word "cost" is slippery. It is used indiscriminately with quite different meanings...[2]

From an accounting standpoint, cost concepts normally attach to such categories as variable and nonvariable costs, direct and indirect costs, historical and current costs, controllable and noncontrollable costs, and the like.[3] Such distinctions are not inherently germane to this study. At times, the program manager may, in fact, be vitally concerned with issues relating to, as an example, direct and indirect costs. Normally when this occurs, however, it is because he is involved in an accounting problem as a subset of a larger management problem. It is not because he is consistently occupied with the accounting categories of costs. When discrete implications of this nature are occasionally required for specificity in this study, they are appropriately articulated at that point.

Similarly, costs are not consistently thought of in the fundamental sense in which economists view them. To the economist, "...costs have meaning only in terms of opportunities that are foregone."[4] In other words, costs of goods or services are viewed by the economist as "...the amount of the next most

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[1] Ibid., p. 60.

[2] Robert N. Anthony, Management Accounting: Text and Cases, 4th ed. (Homewood, Illinois: Richard D. Irwin, Inc., 1970), p. 451.

[3] Ibid.

[4] James E. Hibdon, Price and Welfare Theory (New York: McGraw-Hill Book Company, 1969), p. 135.

valuable good that is foregone by using resources of a given quantity in the production of the first good."[1] While the program manager is painfully aware of the underlying validity of this concept as he considers various alternative uses for his scarce resources, he normally does not define costs in terms of opportunities foregone.

To the program manager, the cost parameter is one of three critical variable program parameters that he must control in order to control his project. Cost data may take many forms, but are normally measured in dollars.

Schedule Parameter

The schedule parameter is the second vital element that must be controlled by the program manager if he is truly to influence the ultimate destiny of his program. It is the easiest of the three parameters to define, is less susceptible to critically divergent interpretations, and is probably the least difficult to measure.

The schedule parameter in this study refers specifically to the time resource required by, available to, and consumed in project execution. It is measured normally in terms of days, weeks, months, quarters, and years as appropriate to the project element under consideration. It is not uncommon that projects spanning years may still have specific elements measured in all of the time units cited. The schedule parameter may be finite through linkage with an actual calendar scale, thus establishing specific dates and times for accomplishment of project plans. The schedule may be somewhat more abstract and measured on an appropriate time scale commencing from time zero, where time

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[1] Ibid.

zero is not tied to a calendar date. This might occur, as an example, where project time-phasing and task sequencing and interrelationships are required, but project go-ahead has not been established as a specific date.

Schedule control is a vital program parameter and a meaningful indicator of program performance. Time is neither authorized nor appropriated by Congress in the sense that the fiscal budget is, but time is budgeted nonetheless. While the calendar cannot be changed and there is only a finite amount available, schedule compression may intentionally be "bought" through application of additional fiscal, personnel, or equipment resources, innovative management initiatives or a combination thereof. In similar manner, calendar time or schedule may be slipped, lost, or "squandered" through reductions in the same resources just cited, management ineptitude, intentional program changes, shifts in priorities, or a variety of other reasons.

As Chestnut has noted in discussing systems engineering: "The subject of time is one that has received broad philosophical treatment."[1] From a pragmatic viewpoint, time represents the "other" major resource (in addition to money) available to a program manager.

Technical Performance Parameter

The technical performance parameter relates to system design objectives and specifications. The primary purpose of technical performance control is the prediction or earliest possible detection of technical (in contrast to fiscal or schedule) problems requiring management attention. The technical performance parameter is perhaps the most difficult of the three paramaters to

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[1]Chestnut, Systems Engineering Methods, p. 221.

define conceptually, the most likely to vary qualitatively between programs, the most complex in terms of the multitude of dimensions of measurement, and the most dynamic in terms of which pertinent dimensions or indices to measure and how to measure them over the full life cycle of the system.

Although difficult to define, Chestnut places system performance[1] in perspective:

> Once the requirements for the overall system and for the corresponding subsystems have been established, it is essential that every effort be directed at meeting these requirements. One of the most important is performance because, in the final analysis, the performance represents the reason why the system was built in the first place. Hence, as a rough approximation the value of the system is strongly a function of its performance.[2]

While Chestnut's commentary is clearly addressed to system performance, the emphasis suggested is equally applicable to the slightly broader context of technical performance. The identification of pertinent measures of technical performance is a function of such factors as the system being managed, the mission or objectives of the system and/or the organization managing it, the maturity of the system in terms of its location in the life cycle, and the degree of control required or desired. One of the most common methods of measurement involves specifying levels of performance as either minimum acceptable or maximum allowable.[3] Due to the lack of homogeneity in the

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[1]In the context used in this study, technical performance and system performance are almost synonymous terms. In a strict sense, however, system performance normally refers to the performance of a physical system. The technical performance parameter is a slightly broader term that includes research, development, test, and evaluation; production; and installation performance considerations.

[2]Chestnut, Systems Engineering Methods, p. 145.

[3]Chestnut, Systems Engineering Tools, pp. 16-17.

dimensions and units used to measure these levels, however, no standard common denominator exists as it does with the cost and schedule parameters.

It should be noted that cost and schedule are simultaneously both resources to be input into project execution and critical dimensions of program progress. The technical performance parameter is a means of establishing objectives and determining program progress only. The significance of this difference attaches to the manner in which the program manager evaluates trade-offs between cost, schedule, and technical performance.

Phases

The phase dimension of the PPL analysis matrix is concerned with the life cycle of the system, program, or endeavor. Complex large-scale endeavors are dynamic and pass through a series of specific stages or states of maturity as they evolve. The phase dimension of the PPL analysis matrix is depicted in Figure 7. Within the DoD, the life-cycle phases are used to describe the general procedures for the research, development, test, and evaluation (RDT&E); production; deployment; and termination of systems. Using these major phases as a vehicle for establishing materiel acquisition operating policy also permits a balancing of risks through creation of major decision points prior to initiation of each successive phase. These milestones provide a logical means for checking system status and health prior to transition into successively more mature states of evolution.

The phase dimension of the PPL analysis matrix has a monetary implication since the proper fiscal appropriations to be utilized for funding various program activities are a function, typically, of the location of the activity and/or the system in its life cycle. The phase dimension is also time

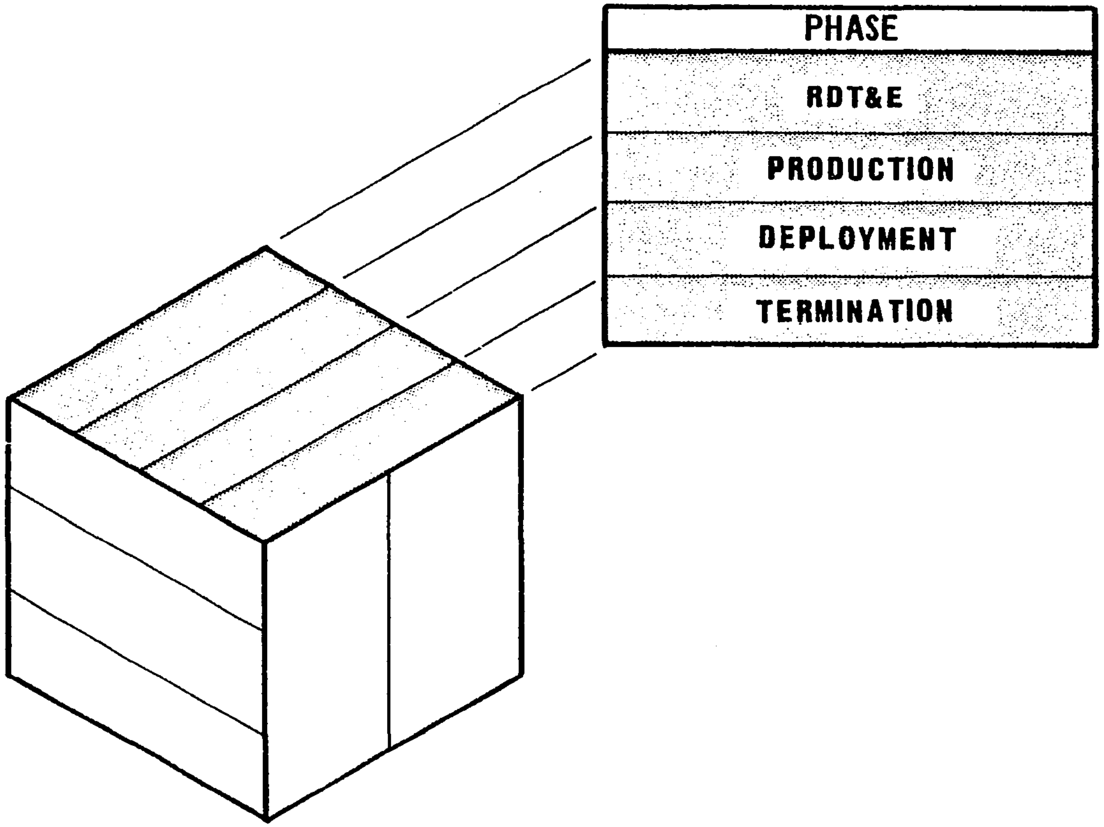

Fig. 7. Phase Dimension of PPL Analysis Matrix

sensitive, but only indirectly. The initiation and termination of phases are typically pegged to calendar dates as a convenience, but the dates are driven by the total program planning activity. Neither the cost nor the time connotations of the life-cycle phase dimension are at vaiance with the money and time aspects of the cost and schedule parameters. As indicated, the phase dimension is a method for describing system maturity as it evolves from state to state through some ordering of activity over time. It is an event-oriented concept. The parameters, on the other hand, are critical characteristics used to assess program status and health.

It should be noted that the fact that the life-cycle phases are depicted as being separate and distinct should not be construed as suggesting that concurrency between phases does not exist, for it frequently does occur. Conceptually, concurrency only indicates the initiation of one phase prior to the completion of an earlier phase. Practically, it can, and frequently does, cause significant technical problems. The time-phased conceptual relationships between phases are depicted in Figure 8.

Research, Development, Test, and Evaluation (RDT&E) Phase

In the development of U.S. Army programs, the RDT&E phase is preceded by a conceptual phase and a validation phase.[1] The conceptual phase of the life cycle is the first phase. The principal objectives of this phase are to initiate concept formulation by means of technical studies; to develop and test the feasibility of experimental prototype hardware; and to formulate doctrinal,

[1] U.S., Department of the Army, Life Cycle System Management Model for Army Systems, Army Pamphlet No. 11-25 (Washington, D.C., May 1975), pp. 1- 2.

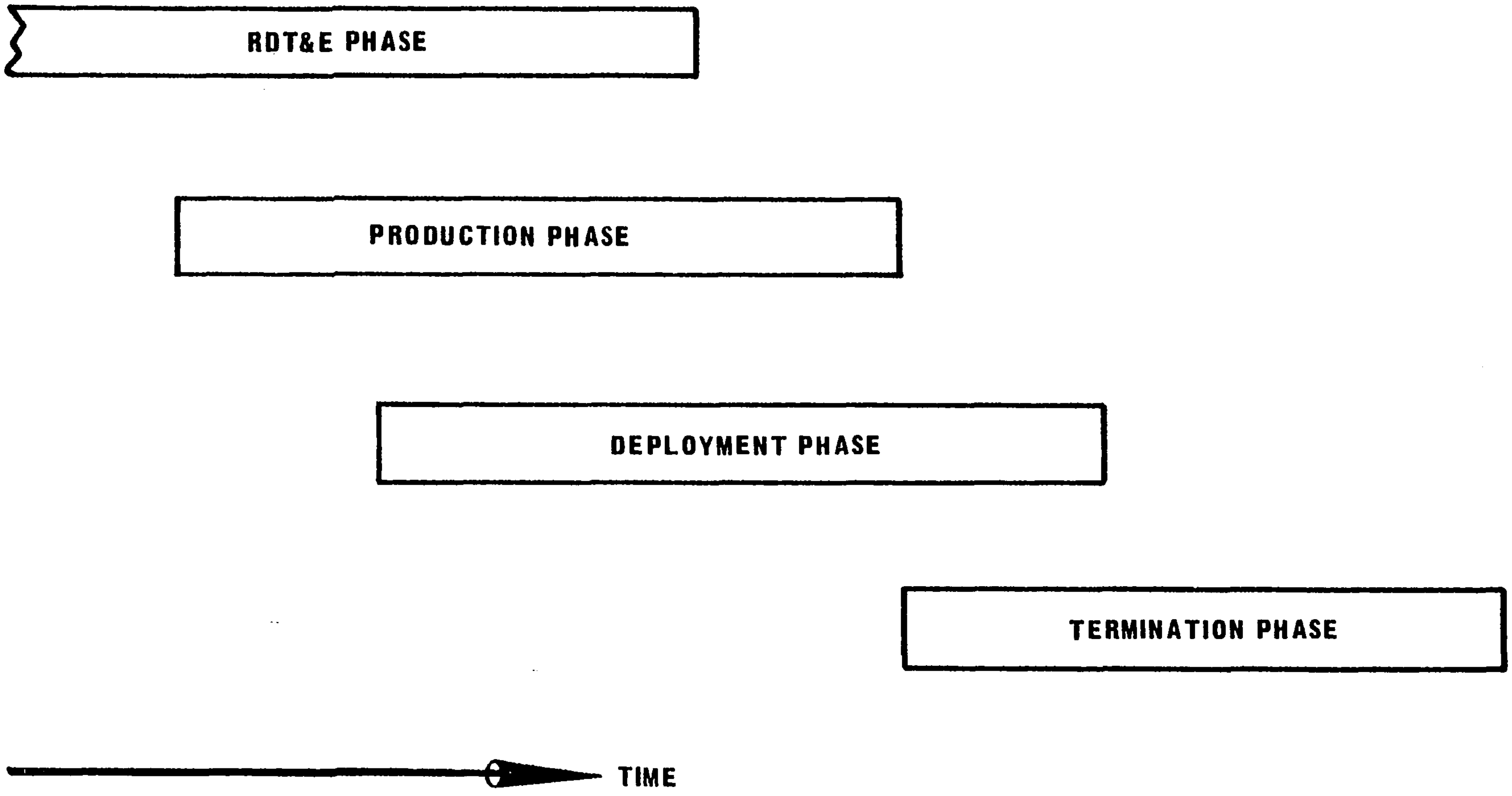

Fig. 8. Relative Sequencing of Program Life–Cycle Phases

operational, and organizational issues pertinent to the proposed system.[1] The validation phase verifies preliminary design and engineering; accomplishes necessary planning for acquisition, deployment, operation, and logistics support; analyzes trade-offs and system alternatives; and generally paves the way for full-scale development.[2] The objectives of full-scale development focus on determining whether the system is suitable to enter the U.S. Army inventory.

During the RDT&E phase, the total system, including all ancillary equipment and items needed for support, is fully developed and tested. Concurrently, technical documentation required for deployment of a system must be developed and finalized. Technical coordination must also be maintained with the organizational elements responsible for production, deployment, and operation of the system. Finally, continuing analysis must be maintained to identify any required revisions to "...funding, schedule, technical planning, and logistic support planning that will have an effect on production and deployment phase plans and estimates."[3]

Production Phase

The production phase represents a significant transition from the relatively flexible development state to the relatively more rigid production state. During development, system design is more fluid because of the inherent exploratory nature of development. System design is intentionally kept flexible to insure that all logical alternatives may be explored and that mandatory changes may be incorporated with minimum effort. The decision to produce, however, normally involves a commitment of potentially greater resources, a

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[1] Ibid. [2] Ibid., p. 2. [3] Ibid.

commitment to a basic system design, and acceleration of production quantities to considerably higher rates. It normally means transition from model shop or job shop type individualized fabrication used during development to more sophisticated volume manufacturing methods. The primary objective of the production phase "...is to produce efficiently and deliver to the operating unit an effective, supportable system in a timely manner and at minimum cost."[1] In the case of Safeguard, it also included construction of major facilities tantamount to the creation of a new, permanent U.S. Army installation.

Concurrency between a continuing development effort (the RDT&E phase) and the production effort requires strict configuration management control of the base-lined system design. Additionally, during the early production activity, many changes are also required in perfecting the manufacturing tooling and the manufacturing process. These changes must be implemented effectively or imbalance will result between change activity and accelerating production rates.[2]

Deployment Phase

This phase of the life cycle defines the period and activity of actually delivering the weapon system and all ancillary equipment to the combat operating unit. It also includes assignment of qualified and properly trained combat operating and maintenance personnel. All required logistics support facilities and activities are operational and supply pipelines filled.

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[1] Ibid.

[2] U.S., Department of the Air Force, Acquisition Management: A Guide for Program Management, AFSC Pamphlet 800-3 (Andrews Air Force Base, D.C.: Air Force Systems Command, 9 April 1976), p. 5-1.

This period also represents a significant transition in the evolution of a new system. A recent U.S. Air Force publication on program management attempts to capture the essence of deployment in these terms:

> Deployment represents the moment of truth for new systems and equipment. All of the laborious acquisition efforts finally culminate in a new mission and support capability provided by the melding together of the many elements that together comprise the system.[1]

It also adds a new dimension to the program management task; combat troops, for the first time in the life cycle, assume responsibility for operation of the system. This may mean "...that a whole new family of problems may surface."[2] This is due primarily to the fact that the laboratory and near-laboratory conditions that prevail to this point in the life cycle are essentially abandoned. Additionally, the logistics support program must begin to operate, and the atypical support enjoyed during development and test activity is no longer applicable.

In sum, deployment is the management of system activation.

Termination Phase

The termination phase for a U.S. Army system is the final phase in the life cycle. The system being phased out is typically removed from the active U.S. Army inventory and transferred to the U.S. Army Reserve Forces. Also quite typically, the system is replaced on a time-phased basis by a newer, more modern system or family of systems.

In addition to system phasedown, the termination phase also includes the transfer, storage, and/or disposal of unneeded facilities and equipment. It also precipitates significant changes both in the government and contractor

[1] *Ibid.*, p. 5-6. [2] *Ibid.*, p. 5-7.

organizations involved in the program. This phase should also include the preparation of "lessons learned" in order that technical and management knowledge gained will be documented as a guide to those that follow. This transfer of knowledge might result in fewer false starts on new programs and a reduction in unprofitable excursions.

The potential benefits of the documenting of lessons learned in the weapon systems acquisition process was vividly expressed at a 1976 Army Project Manager's Conference. In discussing this issue, the then Under Secretary of the Army stated:

> I have always been somewhat disappointed at the relative isolation and insularity that exists between the various military/industrial program management teams and their respective efforts. Consequently, one finds some programs continuing to experience avoidable problems for which solutions were previously developed at considerable expense. I believe that there is too little management transfusion of experiences encountered and handed down from one generation of program management to the next both in-house and out-house. Hence, over and over again we relive that which has been foretold--namely that those who will not examine, ponder, and try to understand history are doomed to repeat it--only in our case at tremendous and wasteful costs which we can ill afford.[1]

Of course the "lessons learned" concept is applicable to all phases of the life cycle, but it is particularly appropriate at the termination phase.

Levels

The two levels of management control activity of specific interest in this study are the strategic and tactical levels. These levels equate generally to hierarchic decision-making levels. The level dimension of the PPL analysis matrix is depicted in Figure 9.

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[1]Address by Herman R. Staudt, Under Secretary of the Army, before the U.S. Army Materiel Development and Readiness Command Project Manager's Conference, Orlando, Florida, 19 October 1976.

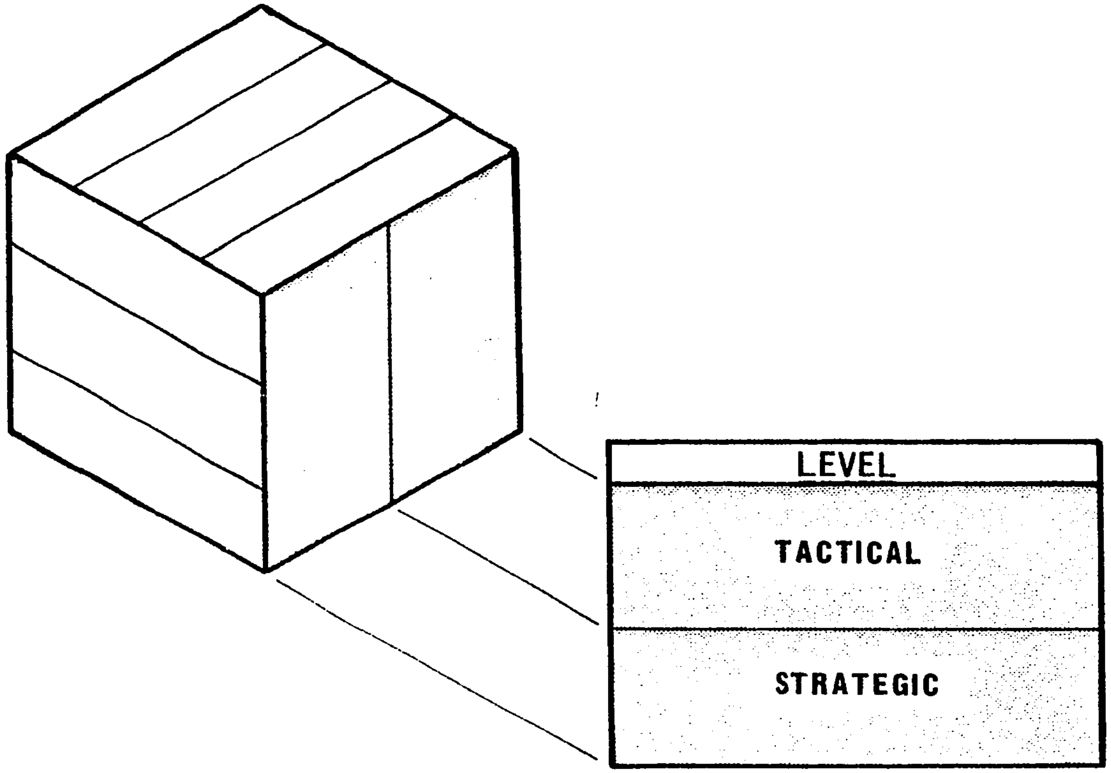

Fig. 9. Level Dimension of PPL Analysis Matrix

As with the phase dimension, the graphic presentation of these two levels suggests a clean distinction that frequently does not exist in real world situations. Such a distinction can be drawn before the fact on the known programmable situations that will ultimately befall a program. These knowns may be analyzed prior to their occurrence; management thresholds or pars may be established, and clear lines of authority may be defined prior to program initiation. This is particularly true in the case of the cost and schedule parameters. It is a valid statement to a lesser degree with respect to the technical performance parameter. Here, the distinctions become less precise and the boundaries between levels broader and overlapping. Clear distinction cannot be drawn with respect to the unknown or nonprogrammable situations. Suffice to say, the separation between strategic and tactical management control levels is sometimes as distinguishable as a pencil line and sometimes as nebulous and ill defined as the center of a fog bank.

Another feature of management control levels is of interest. It is a general concept that decision-makers entitled by either rank, position, or responsibility to operate normally at one level may, on occasion, and generally at their own discretion, operate at a lower level as well, assuming there is a lower level. This method of operation is particularly true in the dynamic environment of large-scale complex endeavors. The reverse, however, is atypical. Only on rare occasions will a manager consistently operate at a level higher than his rank, position, and responsibility entitle him to do. This was illustrated graphically in Figure 2 in Chapter I. The program manager operated freely at the lower end of the strategic level and at the upper boundary of the tactical level. On occasion, however, he operated at a level lower than the tactical level.

Strategic Level

Decision-making levels may most easily be defined for purposes of this study by viewing the hierarchic relationship between them, the magnitude of the commitment involved, and the degree of certainty associated with the levels.

The strategic level is hierarchically above the tactical level. Strategic considerations generally relate to long-range or broad time horizons involving macro program elements; i.e., normally only two or three levels of detail below the total system level on the work breakdown structure.[1] Strategic considerations also normally relate to large commitments of resources, relatively inflexible or essentially irreversible courses of action concerning major program elements, or actions or activities of high public visibility or Congressional sensitivity. Lastly, strategic concerns typically tend to have a high degree of uncertainty associated with them. Kast and Rosenzweig define broadly the arena of strategic considerations by suggesting that they "...relate to the boundary between the organization and its environment."[2] In the case of Safeguard, this boundary essentially defined the separation between the Executive Branch and the Congress.

Tactical Level

By definition, the tactical level of decision-making is lower than the strategic level. It generally relates to near-term time horizons of approximately one year. Program elements involved tend to be more micro in nature and may

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[1] See Appendix II for a description of the work breakdown structure.

[2] Fremont E. Kast and James E. Rosenzweig, Organization and Management: A Systems Approach 2d ed. (New York: McGraw-Hill Book Company, 1974), p. 358.

extend down five or six levels into the work breakdown structure. The magnitude of the resource commitment tends to be smaller, courses of available action present greater flexibility and less sensitivity, and the degree of uncertainty is lower.

Kast and Rosenzweig refer to this level as "coordinative" and define its primary purpose as one of integrating the stategic level with what they term the "operating" level;[1] i.e., a level lower than the coordinative level on their continuum.[2] The integrative aspect of the tactical level is a key characteristic for it captures the essence of this level as pivotal in the decision-making process. The preceding discussion of strategic and tactical decision-making levels is summed in Figure 10.

Examination Considerations

This section concerns study examination considerations. It will be noted that it closely parallels a typical problem-solving or decision-making process modified to accentuate management control activity. The first consideration involves an assessment and definition of the situational elements in order to define the problem. The second consideration attaches to an interrogation or analysis of the defined problem. The intent of this step was to identify the essential elements that might potentially affect the problem, the solution, or both. Having first identified and defined the problem and, second, determined those elements affecting the problem or the solution, the third and

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[1] Ibid.

[2] This lowest level of decision-making was termed "operational" in Chapter I of this study. The operational level of decision-making is generally reactive to the higher levels and, as discussed in Chapter I, is not of specific interest here.

CONSIDERATIONS	STRATEGIC LEVEL	TACTICAL LEVEL
HIERARCHIC LEVEL	HIGHER	LOWER
TIME HORIZON	LONG RANGE	NEAR TERM
PROGRAM ELEMENT	MACRO	MICRO
MAGNITUDE OF COMMITMENT	LARGER	SMALLER
VISIBILITY AND SENSITIVITY	HIGHER	LOWER
DEGREE OF CERTAINTY	HIGHER UNCERTAINTY	LOWER UNCERTAINTY

Fig. 10. Decision-Making Level Considerations

final step was to assess management control requirements as precisely as possible.

Assessment and Definition

The assessment and definition of the situational elements facing the program management team are essential to definition of the problem. The statement of a problem, out of context, is of little value. The purpose of fully formulating the dimensions of the problem is to facilitate the subsequent examination of factors affecting the problem or its solution and the management response to the problem.

Influences

Any management control situation is subject to a variety of exogenous and endogenous influences. To the extent that these influences had an effect on the management control situation, they are identified.

Exogenous influences on BMD activity were considered in terms of the following four dimensions: political, economic, public opinion, and technology.

The political influence concerns the direct Congressional reaction to BMD activity. It was expressed indirectly in terms of public statements, known attitudes of interest groups, and floor debate in both houses of the Congress. It was expressed directly in terms of program fiscal appropriations and authorizations.

The economic environment is quite direct for purposes of this study. It addresses only the extent to which the program was fully funded or under funded. In other words, it relates totally and directly to the Congressional budgetary process.

Public opinion and the level of public visibility is frequently a factor in the public sector. James Webb, Administrator of the National Aeronautics and Space Administration (NASA) from 1961 to 1968, described this factor in these terms:

> In Government enterprises, what is done, how it is done, and who does it are almost always highly visible or open to inspection. In addition, the reporting of successes and failures is frequently keyed to the controversial or spectacular.[1]

Thus, not only public visibility but its probability are prevalent in public works.

The technology factor involved in a program tends to determine the types of tools and techniques that must be applied in the management of that program. In a broad sense, the technology factor pertains not only to the tools and techniques but also to the processes and knowledge that extend human capability. Programs involving high levels of system technology, frequent change, and nonrepetitive activities require the management of a broader and more complicated spectrum of unknown factors than do programs with low technology, stability, and highly repetitive tasks.

Endogenous influences were addressed in terms of the following dimensions: (1) the existing U.S. Army management doctrine, (2) other government agencies, (3) participating contractors, and (4) the management philosophy of the program manager.

The degree to which existing U.S. Army management doctrine either did or did not affect the management control activities of the BMD community was explored as a segment of the internal influence. Doctrine in this case connotes both specific management systems and philosophical considerations.

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[1]Webb, Space Age Management: The Large-Scale Approach, p. 4.

Participation by other government agencies and contractors from private industry was considered part of the internal environment. Both possessed the potential to influence BMD management control to varying degrees.

The personal management philosophy of the Ballistic Missile Defense Program Manager, as the senior executive agent of the BMD program, could not be overlooked as a potential influence.[1] In some respects, the management control system either directly or indirectly provides highly stylized information for the sole use of the program manager. This influence on control requirements may, at times, be highly persuasive. In fact, this type of influence is frequently felt throughout the total organizational structure.

Objectives and Scope

The objectives and scope of the management control activity must be defined as specifically as possible. The organization must address its corporate objectives at this point and translate them into precise definitions of what the control effort is expected to achieve[2] in terms of specificity of information, depth of detail required, the importance of and need for stratified and integrated information, and the use to be made of the information for control purposes.

Mockler summarizes the idea nicely by suggesting that:

> A major question to be answered at this point is "What kind of control action is required in this situation?"[3]

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[1]The importance of this influence is discussed in Cortlandt Cammann and David A. Nadler, "Fit Control Systems to Your Managerial Style," Harvard Business Review 54 (January-February 1976): 65-72.

[2]Mockler, The Management Control Process, p. 26.

[3]Ibid.

A precise answer to this question in terms of needs and expectations satisfies this management control consideration.

Key Factors

Identification of the key factors associated with the management control activity is primarily a matter of determining which factors in the control situation are critical to both full definition and satisfactory solution of the problem. Key factors are more precise and direct than the previously described exogenous and endogenous influences, which tend to be more general and indirect. Key factors differ from the objectives and scope definitions in that the former address needs and expectations, whereas the latter are concerned with those affirmative "givens" that contribute to attainment of the objective.

Key factors are highly sensitive to the degree of program maturity and may shift dramatically over time. In similar fashion, they are affected by the hierarchic level of the decision-making process as well. Key factors are, therefore, highly dynamic and should be reassessed periodically to ascertain their continuing validity. Revisions must be made as periodic analyses dictate.

Examples of key factors are optimal answers to compelling questions, such as the following:

1. Which organizational elements are involved and at what level?
2. What will the information be used for?
3. Where will input data come from and how will it be obtained?
4. Is the control situation repetitive or nonrepetitive?
5. What type of control is required?[1]

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[1]As an example, Newman describes three basic types of control as steering controls, yes-no controls, and post-action controls in Constructive Control: Design and Use of Control Systems, pp. 6-9.

6. How critical is the datum element as a predictive device of future events or potential problems?[1]

7. Is 100 percent measurement of performance required or is statistical sampling acceptable?

8. How critical is the timeliness of reporting and the age of the information being reported?

While this list is by no means all inclusive, it demonstrates the flavor of what is meant by key factors in the control situation.

Interrogation and Identification

This aspect of the examination considerations is concerned primarily with the issue of examining the problem still further in order to define the specific components affecting the problem and its solution. The notion is to "fence" the control situation in sufficiently precise terms to facilitate the development of rational management control requirements.

Constraints

Just as the principles of basic economics stress that all resources are scarce, most control situations are constrained in some fashion. Even if constraints are not evident, rational analytic treatment requires that they be sought out. If none are found, they are absent because they do not exist, not because they were overlooked or neglected.

Constraints basically determine the difference between what a manager "ought" to do or "wants" to do in terms of resolving a control situation

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[1]Newman refers to these elements as "early warning predictors" in Ibid., p. 15.

versus what he is able to do. A simple example might be a manager's recognition that he "ought" to manage a given parameter at the fourth level of the work breakdown structure. Due to dollar or personnel constraints, however, he is forced to raise his actual management control requirement to the third level of the work breakdown structure. In other words, he "ought" to manage at the fourth level, but is only "able" to afford consistent management attention at the third level of the work breakdown structure. This constraint exposes the program manager to additional program risk.

Latent Interdependencies

This topic concerns the ascertainment and development of latent interdependencies among cells in the PPL analysis matrix. In other words, all integrative relationships and linkages among matrix cells must be sought out and identified where they exist.

It is apparent, as an example, that all cost cells contain the common denominator of dollars as the yardstick of measurement. As a result of this logic thread through all cost cells it is possible, if desired, to "roll-up" or add costs across cell boundaries. In similar fashion, all cells sharing a schedule dimension carry a common denominator of time. This logic thread also permits integration and facilitates analysis and comparison among schedule oriented cells. Not so obvious are the logic threads among cells with technical performance as a common dimension.

Even more difficult is the problem of determining interdependencies between any two of the three parameters or among all three.

Essentially the same philosophy holds true for the phase and level dimensions of the PPL analysis matrix. Logic threads are fairly common within each phase or level dimension. The same difficulty occurs as it does with the parameter dimension, however, when attempts are made to integrate across phases or levels.

The real problem, however, is three dimensional because the matrix is three dimensional. The intent of this topic, therefore, is the task of identifying latent logic threads that might exist among any of the cells in the matrix. Identification of latent interdependencies among matrix cells is the key to integration of management control activity. It also provides one of the means of assessing how to rebuild the matrix after each cell has been individually examined. The identification of interdependencies and the establishment of rational logic threads among the matrix cells is a compelling step in the analysis of management control in large-scale, complex program environments.

Characteristics

The characteristics element of the interrogation and identification examination consideration is designed to define any additional distinguishing aspects of the control situation. In some cases the characteristic is common to a complete program performance parameter, phase of the life cycle, or hierarchic decision-making level. In other cases the trait may be characteristic of an individual cell, caused by the unique interaction of the three dimensions of the cell.

This consideration may be subjective in some cases; objective in others. It may involve only one aspect or it may be multifaceted. The purpose is to capture any characteristics, not otherwise identified, that will add to the completeness and accuracy of the definition of the control situation.

Management Control Requirements

The development of management control requirements equates to the development of the solution to the control problem. It pertains to three fundamental management actions involving the development of:

1. Quantified Standards
2. Management thresholds and tolerances
3. Reporting requirements

Each of these will be briefly discussed in the following paragraphs.

Quantified Standards

Quantified standards[1] of comparison or measurement must be developed in order to accurately assess program performance. While it may not always be possible to quantify the standard or standards, it is advisable to do so wherever possible.[2]

On nonrepetitive activities, the standards may be drawn from the program plans used to guide the general progression of the program. In this case, standards are defined more in terms of desired results than in terms of performance. Where repetitive activity is involved, a slightly different view is frequently typical, and standards of performance are established and refined based on continuing repetition of the process. The goal in nonrepetitive or creative activity is primarily to ascertain program progress and to facilitate its optimization, whereas the goal in repetitive activity is primarily to assure stability and to "establish normal performance."[3]

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[1]For an excellent discussion on the anatomy of control standards see J. M. Juran, Managerial Breakthrough (New York: McGraw-Hill Book Company, 1964), pp. 233-56.

[2]Ibid., p. 13. [3]Ibid., pp. 50-51.

It should be noted that standards need not, in fact probably should not be static. Large-scale, complex programs normally exist in an environment that is flexible, highly dynamic, and sometimes controversial. Under such conditions the management control situation assumes the same flavor as the program. Standards, therefore, must be periodically reassessed and revised as required. This is particularly true of creative type activity such as research and development, but it also applies to more routine and repetitive tasks or endeavors. This does not suggest indiscriminate or haphazard change of standards.

Mockler underscores the importance of control standards by stating: "No control system, in fact no control, can exist without standards."[1]

Control Thresholds and Tolerances

The concept of management thresholds and tolerances is associated with the concept of management by exception.[2] Management thresholds define either a "floor" or a "ceiling." The idea of a management floor indicates that performance above the floor is satisfactory and only the exceptions; i.e., that performance falling below the floor, need be reported. The "ceiling" is the reverse, wherein performance that exceeds a specified value must be reported. The concept of tolerance combines both features and suggests a "window" of satisfactory performance bounded by an upper limit (the ceiling) and a lower limit (the floor).

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[1]Mockler, The Management Control Process, p. 74.

[2]For a brief description of the concept of management by exception, see Daniel A. Wren and Dan Voich, Jr., Principles of Management: Process and Behavior, 2d ed. (New York: Ronald Press Company, 1976), p. 347; Johnson, Kast, and Rosenzweig, The Theory and Management Of Systems, p. 61; and Martin K. Starr, Management: A Modern Approach (New York: Harcourt Brace Jovanovich, Inc., 1971), pp. 451-59.

Management control thresholds and tolerances are used primarily to trigger a requirement for exception or special reporting out of sequence with routine reporting or as means of highlighting items of interest in routine reporting. In either case, the appropriate use of management thresholds and tolerances can be of immense benefit to management control activity.[1]

Reporting Requirements

Reporting requirements are influenced by a number of variables. For purposes of this study only three types of requirements are recognized: exception reporting, routine or standard reporting, and special reporting.

Exception reporting is that reporting that occurs whenever a predefined management threshold or tolerance is exceeded or missed. This type of report is issued on an exception basis, normally in addition to standard reporting.[2]

Standard reporting relates to the periodic status and trend reports that are characteristic of typical management control systems. Standard reports are issued on some regular basis and cover a variety of topics pertinent to the program being managed.

Special reporting concerns any special reports called for by management that are not exception or standard reports. They may involve a number of topics or they may be devoted to a specific topic. They represent a method for management to task the management control system for any form of atypical, one-time form of output required for total management perspect.

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[1]A brief summary of the use of control tolerances may be found in Leslie W. Rue and Lloyd L. Byars, Management: Theory and Application (Homewood, Illinois: Richard D. Irwin, Inc., 1977), pp. 171-72.

[2]Exception reports produced by integrated information systems are described in Granville R. Gargiulo, "Decision Makers and the Large-Scale System," Journal of Systems Management 20 (August 1969): 15-18.

Reporting requirements may exceed the three described, but they would probably be subsets rather than additional types of reports.

Examination Methodology

The purpose of this section is to describe how the examination considerations described in the preceding section were applied in the analysis of each of the PPL analysis matrix cells. The first subsection addresses the issue of how each cell was analyzed, first in terms of the assessment and definition considerations and then in terms of the interrogation and identification considerations. The second subsection is related to the first and is concerned with individual cell management control requirements.

It should be noted that the topics and subtopics of assessment and definition and interrogation and identification did not apply in all cases to all matrix cells. Furthermore, where they did apply, the significance was not necessarily of the same magnitude for each matrix cell. As a consequence, the examination considerations were selectively utilized in the analysis of each cell, because some considerations were not important enough to warrant individual cell application. Also, in some cases, the examination considerations applied to a number of cells with equal intensity and in a similar manner. In those cases, the analysis was handled "across-the-board" for the cells affected and not on a cell-by-cell basis. This resulted in the elimination of unneeded duplication.

Individual Cell Examination

The initial phase of the analysis process is the examination of each cell in the PPL analysis matrix. Analysis ordering is priority sequenced through the parameter dimension, then through the phase dimension, and then through the level dimension. All twenty-four cells of the PPL analysis matrix were individually examined in this manner.

Assessment and Definition

Each of the individual cells was examined in terms of the pertinent aspects of each of the three topics of exogenous and endogenous influences, objectives and scope, and key factors. This examination yielded a fairly specific statement of the control problem and its environment for each cell.

Interrogation and Identification

Each cell was then analyzed in terms of applicable constraints affecting the management control situation, the latent interdependencies among the cell being analyzed and other cells in the matrix, and additional characteristics. This analysis resulted in even more precise definition of the management control problem involved with each cell. This analysis, coupled with the previous examination, resulted in a specification for each cell that defined the problem in context with its environment and its solution.

Individual Cell Management Control Requirements

The second phase of the analysis process focused on the BMD management responses to the control situations. This phase, therefore, covered the actual evaluation of the solutions set forth by BMD management to the management control problems defined in the preceding phase; i.e., the individual cell examinations. This second phase of the analysis process was performed on a cell-by-cell basis in the same manner as the first phase. The thrust of this second phase was directed toward the specific requirements of quantified standards, management thresholds and tolerances, and actual reporting requirements.

In this phase, the responses to the control situations defined by BMD management are summarized for each of the three specific requirements (i.e., quantified standards, management thresholds and tolerances, and reporting requirements) within each of the cells in the matrix. These management responses are then analyzed in terms of their adequacy in fulfilling the requirements of the control situation and major control deficits are identified.

Conclusion

The PPL analysis matrix is a technically sound method of examining the three major dimensions of a large-scale complex program. In this study it was structured with twenty-four cells. Figure 1 in Chapter I depicts the make-up of the twenty-four cells.

This chapter has defined the conceptual foundation of the matrix, the examination considerations utilized in the application of the analysis process, and the manner in which the examination was conducted. The next three chapters of this study document the results of the analysis for the cost, schedule, and technical performance parameters respectively.

CHAPTER V

THE COST PARAMETER

This and the next two chapters are similar in format, but different in emphasis. All three chapters are concerned with a critical examination of the PPL analysis matrix cells of their respective parameter. This chapter concentrates on the cost parameter; Chapter VI, on the schedule parameter; and Chapter VII, on the technical performance parameter.

This chapter opens with a discussion of money, both as a scarce resource to be competitively sought and judiciously allocated and as a specific parameter of program performance measurement. The second section contains a discussion of the common characteristics displayed by all cells of the cost segment of the PPL analysis matrix, when subjected to analysis. The next four sections are aligned to the four phase dimensions of the PPL analysis matrix with each further subdivided into the two decision-making levels. These sections reflect the individual cell analyses. The concluding section of the chapter is a brief summary of the cost parameter.

Cost Control Considerations

Money is simultaneously both a resource to be utilized by the program manager in the advancement of his program objectives and a critical means of measuring program performance. While the latter aspect is the one of primary interest, discussion of the former will help to put cost in perspective. The intent is to portray the character of the financial resource in large-scale endeavors in order to underscore the pervasive nature of the cost parameter in management control.

The Nature of the Financial Resource

Program managers within the Department of the Army are chartered to accomplish stipulated mission objectives--typically, the development, production, and deployment of a specified weapon system. Equally important is the program manager's task of insuring that all financial resources provided for his program are administratively controlled in strict accordance with applicable statutes and directives. Thus, the program manager must be highly sensitive to pertinent financial management regulations as they apply to the legal use of appropriated funds.[1]

Definition and Description

The primary source of financial resources for the U.S. Army is from Congressional appropriations.[2] While the national budgetary process is quite complex,[3] Congressional activity (particularly as it relates to DoD weapon system programs) involves two primary actions. First, the Congress takes an authorization action that sanctions the goods and services to be acquired as justified by the Executive Branch budget submission. Secondly, a separate and

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[1]U.S., Department of the Army, Executive Handbook for Financial Management, p. 1-2.

[2]All Safeguard program funds were appropriated funds. Additional (secondary) sources of funds for the U.S. Army are relatively minor by comparison and are not germane to this study.

[3]An excellent article which briefly describes the budgetary process is Francis, "The Congressional Budget and Impoundment Control Act of 1974: Implications for Program Managers," pp. 1-24.

subsequent appropriations action is taken by the Congress to finance those items already authorized plus any items not covered previously in the authorization action.[1] It should be noted that the Congress may decrease and increase the President's budget submission. Financial resources, for purposes of this study, are defined as those funds appropriated by Congress to finance authorized expenditures.

Constraints and Administrative Controls

In addition to the normal restrictions imposed by limited funding, the use of public funds is also subject to both Congressional constraints and administrative controls.[2] These additional limitations are also a part of the environment with which the program manager must contend.

The Congress, in order to discharge a constitutionally directed responsibility for fiscal accountability,[3] has taken four major actions:[4]

1. Instituted the Congressional authorization and appropriation processes previously described.

2. Required the Executive Branch to formulate and implement procedures to insure that funds are not spent beyond those made available.

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[1]U.S., Department of the Army, Army Comptroller Handbook, Army Pamphlet No. 37-4 (Washington, D.C., 15 April 1976), pp. 13-17.

[2]U.S., Department of the Army, Executive Handbook for Financial Management, p. 1-1.

[3]U.S., Constitution, Art. I, Sec. 9.

[4]U.S., Army War College, "Financial System Management," by Billy Peters, Raymond S. Allred, and James P. Edmondson in Army Command and Management: Theory and Practice, Vol. II (3 vols.; Carlisle Barracks, Pennsylvania, August 1976), p. 372.

3. Required that each major department establish a fiscal management organization to provide staff guidance for the management of appropriated funds within the department.

4. Created the General Accounting Office (GAO) as the agent of the Congress responsible for auditing department compliance with all fiscal procedures and regulations.

The Department of the Army requirements in this regard are documented in an Army regulation.[1] Essentially, the Department of the Army requirements summarize to three key elements:

1. To restrict obligations or expenditures to not more than the amount available.

2. To prohibit involving the Government in financial liability or obligation without proper authorization and appropriation action.

3. To pinpoint individual responsibility in the event of violation and provide a process for reporting of same.

The administrative control of appropriated funds applies to "...all activities of the Department of the Army to which appropriated funds are made available for obligation and to all appropriated funds made available to the Department of the Army."[2] It should be added that these administrative controls are enforced by severe penalties.[3]

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[1]U.S., Department of the Army, _Financial Administration: Administrative Control of Appropriated Funds_.

[2]_Ibid._, p. 2.

[3]_Ibid._, p. 9.

Categorization of
Appropriated Funds

The three principal types of Congressionally appropriated funds used in the weapon system acquisition process are functionally oriented. They may be categorized as research funds, investment funds, and operating funds. Research funds are provided by the research, development, test, and evaluation (RDT&E) appropriation to conduct and support research and development activities. Investment funds cover a number of fiscal appropriations and are used primarily to acquire weapon system end items, production facilities including equipment and buildings, and real estate. Operating funds also include a number of individual fiscal appropriations. Operating funds are used primarily to finance the day-to-day operating needs of the Department of the Army.[1]

The Army Management Structure (AMS) is the means utilized by the Department of the Army for "...interrelating programming, budgeting, accounting, and manpower control through a standard classification of Army activities and functions."[2] To the extent possible, the AMS is aligned with the DoD structure of program planning and represents a common language for communication. Thus, the AMS is the official Army framework for correlating the Congressional appropriation structure to Army fiscal accounting codes and terminology and represents the lowest level of fiscal reporting required within the Department of the Army.[3]

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[1]U.S., Department of the Army, Executive Handbook for Financial Management, pp. 2-2 - 2-3.

[2]U.S., Department of the Army, Financial Administration: The Army Management Structure (AMS), Army Regulation No. 37-100-77 (Washington, D.C., February 1976), p. 1-1.

[3]Ibid.

Planning, Programming, Budgeting Activity

At the time of its introduction, PPBS (Planning, Programming, and Budgeting System)[1] was one of the most comprehensive management control systems ever introduced in the public sector. Developed in the Department of Defense (DoD) in 1961 at the direction of the Secretary of Defense, the system was designed to "span the gap" between the existing and well established military planning and military budgeting functions.[2] The key element in this regard is the concept of programming, which is designed "...to provide a bridge between multiyear planning and a one-year budget."[3]

The essence of PPBS, as originally conceived, was decision-making. Its main purpose was "...to develop explicit criteria, openly and thoroughly debated by all interested parties, that could be used by the Secretary of Defense, the President, and the Congress as measures of the need for and adequacy of defense programs."[4] In addition, PPBS had a number of concomitant ideas underlying its fundamental purpose. First, it provided a basis for collective and simultaneous

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[1]For classic advocatory descriptive texts of PPBS, see Harley H. Hinrichs and Graeme M. Taylor, eds., Program Budgeting and Benefit-Cost Analysis (Pacific Palisades, California: Goodyear Publishing Co., Inc., 1969) and Fremont J. Lyden and Ernest G. Miller, eds., Planning, Programming, Budgeting: A Systems Approach to Management, 2d ed. (Chicago: Markham Publishing Company, 1972). For a descriptive text from an adversary point of view see Harold A. Hovey, The Planning-Programming-Budgeting Approach to Government Decision-Making (New York: Frederick A. Praeger, Publishers, 1968). U.S. Army implementation instructions are contained in U.S., Department of the Army, Administration: Planning, Programming, and Budgeting within the Department of the Army, Army Regulation No. 1-1 (Washington, D.C., 25 May 1976).

[2]Charles J. Hitch, Decision-Making for Defense (Berkeley: University of California Press, 1965).

[3]U.S., Department of the Army, Army Comptroller Handbook, p. 1.

[4]Alain C. Enthoven and K. Wayne Smith, How Much is Enough? Shaping the Defense Program, 1961-1969 (New York: Harper & Row, 1971), p. 33.

consideration of military needs and associated costs. Second, it accommodated the need for explicit consideration of alternatives at the upper levels of the decision process. Active use of independent staff assistance and analysis as a check-and-balance technique was a third factor. Fourth, the system was intended to aid the prognostic capability of the DoD by projecting future consequences of current decisions. Finally PPBS was to be an open system in the sense that all data, calculations, assumptions, and criteria were to be documented in a fashion designed to enhance analysis and audit.[1]

Planning

The planning segment of PPBS is concerned with the formulation of comprehensive, realistic, and effective military plans required to accomplish established national objectives. The planning process is a complex and highly technical one. One author, discussing military planning in connection with PPBS, has defined it as "...the selection of courses of action after systematic consideration of alternatives."[2] Continuing, the same author stressed that planning "...should focus on determining what kinds of military capabilities were needed and how they were to be achieved."[3]

It is the responsibility of the National Security Council to develop national objectives based on the postulated external threat to the United States. The threat is assessed not only in terms of its direct implications for the

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[1] Ibid., pp. 35-47.

[2] Theodore W. Bauer, National Security Management: Requirements for National Defense (Washington, D.C.: Industrial College of the Armed Forces, 1970), p. 12.

[3] Ibid., p. 13.

continental United States, but for its world-wide interests as well. The Joint Chiefs of Staff of the military departments are responsible to the Secretary of Defense for the preparation of military plans responsive to these national objectives. The Secretary of Defense is then responsible for the execution of the approved plans through the armed services. Army plans and the joint plans normally cover three time periods identified generically as short-range, mid-range, and long-range.[1]

Programming

As indicated earlier, it is the programming segment of PPBS that is the cardinal element of the concept. It is through this vehicle that multiyear plans are ultimately tied to single-year budgets. It is also through this process that the true impact of individual and isolated budget cuts may be assessed in terms of plans.

At the heart of the programming segment is the Five Year Defense Program (FYDP). By definition, the FYDP is:

> The official program which summarizes the Secretary of Defense approved plans and programs for the Department of Defense.[2]

In other words, the FYDP is the base line document that serves as the audit trail for DoD programs. It is updated three times each year: (1) at the time the individual service five-year-programs submissions are made to the Secretary of Defense, (2) at the time of the individual service budget submissions to the Secretary of Defense, and (3) in the DoD budget submission as part of the

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[1] U.S., Department of the Army, Army Comptroller Handbook, p. 1.

[2] Ibid., p. 76.

President's budget submission to Congress.[1] The FYDP reflects the total defense program in terms of military output for eight years and costs and manpower requirements for five years.[2]

The individual service five-year programs are submitted to the Secretary of Defense by means of a Program Objective Memorandum (POM). This document is the vehicle used by the services to translate program guidance into specific proposals for resource allocation. Following review and modification, as required by the Secretary of Defense, the POM becomes the approved service five-year program. The first-year portion of the POM is the basis for the development of the annual budget for that same fiscal year.

The programming segment, like the planning segment of PPBS, has varying levels of detail. At the weapon system level both programming and planning data are detailed and specific. As information is processed upward through the chain of command, it tends to become more summarized and less detailed.[3] This is a pragmatic consideration that is consistent with normal management information processing in a layered organization structure.

Budgeting

The third segment of PPBS is budgeting. It is both the end of one PPBS cycle and the first step in the following cycle.[4] Since the budget is the fiscal expression of the plan for carrying out the desired program objectives for a

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[1]U.S., Department of the Army, Administration: Planning, Programming, and Budgeting within the Department of the Army, p. 6-1.

[2]Bauer, National Security Management: Requirements for National Defense, p. 33.

[3]Ibid. [4]Ibid., p. 112.

given year, it represents a value judgment by the administration of the funds required to accomplish the military mission. Upon approval by Congress, it becomes a specific control device both for the allocation of financial resources and for the execution of approved programs. To the extent that the approved budget differs from the five-year program, the planning segment must be re-energized and the next PPBS cycle initiated.

The budget process is a dynamic one. While budget formulation concentrates on developing detailed fund estimates for individual fiscal years, a program manager, at any given time, is actively involved with at least three distinct annual budgets. Additionally, the program manager is normally still executing not only the current year budget, but prior year budgets as well. As an example, in early fiscal year (FY) 1977, a typical program manager is simultaneously: (1) executing the FY 77 (current year) budget, (2) fine tuning and justifying the FY 78 (budget year) budget before Congress, and (3) formulating the FY 79 (target year) budget. From a programming standpoint, the program manager is also re-evaluating and reprogramming his FY 79 through FY 82 program as it interrelates to the FY 78 budget submission. Thus, the FYDP and the programming time-frame would cover the period of FY 78 through FY 82 in this example.[1] These relationships are depicted in Figure 11.

The three year budget period for the current through the target year depicts what is referred to as the operating budget. For a weapon system it reflects a plan of tasks to be accomplished and the financial resources available for utilization and a control standard for cost control.[2] It should be noted that

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[1] U.S., Army War College, "Financial System Management," pp. 408-15.

[2] Ibid., p. 409.

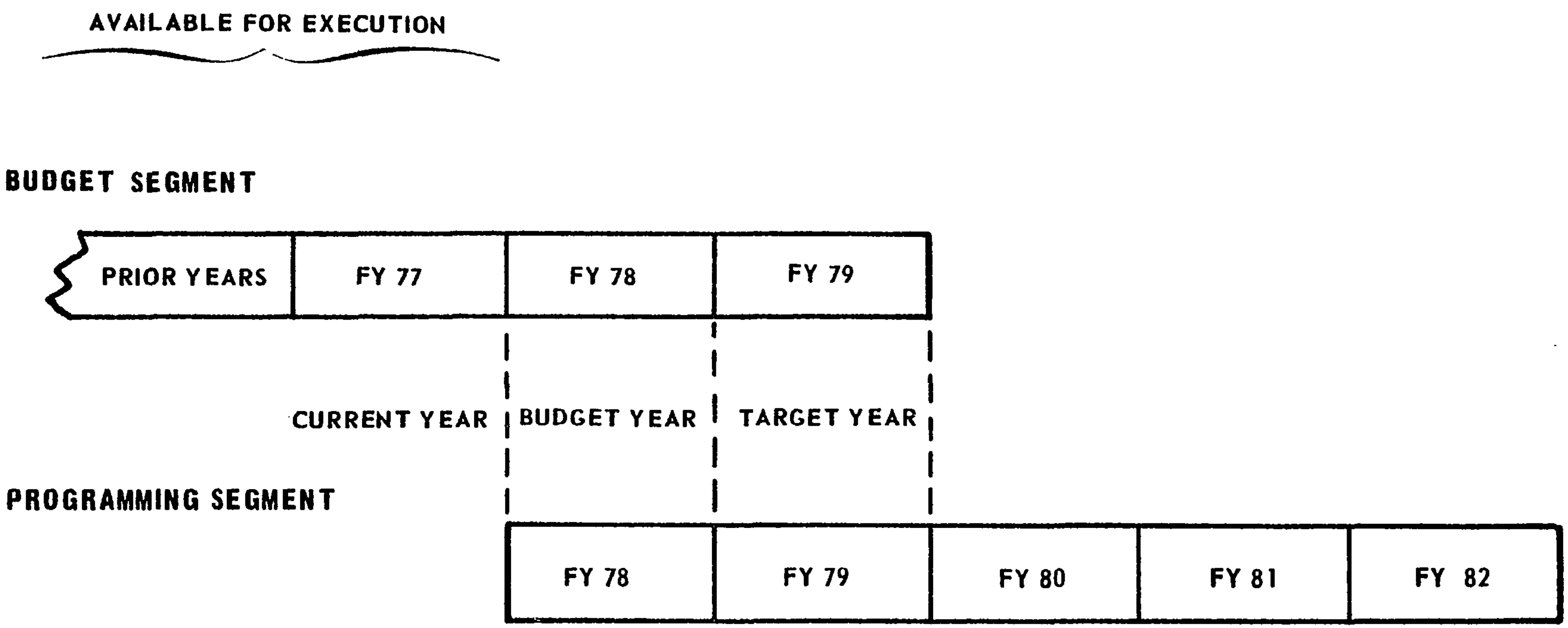

Fig. 11. Fiscal Year Relationships Between Budget and Programming Segments of PPBS

FY 77 was the final budget year for Safeguard. No funding was authorized for the program in subsequent fiscal years.

A graphic illustration of the conceptual interrelationships between the segments of PPBS and the continuous, closed-loop nature of the total system is depicted in Figure 12.

Program Execution

Program execution[1] is concerned with the implementation of programs through the allocation, obligation, expenditure, and reporting of funds. Several aspects of program execution are essential to an understanding of cost control considerations. They are discussed briefly in the following paragraphs.

Funding Authorization

Following approval of the DoD budget by Congress, the Army must obtain obligational authority from DoD. This is accomplished through an apportionment process that originates in the Office of Management and Budget (OMB). By public law, each government agency must submit an apportionment request to the OMB for distribution of the financial resources appropriated by Congress and signed into public law by the President.[2] The Apportionment

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[1]In theory, the obligation, expenditure, and reporting of current and prior year program funds is referred to as "budget execution." As a process of financial administration, budget execution is an integral part of the PPBS concept. As a practical matter, however, the execution process is more easily discussed as an adjunct to, rather than an integral part of, the PPBS. The latter treatment is used in this study. The terminology "program execution" has been adopted to underscore this slight departure from a literal interpretation of the PPBS concept.

[2]U.S., Department of the Army, Army Comptroller Handbook, p. 19.

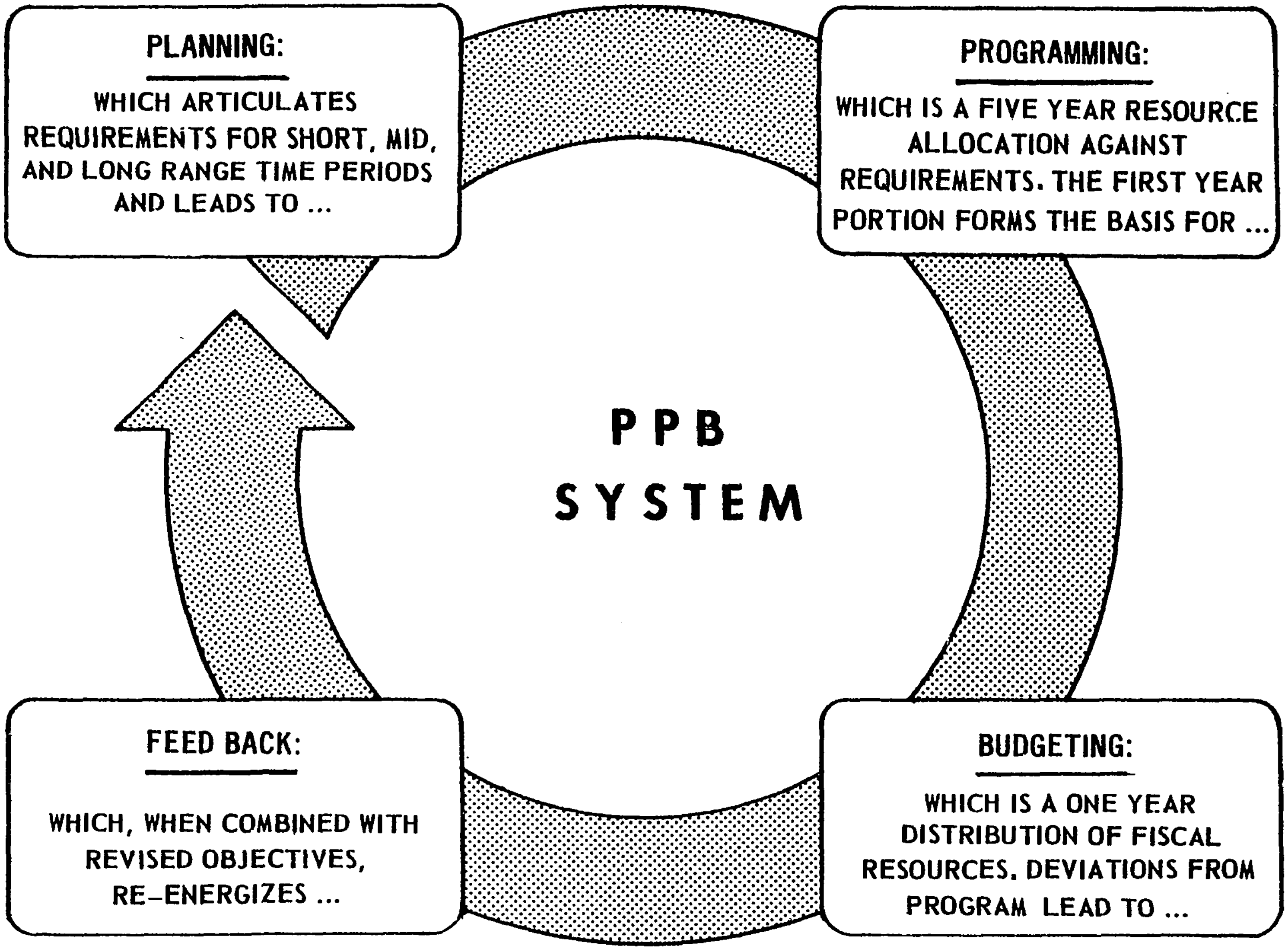

Fig. 12. Planning, Programming, and Budgeting Relationships

Request, by direction, "...contains the latest actual data for the current year and significant changes in requirements for the budget year."[1]

The Army Apportionment Request to DoD is similar in form to the original budget submission. Once approved by DoD and returned to the Department of the Army, the apportionment constitutes authority to obligate funds. This obligational authority is released to the field commands with direction to proceed with the implementation of approved programs.[2]

Obligation of Funds

The placing of orders with other government agencies or the awards of contracts obligates funds. Every transaction involving public funds must be documented in terms of the availability of those funds and the appropriate accounting classification. Accurate records must be maintained for fiscal accounting purposes and systematically reported upward through the chain of command.[3]

Unfinanced Requirements

Unfinanced requirements represent those elements of a program that the program manager believes ought to be accomplished, but for which no funds have been appropriated. In other words, they represent a need that is unfunded. Unfinanced requirements may occassionally be financed through transfer of funds from one program element to another, through use of unliquidated prior year funds, through reprioritization of tasks which results in previously funded tasks simultaneously becoming unfinanced, or by a number of other means.

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[1] Ibid. [2] Ibid.

[3] Ibid., pp. 19-20.

In the event a major reprogramming action is required involving either a sizable dollar amount or a transfer of funds from one fiscal appropriation to another, it may be necessary to secure Congressional approval.[1]

Budget execution is an iterative process requiring the program manager to keep constantly abreast of the status of his program. Budget execution has an impact on both the planning and programming segments. The illustration of unfinanced requirements is a compelling example. As indicated above, unfinanced requirements may become funded during the current year. It is also possible, however, that it may not be possible to fund in the current year and the requirement must be recycled into the budget year, target year, or beyond. It is also possible that an unfinanced requirement is never funded and it simply expires due to the passage of time.

Review and Analysis

Review and analysis is a generic term applied to independent evaluation of program performance. The evaluation compares program progress and accomplishments against established plans and standards to determine real or potential problem areas, to assess program impacts, and to provide recommendations for management action. In short, it is a focused, independent audit of program performance.

The tools and techniques of review and analysis may be utilized with all three control parameters. As applied to program management cost control, review and analysis activity attaches primarily to those critical statutory and regulatory requirements associated with the use of public funds the thrust of the activity being to insure total compliance. Review and analysis may also be

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[1] Ibid., p. 19.

applied to cost control as an independent audit of the effectiveness of the total financial management program.

The essence of the review and analysis concept is that it is an independent assessment. Direction of the activity may be under the aegis of the program manager, but it is separate and distinct from the control activity of operating officials. Even though review and analysis frequently utilize the same base data used by operating officials, the analysis is performed independently, and differing conclusions may be drawn.

Cost Parameter Analysis Overview

The cost parameter of the PPL analysis matrix contains eight individual cells as follows:

1. RDT&E Phase/Strategic Level
2. RDT&E Phase/Tactical Level
3. Production Phase/Strategic Level
4. Production Phase/Tactical Level
5. Deployment Phase/Strategic Level
6. Deployment Phase/Tactical Level
7. Termination Phase/Strategic Level
8. Termination Phase/Tactical Level

These relationships, as well as the allied schedule and technical performance relationships, were introduced illustratively in Figure 1 in Chapter I.

All cells in the cost segment of the PPL analysis matrix displayed common characteristics when subjected to examination of the assessment and definition factors and the interrogation and identification criteria. These particulars of commonality are discussed in terms of the total parameter prior to delving into the specifics of each individual cell in succeeding sections. The examination of management control requirements was conducted only on a cell by cell basis.

Assessment and Definition

The total cost parameter is subject to a number of exogenous and endogenous influences.

In the case of the ABM debate, the external or publicized focus of the political issue was the deployment decision. The arguments tended to polarize around "go" and "no-go" alternatives with little, if any, middle ground. The authoritative debates were principally technical in nature, but the vehicle of expression was found in the authorization and appropriation legislation.

The level of funding for weapon system programs is increasingly becoming an economic affordability issue. The service budgets under PPBS must compete on a priority basis in order to form a comprehensive DoD budget which, in turn, must compete with nondefense budgets. It is interesting to note that the composition of federal expenditures has shifted dramatically in recent years. As an example, in 1960 defense expenditures amounted to over half of the total spending, while in 1976 the defense budget fell to less than 30 percent of the total budget outlay.[1] The 1976 President's budget reflected a reversal of this trend, as did the 1977 budget.[2] The 1978 budget submission to Congress by the President also proposed a real increase, after adjustment for inflation, in defense

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[1] Barry M. Blechman, Edward M. Gramlich, and Robert W. Hartman, Setting National Priorities: The 1976 Budget (Washington, D.C.: Brookings Institution, 1975), p. 7.

[2] U.S., Executive Office of the President, Office of Management and Budget, The United States Budget in Brief: Fiscal Year 1978 (Washington, D.C.: Government Printing Office, 1977), pp. 16, 28.

spending.[1] Affordability was an economic issue in 1967 at the time of the production decision, but the concern was aimed primarily at the investment fund expenditure and not the appropriation of development funds. The principal concern was that ABM would divert money from domestic programs.[2]

Public opinion concerning the defensive utility of Safeguard varied throughout the program's life cycle, but it was generally keen particularly in the academic, intellectual, and scientific communities. Not unlike the political influence, public opinion ultimately found expression in the authorization and appropriation processes.

The technology factor in the Safeguard program was extraordinarily high throughout the life span of the program. This was particularly true of the RDT&E phase. This effort was subject to considerable change in direction and was nonrepetitive in nature. Even the production program represented a high level of technological attainment, but many aspects of it were repetitive.

Endogenous influences also had a dramatic effect on the cost parameter. Existing Department of the Army management doctrine was well articulated with respect to cost control and it applied with equal intensity to all fiscal appropriations. All Department of the Army activities participating in the Safeguard program were bound by the same regulations. Other government agencies outside the Department of the Army were generally bound by similar regulations since all basically derived their precedent from public law.

Participating contractors generally had their own cost accounting systems. When deemed compatible with the DoD requirements, contractor systems were acceptable. When not acceptable, contractor cost accounting

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[1] Ibid.

[2] Adams, Ballistic Missile Defense, p. 210.

systems generally had to be upgraded until they met minimum criteria. The type of contract specifies the cost data to be reported by a contractor. Detailed and explicit data may be required under some forms; others may require less. This must be considered in defining cost reporting standards. Prime contractors were required to secure appropriate cost reporting from their subcontractors and vendors.

The original program manager held a highly disciplined view of program management, particularly with regard to cost control. His influence was apparent throughout the total organization. The primary mechanism used by the program manager for expressing his management requirements was the Safeguard System Master Plan (SSMP).[1] Specifically, the SSMP was:

> ...utilized by the SENSM as the vehicle for approval of major concepts and program actions, as documentation for obtaining necessary approvals of major concepts and program actions, as documentation for obtaining necessary approvals of higher authority, for review and analysis of program plans and accomplishments, for coordination of system activities and developing standardized procedures including a uniform and formal planning process.[2]

The SSMP was a dynamic plan. It was revised as the program moved forward and as program direction and emphasis changed over time.

The objective and scope of the cost control action was very straightforward. In sum, it amounted to active participation in the PPBS for all Safeguard activities. This translated into controlling the allocation and utilization of Safeguard fiscal resources approved in the Five Year Defense

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[1]The Safeguard System Master Plan (SSMP) was redesignated the Ballistic Missile Defense Master Plan (BMDMP) during the 1974 reorganization. Both designations are used in this study interchangeably. It should be noted that only the latest revision of the BMDMP is cited in the bibliography.

[2]U.S., Department of the Army, Principles of Management, SSMP Part No. 2.01 (Washington, D.C.: Office Chief of Staff, 13 April 1968), p. 16.

Program (FYDP) and authorized for obligation, preparation of all budget documentation, and submission of required planning and programming information.

Several factors were critical in defining the type of control action required for management control of costs. First, the program manager was responsible for all Safeguard fiscal resources used by other participating government agencies, and all such agencies were required to render periodic plans and reports to the program manager. Second, the cost information collected was used to: (1) prepare required higher headquarters reports and inputs, (2) permit assessment by the program manager of program progress, (3) facilitate implementation of corrective action and reprogramming as required, and (4) enhance the effective utilization of Safeguard fiscal resources. Third, cost reporting data were required from all activities using Safeguard funds. Fourth, the control situation was highly repetitive, requiring monthly reporting of many aspects at a minimum. Fifth, proactive control was required. This meant that the control mechanism had to be a "steering" type control capable of providing management with the information necessary to seek out positive beneficial opportunities for program advancement and direction through disciplined search of anticipated future activities and occurences. The control mechanism also had to be capable of early detection of future trends by means of leading indicators. Sixth, cost is a sensitive predictive device for program progression. This asset had to be exploited to the fullest. Seventh, the cost control situation required essentially 100 percent tracking or measurement; statistical sampling was not an acceptable alternative. Finally, timeliness of reporting and age of data were two important factors in defining the cost control problem.

Interrogation and Identification

There should have been few, if any, constraints in the cost control situation with the possible exception of the affordability of desired control actions. Timeliness of reporting and currency of data reported are common problems with large-scale formal control systems. The Safeguard situation was such that timely reporting of cost data was essential to successful management of the total effort. The vacillation in program guidance, manifested in continual reductions in the number of planned sites, also caused added stress to the control situation.

Affordability of the cost control system did not materialize as a significant issue at the outset. It was only as the Safeguard fiscal program was incrementally decreased that the costs of the cost control system became more expensive than the benefits derived.

The obvious integrative linkage in the cost parameter is the common denominator of dollars as a yardstick of measurement. Care must be used in exercising this linkage, however, due to the effect of inflation on dollars, which is a function of time. Thus, while a compilation of figures shown in current dollars reflects the differences in actual cash outlays by year, the "real" purchasing power of the dollars must be equated to a base year, and all other year dollars either inflated or deflated accordingly. This characteristic of dollars changing in value over time due to inflation has an effect on the budget process in particular. Future year budget estimates are inflated by a predetermined inflation formula which does not always match the actual rate. Actual inflation rates higher than the formula result in shortfalls in the budget, while inflation rates lower than the formula result in windfalls.

The common characteristics of the cost parameter, resulting from an across-the-board examination of the assessment and definition factors and the interrogation and identification criteria, are summarized for convenience in Table 2.

RDT&E Phase

This section of this chapter contains the first analysis of individual cells in the PPL analysis matrix. Two cells are analyzed in this section and two each are analyzed in the succeeding three sections for a total of eight cell analyses in this chapter.

The two cells discussed in this section share a common phase dimension. They are differentiated by the level dimension. The first cell is defined by the strategic level while the second cell is defined by the tactical level.

The cost parameter in the RDT&E phase is concerned with research funds. These funds are provided under the research, development, test, and evaluation (RDT&E) fiscal appropriation. It is the only fiscal appropriation available for use in this phase.

Strategic Considerations

Research and development activity, by its very nature, is exploratory in character and is best controlled in a general rather than a specific manner.[1]

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[1]Interesting discussions on program control in research and development may be found in Robert W. Samuel, "Research: Meaning of the Term," in National Security Management: Defense Research and Development, ed. by Ralph Sanders (Washington, D.C.: Industrial College of the Armed Forces, 1968), pp. 75-79; Chase and Aquilano, Production and Operations Management: A Life Cycle Approach, pp. 607-11; and Roman, Research and Development Management: The Economics and Administration of Technology, pp. 364-65.

TABLE 2

EXAMINATION RESULTS COMMON TO ALL PPL ANALYSIS MATRIX CELLS IN THE COST PARAMETER

EXAMINATION CONSIDERATIONS	SUMMARY EXAMINATION RESULTS
ASSESSMENT AND DEFINITION	
INFLUENCES	
EXOGENOUS	POLITICAL – HIGH VISIBILITY IN CONGRESS
	ECONOMIC – QUESTION OF AFFORDABILITY; DIVERSION OF FUNDS FROM DOMESTIC PROGRAMS
	PUBLIC OPINION – KEEN INTEREST
	TECHNOLOGY – RELATED PRIMARILY TO TECHNICAL PERFORMANCE
ENDOGENOUS	EXISTING U.S. ARMY MANAGEMENT DOCTRINE – STRUCTURED
	OTHER GOVERNMENT AGENCIES – BOUND BY ARMY DOCTRINE
	PARTICIPATING CONTRACTORS – UNSTRUCTURED BUT DISCIPLINED ; FAMILIAR WITH U.S. ARMY REQUIREMENTS
	MANAGEMENT PHILOSOPHY OF PROGRAM MANAGER – DISCIPLINED
OBJECTIVES AND SCOPE	CONTROL ALLOCATION AND UTILIZATION OF ALL FISCAL RESOURCES APPROVED FOR PROGRAM IN FIVE YEAR DEFENSE PROGRAM (FYDP)
KEY FACTORS	ALL PARTICIPANTS MUST REPORT COST INFORMATION
	INFORMATION USED TO CONTROL COSTS
	INPUT DATA FROM PARTICIPANTS IN REQUIRED FORMAT AND ON SPECIFIED TIMES
	CONTROL SITUATION REPETITIVE
	PROACTIVE CONTROL REQUIRED
	DATUM GOOD PREDICTIVE DEVICE
	100 PERCENT MEASUREMENT REQUIRED
	TIMELINESS OF REPORTING IMPORTANT
INTERROGATION AND IDENTIFICATION	
CONSTRAINTS	TIMELINESS OF REPORTING ; VACILLATION IN PROGRAM GUIDANCE
LATENT INTERDEPENDENCIES	DOLLARS AS COMMON DENOMINATOR
CHARACTERISTICS	DOLLARS CHANGE OVER TIME DUE TO INFLATION

This is not to suggest that research and development is uncontrollable from a management perspective, but rather that control of research and development activity reflect a managerial philosophy consistent with program objectives. The control of development funds may be used as a direct means for accomplishing this purpose.

Assessment and Definition

Prior to the production and deployment decision, the development program was managed as an end in itself. Production planning was pursued, but it was integral to the development effort. The advent of the production and deployment decision added a whole new dimension to the program management task. The development program became a portion of the total activity in lieu of being the sole activity. As a consequence, it became necessary to integrate the research and development program funding profile and cost control management activities into a total financial management system incorporating all fiscal appropriations. This effort became a problem at the outset of the Safeguard program.

The development contractor utilized a cost reporting method that was function or task oriented and basically paralleled the organization structure. The method had been in use for some time prior to the production decision and had been deemed satisfactory for cost control by Army program management personnel. In a program as large and complex as the Safeguard program, however, an extensive quantity of data had to be integrated and summarized in order to satisfy the management information requirements of various levels of management. This mandated the use of a common management structure with standard definitions. This standard structure was the Safeguard Project Work

Breakdown Structure (WBS).[1] Because of the methodology used by the development contractor, development costs were not directly relatable to the Safeguard Project Summary WBS. This deficiency, in turn, precluded summarization of cost data upward to established WBS subsystem levels and prevented fiscal audit downward in the WBS to standard work package elements. An RDT&E contract WBS[2] was utilized for cost reporting purposes, but it had no validity in the approved Safeguard Project Summary WBS. The result was that detailed development program costs for the prime development contractor were relatable neither to other development program costs nor to common work package elements of other fiscal appropriations.

Interrogation and Identification

The development contractor cost reporting difficulty mentioned above represented a serious constraint in attempts to develop realistic and accurate cost control programs involving data summarization, audit downward through a common WBS with standard definitions, and fulfillment of higher headquarters cost reporting requirements.

The deficiency had a more subtle impact as well. Without the ability to track costs into the Safeguard Project WBS, the use of dollars as a common denominator with other fiscal appropriations was seriously undermined. In effect, the prime contractor portion of the development program under these

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[1] U.S., Department of the Army, Project Summary Work Breakdown Structure, Safeguard System Master Plan (SSMP) Part No. 3.05 (Revision No. 1) (Washington, D.C.: Office of the Chief of Staff, 2 November 1970), pp. iii-iv.

[2] U.S., Army Safeguard System Command, Safeguard RDTE Development Contract Work Breakdown Structure, Safeguard System Master Plan (SSMP) Supplement No 3.05.B (Huntsville, Alabama, 27 January 1972).

conditions became an independent cost program almost totally isolated from the standard cost control activity.

Management Control Requirements

The problem was never solved directly. It was finally diminished through passage of time and a series of compromises. In October, 1970, the program manager authorized use of the existing techniques for prime development contractor cost reporting. He stipulated, however, that the development contract data be incorporated into the Safeguard Project Summary WBS through a process of direct correlation. Allocation of costs was to be made only when the effort could not be uniquely identified. The approval was a one-time deviation for the specific contractor involved. It was granted to preclude undue interruption in the program during a critical time in the development and test effort.[1]

The primary quantified standard used in the cost control area was the forecast of obligations for all current and prior year funds. The forecasts for obligations were derived from each agency's approved plan for execution of its approved program. The plans were developed at the budget project account or summary program level by fiscal year. Each installation and activity receiving RDT&E funds in support of the Safeguard program by allocation, sub-allocation, allotment, or as an approved operating budget were required to report. This

[1]Alfred D. Starbird, Lieutenant General, USA, Safeguard System Manager, "Management of the Safeguard Development Effort," letter to Commanding General, U.S. Army Safeguard System Command, 19 October 1970, Ballistic Missile Defense Organization Files, Washington, D.C.

statement of applicability was to insure that all funds were reported, but not more than once.[1]

The control tolerances were direct and meaningful. Variations in the running monthly cumulative totals exceeding plus or minus 10 percent between successive monthly reports were to be comprehensively yet concisely explained at the level of detail reported. Variations in the end of quarter (three-month time period) or total fiscal year totals exceeding plus or minus 10 percent between successive monthly reports were also to be explained. In this latter case, however, explanations were only required at the fiscal appropriation total level. Explanations were to accompany the standard report. No requirement existed for exception reporting.[2]

Reporting requirements were specified as monthly, and no requirement for exception reporting was established in SSMP 2.06.02.[3] The potential of exception reporting was recognized as a principle of financial resources management, however.[4]

Tactical Considerations

Tactical considerations included a philosophical need to control research and development to a lower level than required for reporting at the strategic level. This still suggests, however, a general rather than a specific control methodology.

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[1]U.S., Department of the Army, Safeguard Status of Funds Report RCS SAFSM-8 (R-1), Safeguard System Master Plan (SSMP) Part No. 2.06.02 (Revision No. 1) (Washington, D.C.: Office Chief of Staff, 6 March 1970), pp. 2, 4, 6.

[2]Ibid., p. 4. [3]Ibid., p. 1.

[4]U.S., Department of the Army, Sentinel Principles of Management, p. 19.

Assessment and Definition

At the tactical level, the prime mission was one of managing the prime development contractor expenditures. Integration of cost data with similar cost data from other installations or activities was viewed by many at this level as only a concomitant and not particularly compelling requirement. For purposes of managing the prime contractor effort, the system in use had historical precedence and acceptance, was viewed as consistent with a philosophy of general as opposed to specific control of research and development activity, and maintained the status quo of the management situation.

At this level of management and decision-making the cost control system was deemed totally acceptable as a control technique. Except for the difficulties encountered in integrating the data with other comparable data, the system was workable. In other words, viewed from the tactical perspective as a tactical tool, the system was at least adequate.

Interrogation and Identification

Viewed as essentially a stand alone and independent management control situation (which is how the situation was viewed at this level), the cost control reporting system had no major constraints, no potential for latent interdependencies, and no distinguishing characteristics.

Management Control Requirements

The primary quantified standard used in the cost control area at the tactical level was the same as at the strategic level, with two notable exceptions. First, the data were collected and reported at a significantly lower level of detail. Second, reports were submitted to the applicable installation or activity commanders rather than to the program manager. These reports were generally the base reports from which strategic level reports were generated.

Tolerances and reporting requirements were consistent with strategic requirements. Individual installation or activity commanders were permitted to establish more stringent thresholds and tolerances than imposed at the strategic level and they frequently did so.

Production Phase

The two cells discussed in this section are differentiated only by the level dimension. The first cell concerns the strategic level, while the second is defined by the tactical level.

The cost parameter in the production phase is concerned with investment funds. These funds are provided under both the Procurement of Equipment and Missiles, Army (PEMA)[1] and the Military Construction, Army (MCA) fiscal appropriations.

Strategic Considerations

Production activity tends to be more certain in character than research and development activity. Elements of the activity may still be enormously complex, but, in general, it is more predictable than research and development and more susceptible to specific control. The trend toward more specific cost control is also a function of program maturity. As an example, the Safeguard System Charter in 1970 specifically charged the program manager with

[1]In FY 72, Congress revised the PEMA appropriation to separate it into five separate appropriations. The appropriation cited for missile procurement was designated simply Missile Procurement, Army (MIPA). Safeguard reporting documents continued to use the designation "PEMA," so it will be used in this study as well.

responsibility for insuring "...that procurement cost is minimized through cost control, change control, contractual enforcement, and contractor motivation."[1] The original Sentinel charter did not contain such a proviso.

Assessment and Definition

In addition to the development program problem described above, it was recognized early in the Safeguard program that an incompatibility of system management control documentation existed. The major areas of concern involved the inconsistencies in nomenclature, definitions, and hierarchic descriptions of the program. Specifically, severe differences existed between the Safeguard WBS, the weapon system generation breakdown, the system specification tree, and the milestone coding system. This lack of commonality of definition and subdivision of program elements seriously jeopardized attempts to assure a common understanding, recording, and reporting of data throughout the BMD community. Additionally, these major descrepancies were not in accord with the spirit and intent of Department of Defense requirements and regulations.[2]

The origin of the problem was almost identical to the RDT&E problem previously mentioned. The prime production contractor was reluctant to change from the production planning structure developed three years earlier by a joint contractor/Army team. Stated reservations were anticipated cost impacts and

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[1]Stanley R. Resor, Secretary of the Army, "System Charter: Safeguard Ballistic Missile Defense System," Memorandum for Chief of Staff, U.S. Army, 14 August 1970, Ballistic Missile Defense Organization Files, Washington, D.C.

[2]Billy L. Walker, Major, USA, "Implications of Approval of the New Safeguard Work Breakdown Structure," Memorandum for General Starbird, 10 August 1969, Ballistic Missile Defense Organization Files, Washington, D.C.

loss of familiarity with the management system by experienced personnel.[1] Additionally, the contractor foresaw a proliferation of line items in the contract instrument with attendent detailed reporting and serious impact on contracting, financial, and engineering activities for both itself and its subcontractors.[2]

The basic issue was actually interwoven with the underlying principle that common definitions and subdivision of work elements provided a vehicle for more pervasive insight into the details of program accomplishments and progression. This, in turn, inherently formed a basis for more meaningful analysis and greater control of all program activity by the program manager. It is distinctly possible that this potential for added visibility at the strategic level was purposefully resisted at the tactical level by the prime contractor.

Interrogation and Identification

The prime production contractor's reluctance to incorporate the common program WBS impeded the program manager's attempts to integrate cost data from all participants except artificially through pro ration and synthetic allocations of cost details. It also created significant problems at the strategic level in determining prudent allocation of financial resources.[3]

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[1] S. C. Donnelly, General Manager Safeguard System, Western Electric, "Safeguard Work Breakdown Structure," letter to Brigadier General R. C. Marshall, Commander, U.S. Army Safeguard System Command, 15 September 1969, Ballistic Missile Defense System Organization Files, Washington, D.C.

[2] M. L. Fox, Manager, Contract Management, Western Electric, "Preliminary Baselines for Safeguard Summary Work Breakdown Structure," letter to Commanding General, U.S. Army Safeguard System Command, 1 July 1969, Ballistic Missile Defense Organization Files, Washington, D.C.

[3] Alfred D. Starbird, Lieutenant General, USA, Safeguard System Manager, "Safeguard System Project Summary Work Breakdown Structure (SSMP 3.05)," letter to Commanding General, U.S. Army Safeguard System Command, 18 December 1969, Ballistic Missile Defense Organization Files, Washington, D.C.

Management Control Requirements

The problem was resolved, essentially without compromise, when the prime production contractor was directed to accept and utilize the Safeguard WBS developed by the Army.[1]

The quantified standards used in the PEMA and MCA fiscal appropriations were notionally similar to that established for the RDT&E fiscal appropriation. Differences were evident in the level of detail selected for reporting, however. Plans and accomplishment reporting were required for the system major item level for the PEMA fiscal appropriation. This is one level lower in detail in the WBS. Totals were summed to the budget project account and fiscal appropriation by fiscal year. The MCA fiscal appropriation was reported at the summary activity account level, which was effectively one level lower still in the WBS than the PEMA requirement. Totals were summed to the functional summary level (i.e., planning/design, real estate acquisition, construction) and fiscal appropriation by fiscal year.[2]

Control thresholds and tolerances and reporting requirements were as described above in the subsection on the cost/RDT&E/strategic cell.[3]

Tactical Considerations

Tactical level decision making involved a considerably greater depth of detail than did the strategic requirements. From a cost standpoint, the degree of

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[1]Minutes of Meeting, "Minutes of Work Breakdown Structure Meeting in Greensboro on September 24, 1969," 25 September 1969, Ballistic Missile Defense Organization Files, Washington, D.C.

[2]U.S., Department of the Army, Safeguard Status of Funds Report RCS SAFSM-8 (R-1), pp. 4-6.

[3]Ibid., p. 1.

control over PEMA and MCA funds is more specific than with RDT&E funds. Individual tasks are capable of more explicit definition and may be subdivided into smaller and more precise tasks. The relationships between cost, schedule, and technical performance data are also more definitive than with development activity, due to the higher degree of certainty associated with the production phase. The potential for downstream costs savings in the PEMA area are high through cost reduction effort during volume production.

Assessment and Definition

At the tactical level, the primary mission associated with the Safeguard BMD system was separated into four distinct activities: (1) execution of the approved procurement and production program[1]; (2) supervision of the activation program at tactical sites, including hardware installation and testing from the delivery of facilities by the Corps of Engineers until acceptance of the operational site by the combat user;[2] (3) preparation for system equipment logistic support to include a National Inventory Control Point (NICP), National Maintenance Point (NMP), depots, and transportation control systems;[3] and (4) design, construction, and acceptance of Safeguard tactical facilities.[4]

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[1]U.S., Army Sentinel System Command, Organization and Management Manual, p. 3.

[2]Ibid., p. 4.

[3]Alfred D. Starbird, Lieutenant General, USA, Sentinel System Manager, "Sentinel System Deployment Task Assignment - USAMC," letter to Commanding General, U.S. Army Materiel Command, 4 October 1968, Ballistic Missile Defense Organization Files, Washington, D.C.

[4]Alfred D. Starbird, Lieutenant General, USA, Sentinel System Manager, "Sentinel System Deployment Task Assignment - Chief of Engineers," letter to Chief of Engineers, U.S. Army, 4 October 1968, Ballistic Missile Defense Organization Files, Washington, D.C.

The task with respect to cost control was one of accomplishing mission within resources and on schedule. As a consequence, a situation similar to the RDT&E control problem existed for the prime contractor effort. The techniques and tools in use were adequate for control. They lacked only the inherent ability to relate directly to comparable data from other sources. This was not viewed as an insurmountable problem. As previously indicated, it was finally resolved, and the base data gathered at the tactical level was fully integratable through the common structure of the WBS.

Interrogation and Identification

The gradual conversion of all major control documents to common definitions and work packages enhanced the control of activity at the tactical level and permitted fulfillment of strategic reporting requirements. This conversion also demonstrated the use of interdependencies in addition to dollars. As an example, it became evident that commonality between the system generation breakdown and the WBS would permit cross reference between work packages and engineering drawing part numbers. This was a significant breakthrough for summation of costs. It also had implications for integration of cost, schedule, and technical performance data.

Management Control Requirements

Analysis of the management control requirements at the tactical level revealed the same basic relationship to the strategic level as was noted in the two RDT&E cells.

Deployment Phase

As with previous sections, the two cells discussed here are identical except for the level dimension. The first cell is the cost parameter/deployment phase/strategic level cell, while the second is the cost parameter/deployment phase/tactical level cell.

The cost parameter in the deployment phase is concerned with operating funds. These funds are provided under both the Operation and Maintenance, Army (OMA) and the Military Personnel, Army (MPA) fiscal appropriations.

The deployment phase is not normally under the purview of the program manager. In the early planning for Safeguard deployment, the program manager's direct responsibility for a tactical site was to conclude with the transfer of that site to the U.S. Army Air Defense Command (ARADCOM), the using element of the Army.[1] This relationship was changed in the 1974 BMD reorganization, wherein the program manager was assigned responsibility for operation of the Safeguard tactical facilities in North Dakota,[2] subsequently designated the Stanley R. Mickelsen Safeguard Complex.[3]

Strategic Considerations

The assignment of responsibility for operation of the Safeguard Complex was an atypical management responsibility for a program manager. It presented only a minor perturbation to the cost control situation, but no major increase in cost control situation complexity. This minimization of impact was due to a number of reasons. First, the program manager was responsible for

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[1]Resor, "System Charter: Safeguard Ballistic Missile Defense System."

[2]Howard H. Callaway, Secretary of the Army, "Program Charter: Ballistic Missile Defense Program," 20 May 1974, Ballistic Missile Defense Organization Files, Washington, D.C.

[3]U.S., Department of the Army, General Orders No. 21 (Washington, D.C., 21 June 1974).

operation of the site during installation and test of tactical equipment in preparation for activation. During the final stages of this period, the site was operated as a test facility in a pseudo-tactical mode. The cost situation closely paralleled that of tactical operation. Second, the cost situation involved in the operation of a tactical site is fairly straightforward and relatively simple. Requirements are well documented in Army Regulations. Finally, only one site was involved and the period of deployment lasted less than a year.

The fact that the site achieved operational status was significant from both a technological and political viewpoint, but it had minimal significance, for purposes of this study, in terms of the cost parameter.

Assessment and Definition

By definition the OMA and MPA fiscal appropriations are associated with the deployment phase, but use of these appropriations is not limited solely to this phase. Both appropriations may legitimately be used after production has been initiated. As an example, OMA funds may be used for such activities as pay of civilian personnel, procurement of organizational equipment, and for the operation and maintenance of organizational equipment and facilities. The MPA appropriation is used for pay, allowances, and subsistence of military personnel within program management offices.[1] As a consequence, the cost control environment in the Safeguard program had already encountered these two appropriations.

The minor perturbation, referenced earlier, involved the institution of Base Operations Accounts included in the OMA fiscal appropriation. These

[1]U.S., Department of the Army, Financial Administration: The Army Management Structure (AMS), pp. 4-1, 5-1.

accounts cover costs incurred for items which become post, camp, and station property and would not normally be deployed with using units.[1]

The management cost control system included provision for the OMA and MPA fiscal appropriations. It was expanded in coverage to encompass the funds associated with the deployment phase, including the Base Operations Accounts.

Interrogation and Identification

The addition of responsibility for the deployment phase presented no major constraints, provided no added potential for PPL analysis matrix cell interdependencies, and added no distinguishing characteristics to the cost parameter.

Management Control Requirements

The quantified standards used in the OMA and MPA fiscal appropriations were notionally similar to those established for the RDT&E fiscal appropriation. Planned and actual data were to be reported at the summary activity account level (similar to the MCA fiscal appropriation), with totals summed to the budget project account, budget program, and appropriation levels by fiscal year. MPA planned and actual data were to be reported at the appropriation level by fiscal year.[2]

Control thresholds and tolerances for Safeguard reporting were removed and did not apply to the deployment phase of Safeguard.[3]

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[1] Ibid., p. 5-4.

[2] U.S., Department of the Army, Status of Funds Report RCS BMDPM-8 (R-5), Ballistic Missile Defense Master Plan (BMDMP) Part No. 2.06.02 (Revision 5) (Washington, D.C.: Office Chief of Staff, May 1976), pp. 4-5.

[3] Ibid.

Reporting requirements were monthly, with the potential for special or exception reporting recognized.[1]

Tactical Considerations

The cost parameter/deployment phase/tactical level cell in the PPL analysis matrix did not add any additional considerations to the cost control situation beyond those described for the strategic level. The depth of detail required is lower in the WBS, but solution of the strategic level cost problem inherently resolves the problem at the tactical level. In essence, this cell did not materially influence the cost control problem or its solution beyond that already defined. Further description of this cell would be redundant and has been excluded from this study.

Termination Phase

For purposes of defining the cost control problem through consideration of the cost parameter, the termination phase is primarily an extension of the deployment phase. The two major fiscal appropriations are OMA and MPA. The termination phase adds no unique considerations or characteristics to the cost control situation. Therefore, further description of either cell would be redundant and has been excluded from this study.

Cost Control in Perspective

The focus of cost control in program management is financial management. This reflects a shift from the historical emphasis on financial accounting to a broader perspective of the cost parameter as both an input resource and a significant parameter for controlling program performance.

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[1] Ibid.

The cost parameter demonstrates an indirect sensitivity to the life-cycle phases, but primarily through the surrogate of fiscal appropriations. Stated differently, close examination of the management control requirements established for the cost parameter reveals that they were articulated by fiscal appropriation and not by life-cycle phase. Examination further reveals that fiscal appropriations are related to life-cycle phases, but with some overlap. As a consequence, fiscal appropriations tend to define their own particular functional phases in a slightly different manner than the typical life-cycle phases. The primary exception to this analysis is the direct correlation of the RDT&E fiscal appropriation to the RDT&E phase.

Management control requirements for the cost parameter at the strategic level, it would appear, should be derived independently of tactical level requirements and should be derived first. The concept of reporting increasingly higher level information summarizations to increasingly higher level managers suggests that tactical level requirements specify a greater depth of detail than strategic requirements. This means that each succeedingly higher echelon of management receives an increasingly higher level of information summarization. It also means that each level of summarization is supported by a lower level of detail corresponding to the lower level of decision-making. In theory, then, the cost parameter is highly sensitive to the level dimension of the PPL analysis matrix.

CHAPTER VI

THE SCHEDULE PARAMETER

This chapter is concerned with the schedule parameter of management control. It begins with a discussion of time both as a resource of program management and as a parameter of program performance measurement. In short, the first section delves into the nature of the schedule parameter. The next section pertains to those characteristics determined to be common to all cells in the schedule segment of the PPL analysis matrix when examined. The next four sections are correlated to the four phase dimensions of the PPL analysis matrix. Each section is subdivided into the two decision-making levels. The concluding section of this chapter is a brief summary of the salient features of the schedule parameter.

Schedule Control Considerations

Time has been defined by one authority as "...a resource in systems management, to be treated with indifference or used well like any other resource."[1] It is also a vehicle for measuring program performance. In these two particulars time is similar to money, as discussed in the previous chapter. Time differs from money in that it is neither authorized nor appropriated by Congress.

[1] J. Stanley Baumgartner, "Comment on the Value of Time and Its Effect on Defense Systems Acquisition," Defense Management Journal 8 (July 1972): 53.

Time cannot be deposited in an account, nor can it be stored. It is budgeted and scheduled nonetheless, and it may be critical in times of military urgency. Time limitations may also be imposed on programs much as dollar constraints are frequently imposed.

The schedule philosophy underlying a program plan may influence both cost and technical performance in either a positive or a negative way. It is the intent of this section to explore some of these relationships in general and some of the major considerations of schedule control in particular.

The Nature of Schedules

In a broad sense, program schedules tend to reflect either a cost emphasis or a time emphasis.[1] In the former, acquisition costs are minimized and program phases are predominately sequential with little overlap. In the latter, program phases are overlapped and acquisition costs are generally higher. Cost-emphasis schedules tend to be associated with peacetime conditions while time-emphasis schedules, with pressures for schedule compression and earliest possible deployments, tend to be associated with periods of national urgency such as the Korean conflict, the Vietnam hostilities, and putting man on the moon in the decade of the 1960s.

Definition and Description

Program schedules depict the time phasing of and interrelationships between the numerous activities and events associated with accomplishment of program objectives. Development of initial program schedules is accomplished as a function of the planning process of management. Steiner specifies the

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[1] Ibid., p. 56.

time-relatedness of the planning process in defining it as "...deciding in advance what is to be done, when it is to be done, how it is to be done, and who is to do it."[1] Of specific interest in this definition is the reference to a time element or schedule; i.e. "when it is to be done." Baumgartner expresses the same time-relatedness aspect in describing a program plan as a written document "...covering what is going to be done, how, when, by whom, for how many dollars, and what the major foreseeable problems are and how they will be overcome."[2] Archibald also underscores the need for program schedules in his description of the project summary plan.[3] The time-phased program plan, depicting summary and detailed schedules, is the primary target of schedule control activity.

Martino defines a schedule as "...a calendar timetable for allocating or committing resources to project activities within the limits available."[4] He further suggests that the primary purpose of scheduling "...is to complete the project in the best time and at the least cost."[5] A number of conventional scheduling tools and techniques are in use today to facilitate the scheduling process.[6] Frequently, these models not only provide the means for scheduling

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[1] George A. Steiner, Top Management Planning (New York: Macmillan Publishing Co., Inc., 1969), p. 7.

[2] J. Stanley Baumgartner, Project Management (Homewood, Illinois: Richard D. Irwin, Inc., 1963), p. 17.

[3] Russell D. Archibald, Managing High-Technology Programs and Projects (New York: John Wiley & Sons, 1976), pp. 136-137.

[4] R. L. Martino, Applied Operational Planning, (Vol. II of Project Management and Control) (New York: American Management Association, 1964), p. 17.

[5] Ibid.

[6] For a representative sampling see: Chase and Aquilano, Production and Operations Management: A Life Cycle Approach, pp. 250-311, 502-33;

program activity, but they also serve as the basis for performing the schedule control task. In a classic article on the interrelationships between planning and control, Peirce captured the essence of the thought in this manner:

> In the modern sense of an integrated planning and control system, then, planning refers to the construction of an operating program, comprehensive enough to cover all phases of operations, and detailed enough that specific attention may be given to its fulfillment in controllable segments. It may therefore be reiterated that the planning process must be conducted in direct relation to the needs of control.[1]

Thus, the output of the planning process may serve not only as a plan of future activities sequenced over time, but also as the schedule control standard against which to measure progress. Conceptualized in this manner, the schedule plan typically is a prime candidate for change when managerial control activities dictate the need for remedial action.

Concurrency

The topic of schedule concurrency has already been touched upon, but it requires amplification.

Schedule concurrency is defined as the overlapping of the RDT&E phase and the production phase in the execution of a program plan. The effect of concurrency is program schedule compression. The greater the degree of concurrency and the tighter the schedule, the greater the amount of overlap between the RDT&E and production phases. Conversely, the smaller the degree

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R. L. Martino, Allocating and Scheduling Resources, (Vol. III of Project Management and Control) (New York: American Management Association, 1965); Steiner, Top Management Planning, pp. 383-85; and Robert J. Thierauf and Robert C. Klekamp, Decision Making Through Operations Research, 2d ed. (New York: John Wiley & Sons, Inc., 1975), pp. 120-53.

[1] James L. Peirce, "The Planning and Control Concept," Controller 22 (September 1954): 403.

of schedule concurrency and the more relaxed the schedule, the smaller the amount of phase overlap.

In essence, schedule concurrency is a method for attempting to shorten the time required to put a new weapon system into operational use. It may also be the result of having deployment dates accelerated by higher headquarters. Under this concept, volume production of the weapon system is initiated with a system design configuration not yet fully tested and prior to completion of final design specifications. It should be noted that concurrency is a matter of degree, since some overlap between RDT&E and production almost invariably exists in weapon system acquisition.

Viewed from a cost perspective, excessive concurrency carries with it a heavy premium. Extensive redesign of a product after it is in volume production is a costly affair when it impacts production processes, procured vendor items and parts, raw materials, tooling, and retrofit of already produced items.[1] From a technical performance standpoint, it may result in imbalance between subsystem developments, reduction in development testing and evaluation, significant increase in the number of engineering design changes, and impairment of required performance characteristics.

On the other side of the ledger, time-emphasis schedules may result in earlier deployment with the combat user, earlier "wring-out" of the new system by the user, reduced influence of inflation on program costs, and longer operational life prior to obsolescence. In the final analysis, the time-emphasis

[1]Baumgartner, "Comment on the Value of Time and Its Effect on Defense Systems Acquisition," p. 54.

tight schedule may yield greater economic value through prolonged operational life.[1]

In the case of the original Sentinel program and the early Safeguard program a second type of concurrency also existed; i.e., a deployment concurrency. This form of concurrency involved the extensive overlap of site construction and installation activities at the many sites originally planned for activation. Early planning called for simultaneous construction and installation activity at as many as four to five sites. While it is difficult to quantify the significance of this form of concurrency, some insight may be gained through realization that each site was to be roughly equivalent to a fully self-sufficient Army installation.

Concurrency is generally regarded as a contributor to cost overruns in weapon system acquisition. During periods of cost-emphasis scheduling, which automatically deemphasize the time element, concurrency is to be avoided. It is notionally justified only when the need is urgent.[2]

Scheduling Models

The accomplishment of program effort in large-scale, complex endeavors is frequently performed in blocks or groupings of activity by multiple organizations. Specific blocks of effort are determined through system analysis to arrive at a logical management framework for program accomplishment. In the case of Safeguard, the blocks of effort were defined primarily by the work breakdown structure (WBS).

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[1] Ibid., p. 56.

[2] U.S., Congress, Joint Economic Committee, The Acquisition of Weapon Systems, Hearings, before the Subcommittee on Economy in Government, 91st Cong., 2d sess., 1970, pp. 441, 446.

Two basic scheduling models were used in defining Safeguard effort. They were the Program Evaluation and Review Technique (PERT) and milestone planning and control.

PERT[1]

The Safeguard PERT program was based on the fundamental concept that WBS work packages specified for PERT planning and control could be subdivided into subtasks and incremental activities as time-phased flow diagrams. Further, the Safeguard PERT program thoroughly embraced the basic PERT premise of requiring clear delineation and identification of project milestones, events, activities, and constraints and their sequence and precedent interrelationships.[2]

A major feature of the Safeguard PERT application was its capability to predict future schedule progress based on known status. Through use of the PERT data base, it was possible to conduct trade off and schedule simulation

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[1] Introductory explanations of the PERT concept may be found in: Evarts, Introduction to PERT; Joseph Horowitz, Critical Path Scheduling: Management Control Through CPM and PERT (New York: Ronald Press, 1967); J. J. Moder and G. R. Phillips, Project Management with CPM and PERT (New York: Reinhold Publishing Corp., 1964); and D. C. Robertson, Project Planning and Control (Cleveland, Ohio: CRC Press, 1967). Summarized descriptions may be found in: Arch R. Dooley, "Interpretations of PERT," Harvard Business Review 42 (March-April 1964): 160; Robert W. Miller, "How to Plan and Control with PERT," Harvard Business Review 40 (March-April 1962): 93-104; and Peter P. Schoderbek and Lester A. Digman, "Third Generation PERT/LOB," Harvard Business Review 45 (September-October 1967): 100-110. An Army view may be found in: U.S., Army Materiel Command, Army Programs: Program Evaluation and Review Technique (PERT) AMC Pamphlet 11-6 (Washington, D.C., January 1972).

[2] U.S., Army Safeguard System Command, Safeguard Management Information System Schedule Control Manual (Huntsville, Alabama: Management Data Systems Office, n. d.), p. 4-1.

studies in order to analyze alternatives prior to actual commitments to specific courses of action.[1]

Milestone Planning and Control[2]

The milestone planning and control model provided for the scheduling and control of specified program milestones. Milestones were both PERT supported and non-PERT supported. PERT supported milestones were significant events designated in the PERT networks for extraordinary management attention. Non-PERT supported milestones were significant events that served as management schedule control points, but were not suitable for incorporation in PERT networks. Non-PERT supported milestones were typically sufficiently quantified to facilitate determination of the degree to which milestone requirements had been met.[3]

In spite of the quantification of milestone requirements, non-PERT supported milestone data were more subjective than PERT schedule status because of the greater depth of detailed planning and management discipline required by PERT. By comparison, the milestone planning and control technique was generally less definitive than the PERT and tended to be operative at a higher level of summarization. In contrast, the PERT program contained a wealth of detail. It was used as a means of communicating detailed schedule information. It also was capable of summarization to those milestones which it

[1] Ibid.

[2] A brief discussion on the milestone concept and its relationship to other scheduling techniques may be found in: U.S., Department of the Army, Work Scheduling Techniques, Department of the Army Pamphlet No. 1-54 (Washington, D.C.: Government Printing Office, March 1968).

[3] Ibid.

supported, provided a reliable audit trail for applicable schedule data, and aided in determining interrelationships between milestones.

For control purposes, milestones contained only in the milestone planning and control model were monitored only through that model. Milestones contained in the PERT model were monitored both in the PERT model and the milestone planning and control model.[1]

Schedule Plan Execution

Execution of the schedule plan is integral to and a subset of program execution. The implementation of approved programs triggers the expenditure of funds for goods and services in accordance with program plans.

The execution of schedule plans encompasses many related activities such as plan base-lining, determination of critical schedule paths, performance reporting and feedback, and review and analysis. All are essential to comprehensive schedule control activity.

Schedule Plan Base-lining

Following completion and approval of the schedule plan, it is base-lined and controlled in much the same manner that technical documentation is controlled through the configuration management technique. This process insures that all proposed changes are properly coordinated, that only authorized changes are incorporated into schedule plans, and that an adequate audit trail is established and maintained. The base-line schedule constitutes a reference point of departure to which all changes and deviations must be specifically related.

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[1] Ibid.

Base-lining of costs and schedules is inherent in the planning, programming, budgeting system, but the primary emphasis is on the cost aspects.

Concept of Critical Paths

Identification of critical schedule paths in time-phased flow diagrams is a means of surfacing those program activities that will most benefit from intensified management.[1] Simplistically, the critical path in a schedule network is the longest time path through the network. Identification of the critical path, or in some cases the two or three most critical paths,[2] permit the manager to redistribute resources if he is attempting to shorten lead time or simply monitor the pacing program activities with greater intensity. Since redistribution of resources to reduce time in the critical path (to the point where it ceases to be the critical path) automatically, if successful, raises a limit path to critical path, the system is dynamic. It should be noted that this concept identifies the most critical schedule path, not necessarily the most essential or complex program path.

Performance Reporting

Once schedules are base-lined and implemented, they must be kept up to date through performance reporting. This feedback is essential if schedule control is to be effective.

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[1]An interesting alternative method of allocating management time may be found in George B. Stanton, Jr., "Put Your Time on the Winners," Industrial Engineering 9 (November 1977): 22-25.

[2]Secondary and tertiary paths are sometimes referred to as "limit paths" signifying that they are significant but less critical than "the critical path."

Schedule performance inputs should reflect sufficient depth to insure clear understanding of all performance data and proposed changes. As a minimum, schedule performance data should include:

1. Added/revised/deleted activities/events in the network.

2. Changes in activity/event sequence occurring during the reporting period.

3. Actual completion dates occurring during the reporting period.

4. Schedule date changes.

5. Forecast completion dates.

6. Activity time estimate changes for in-process or future activities.

7. Degree to which quantified requirements for completion of milestones were accomplished during the reporting period.

8. Narrative assessments and justifications.

Specific reporting requirements will vary with the peculiarities of the program, but the thrust is free and full disclosure of all relevant information.

Review and Analysis

Review and analysis activity applied to schedule control is generally focused on independent assessment of the basic management and technical logic underlying the base-line schedule and proposed changes to the base line. Specifically, this aspect of the review and analysis work might concentrate on validation of the priority sequencing of schedule events and activities and the associated time factors. This effort would also seek to identify errors of omission in the logic pattern. Discovery of such errors, if any exist, tends to eliminate or minimize the impact of program voids or stoppages caused by such omissions.

Interfaces between blocks of effort or activity representing organizational interfaces and shared responsibility would also be prime candidates for independent assessment. The prime concern here would be reverification that interfaces were fully defined not only as to management and technical logic, but in terms of the temporal reference as well.

Finally, the review and analysis activity might be prudently applied to the non-PERT supported milestones. Here the logic is normally more subjective and less well defined than with PERT supported milestones. The interrelationships between activities may not be indicated, and milestones do not provide a detailed framework for allocation of resources.[1]

Schedule Parameter Analysis Overview

The schedule parameter of the PPL analysis matrix is structured identically to the cost parameter. It contains the following eight individual cells:

1. RDT&E Phase/Strategic Level
2. RDT&E Phase/Tactical Level
3. Production Phase/Strategic Level
4. Production Phase/Tactical Level
5. Deployment Phase/Strategic Level
6. Deployment Phase/Tactical Level
7. Termination Phase/Strategic Level
8. Termination Phase/Tactical Level

As was found in the cost examination, all cells in the schedule segment of the PPL analysis matrix displayed common characteristics when analyzed. These

[1] Steiner, Top Management Planning, p. 384.

common traits are discussed for the total parameter in terms of the assessment and definition factors and the interrogation and identification criteria.

Assessment and Definition

The program schedule and the schedule control parameter are directly influenced by time-emphasis considerations that stress the temporal reference. Cost-emphasis and technical performance-emphasis considerations, on the other hand, influence program schedule and schedule control in a more subtle or indirect manner. With time emphasis, the schedule control parameter is normally highlighted due to the direct emphasis on schedule. When either of the other two parameters is emphasized, schedule is driven by cost or technical performance factors, but schedule control may still be accentuated due to its importance in helping control the other two parameters. As a consequence, the schedule control parameter tends to retain a high degree of importance to program management irrespective of the central thrust of program emphasis.

In general, Congressional interest in the antiballistic missile (ABM) program centered on the basic validity of deployment prior to the deployment decision and on the scope of the program following the decision. The political influence emanating from this interest took form in the authorization and appropriation of fiscal resources. While Congressional support existed, fiscal resources flowed into the program. As that support faded, so did the resource allocations. The deployment schedule was not of direct concern, and the schedule control parameter was influenced little by the political environment.

This same basic conclusion is true also of national economic and public opinion influences. Both found expression ultimately in the allocation of fiscal resources to the program rather than through schedule constraints.

The technology factor was the only major external influence that directly affected the schedule control parameter. The RDT&E activity represented an extraordinarily high level of technological complexity and was nonrepetitive in nature. These two factors alone suggested some form of Line of Balance technique such as PERT as a logical candidate for consideration as the principal schedule control technique. Additionally, the production program, involving construction of a number of intricate structures, also seemed to suggest PERT as a schedule control tool.

The internal environment had an impact as well on the schedule control parameter. Department of the Army management doctrine was not as concise regarding schedule control as it was concerning cost control. This meant, therefore, that schedule control requirements were more flexible than cost control requirements and permitted the program manager greater latitude in establishing his requirements. It also meant, however, that there was less existing uniformity in the ongoing schedule control systems operating generally within other government agencies and military/aerospace industrial firms.

The introduction of the Cost/Schedule Control Systems Criteria (C/SCSC)[1] into the Safeguard program in the early 1970s signaled a new initiative toward attainment of consistency in cost and schedule performance measurement by major contractors. Introduction of C/SCSC did not cause any major changes in the schedule control parameter. It did serve to provide greater confidence in the fidelity of cost and schedule performance data reported by validated contractors.

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[1] A brief, authoritative description of C/SCSC may be found in J. Stanley Baumgartner, "C/SCSC Alive and Well," Defense Management Journal 10 (April 1974): 32-35.

From the outset, the program manager expressed his preference for hierarchic milestones as the primary schedule control tool.[1] Milestones reported to and monitored by the program manager constituted the approved schedule base line.[2] The concept envisioned that the milestones reported to the program manager would be supported by more detailed schedule data at succeedingly lower levels in the chain of command.[3] Concisely stated, the objective and scope of the schedule control action was to control the temporal element of program activities, events, and milestones in all phases of the Safeguard program life cycle.

Analysis of the key factors contributing to definition of the type of required control action revealed similarities to the companion analysis for the cost parameter. The analysis also resulted in a reasonably definitive profile of the type of schedule control action required. First, all participating government agencies and weapon system contractors were required to report schedule performance and change data to the program manager. Second, the schedule performance data were used to: (1) maintain the schedule data base, (2) prepare required higher headquarters reports and schedule performance inputs, (3) permit the program manager to monitor pertinent milestones, (4) facilitate the effective allocation of all program resources, and (5) facilitate the establishment and maintenance of program and organizational interrelationships. Third, schedule

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[1] U.S., Department of the Army, Sentinel System Control and Reporting, Sentinel System Master Plan (SSMP), Part No. 2.06 (Washington, D.C.: Office Chief of Staff, 1 August 1968), p. 1.

[2] U.S., Department of the Army, Milestone Report RCS SAFSM-3, Safeguard System Master Plan (SSMP), Part 2.06.01, Revision 1 (Washington, D.C.: Office Chief of Staff: 23 June 1969), p. 1.

[3] U.S., Department of the Army, Sentinel System Control and Reporting, p. 1.

performance data were required from all organizations using Safeguard funds. Fourth, the control situation was simultaneously nonrepetitive and repetitive. The RDT&E activity was nonrepetitive and marked by a high degree of complex interrelationships. The hardware fabrication element of the production program was predominately repetitive, while the missile site construction activity was nonrepetitive. These concurrent yet different situations suggested the use of several schedule control tools and techniques. Fifth, as with cost control, proactive control was required in the schedule parameter as well.

Sixth, the schedule parameter is an excellent predictive device or early warning indicator. In a time-emphasis environment, schedule is its own indicator. In a cost-emphasis environment, negative schedule variances tend to indicate poor planning, true schedule slippage, or a combination of both. All three conditions impact costs adversely and drive them up. Negative schedule variance trends typically surface in performance data before negative cost trends appear. In a technical performance-emphasis environment, schedule variance tends to lag technical performance variance, but it is frequently easier to assess. As a consequence, schedule variance is more visible. Seventh, the schedule control situation did not require one hundred percent measurement or tracking. In some instances, tracking of milestones alone was sufficient. Finally, timeliness of reporting and age of performance data were two highly significant factors in defining the schedule control situation. This assessment was identical to that for the cost parameter.

Interrogation and Identification

The interrogation and identification aspect of the examination considerations, it will be remembered, is concerned with defining the constraints, latent interdependencies, and characteristics of the control problem. Here again, there was a degree of commonality between the cost and schedule parameters.

Timeliness of reporting and currency of performance data reported was a major constraint in the schedule parameter. Particularly during the original Sentinel program, the high degree of deployment concurrency made timely reporting of schedule performance and proposed changes absolutely essential. Reductions in the degree of deployment concurrency brought about by Safeguard planning and the final reduction of effort to one site greatly ameliorated this constraint in the schedule parameter.

Affordability of the schedule control system was questioned in inverse relationship to incremental reductions in the program. As the program was phased down to ultimate termination, the need for a large-scale schedule control system also diminished, and the cost of the system as a function of its utility rose to a point where it became cost prohibitive. At that point the entire management control system was reduced in scope, the dedicated automatic data-processing equipment released, and dedicated schedule control personnel reassigned.

A clearly meaningful integrative linkage in the schedule parameter is the common denominator of time as a reference of measurement. Normally, in a large-scale project, the common unit of measure is "work days," but "calendar days" are also used as a reference. This basic unit may be expanded into weeks, months, or years. It may also be subdivided into shifts and hours. The basic units of measurement and reporting and proper conversion factors are typically specified in the schedule control plan. Schedule may also be converted to dollars rather easily, thus permitting both schedule and cost status and variances from plan to be measured in a common reference of dollars.[1]

An unchanging characteristic of time is its finitude. The amount of calendar time is finite and inflexible and can be neither expanded nor contracted. The effect of this characteristic on activity schedule may be altered, however, through the time-cost function. In its simplest form, the time-cost function assumes that cost and time in a large-scale endeavor are related inversely and linearly, although other relationships may be determined or assumed.[2]

The common characteristics of the schedule parameter resulting from an across-the-board examination of the assessment and definition factors and the interrogation and identification criteria are summarized in Table 3.

RDT&E Phase

This section of this chapter contains the first analysis of individual cells in the schedule parameter. Two cells in the PPL analysis matrix are analyzed in this section. Two each are analyzed in the next three sections for a total of eight cell analyses in this chapter.

The two cells examined in this section share the common phase dimension of RDT&E, but are differentiated by the level dimension. The first cell is defined by the strategic level; the second by the tactical level.

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[1] This is the basic premise upon which the DoD Cost/Schedule Control System is built. Schedule is converted to and expressed in dollars through means of a time-phased budget plan reflecting the budgeted cost of work scheduled.

[2] J. N. Holtz, An Analysis of Major Scheduling Techniques in the Defense Systems Environment, Memorandum RM-4697-PR (Santa Monica, California: Rand Corporation, October 1966), p. 42.

TABLE 3

EXAMINATION RESULTS COMMON TO ALL PPL ANALYSIS MATRIX CELLS IN THE SCHEDULE PARAMETER

EXAMINATION CONSIDERATIONS	SUMMARY EXAMINATION RESULTS
ASSESSMENT AND DEFINITION	
INFLUENCES	
EXOGENOUS	POLITICAL – CONGRESSIONAL INTEREST RELATED TO COST
	ECONOMIC – COST AFFORDABILITY INFLUENCED SCHEDULES
	PUBLIC OPINION – RELATED PRIMARILY TO COST
	TECHNOLOGY – HIGH LEVEL OF TECHNOLOGICAL COMPLEXITY; BOTH REPETITIVE AND NONREPETITIVE
ENDOGENOUS	EXISTING U.S. ARMY MANAGEMENT DOCTRINE – LESS STRUCTURED THAN COST; LESS DETAIL REQUIRED
	OTHER GOVERNMENT AGENCIES – UNSTRUCTURED
	PARTICIPATING CONTRACTORS – UNSTRUCTURED BUT DISCIPLINED; FAMILIAR WITH U.S. ARMY REQUIREMENTS
	MANAGEMENT PHILOSOPHY OF PROGRAM MANAGER – DISCIPLINED
OBJECTIVES AND SCOPE	CONTROL THE TEMPORAL ELEMENT OF PROGRAM ACTIVITIES, EVENTS, AND MILESTONES IN ALL PHASES OF THE LIFE CYCLE
KEY FACTORS	ALL PARTICIPANTS MUST REPORT SCHEDULE INFORMATION
	INFORMATION USED TO CONTROL SCHEDULES
	INPUT DATA FROM PARTICIPANTS IN REQUIRED FORMAT AND ON SPECIFIED TIMES
	CONTROL SITUATION CONTAINS BOTH NONREPETITIVE AND REPETIVE ELEMENTS
	PROACTIVE CONTROL REQUIRED
	DATUM EXCELLENT PREDICTIVE DEVICE
	100 PERCENT MEASUREMENT NOT REQUIRED
	TIMELINESS OF REPORTING IMPORTANT
INTERROGATION AND IDENTIFICATION	
CONSTRAINTS	TIMELINESS OF REPORTING
LATENT INTERDEPENDENCIES	DAYS AS COMMON DENOMINATOR
CHARACTERISTICS	FINITUDE OF TIME

Strategic Considerations

The RDT&E phase of the Safeguard program was a technical performance-emphasis program. The program manager monitored schedule performance at the strategic level on the basis of accomplishment, slip, or change of significant milestones in the RDT&E program. His initiatives regarding management of the RDT&E program were driven both by his responsibility for management of the program and the pressures of regulatory influences external to the project. The major cause for concern in the RDT&E phase was the prime development contractor. The contractor's technical capability was not at issue. The concern centered on the contractor's management philosophy.

Assessment and Definition

The use of PERT for schedule control was a contractual requirement with the prime development contractor prior to the production and deployment decision.[1] The utility and true effectiveness of the PERT application in the RDT&E program was under scrutiny at the time,[2] however, and the assessment of PERT utility continued for more than two years following the production and deployment decision.[3]

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[1]For a brief description of initial efforts, see R. L. Bryant, "PERT in the Nike-Zeus," Aerospace Management 6 (January 1963): 20-24.

[2]U.S., Army Sentinel System Command, Recommendations for Sentinel Schedule Control, by J. A. Mullin, Interim Report SENSCOM-29160-1 (Huntsville, Alabama: Brown Engineering Company, Inc., February 1968), pp. 1-3.

[3]Approval to delete PERT from the development contract was contained in George Mayo, Jr., Brigadier General, USA, Deputy Safeguard System Manager, "Use of PERT in the Safeguard Development Program," letter to Commanding General, U.S. Army Safeguard System Command, 12 May 1970, Ballistic Missile Defense Organization Files, Washington, D.C.

The PERT effort was neither productive nor effective in the RDT&E program for a number of reasons.[1] First, the prime development contractor never used the PERT system imposed by the Army for internal control. Second, even though the prime development contractor imposed a similar PERT requirement on its principal subcontractors, it was not successfully used across the board at that level either. Third, the prime development contractor consistently submitted contractually required PERT reports to the Army later than required. Fourth, the reports frequently contained numerous errors and discrepancies. Fifth, the methodology used precluded determination of predicted progress in comparison to established schedules. Finally, efforts by the Army to correct the situation had met with only mediocre success. In short, the PERT system was being used principally to record historical data rather than to manage the RDT&E program. Management and technical personnel both within the Army and within the development-contractor structure were using internal schedule control systems to manage the program at the tactical level.

At the strategic level, the issue tended to center on the fidelity of the milestone data being reported, the use of the Safeguard Project Summary Work Breakdown Structure (WBS) as a common reference, and the use of standardized performance reports to permit correlation and comparison of interfunctional

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[1]Reasons cited summarized from U.S., Army Sentinel System Command, Recommendations for Sentinel Schedule Control, pp. 6–7, 24–25; W. O. Turney, Contracting Officer, "R&D PERT Report," letter to Western Electric Company, 8 October 1968; R. C. Marshall, Brigadier General, USA, Commanding General, U.S. Army Safeguard System Command, "Use of PERT in the Safeguard Development Program, letter to Safeguard System Manager, 22 April 1970; and Management Data Systems Office, "Schedule Control System for the Development Program," Disposition Form for Research, Development, Test, and Evaluation Directorate, 17 June 1970, Ballistic Missile Defense Organization Files, Washington, D.C.

data.[1] The change in emphasis by DoD from requiring specified management systems to requiring compliance with control systems criteria occasioned by the implementation of C/SCSC permitted the program manager to shift his focus from PERT itself to the broader arena of schedule control technique. This tended to ease the specificity of Army management doctrine, thus opening up new alternatives to the program manager for resolution of the RDT&E phase schedule control issue.

Interrogation and Identification

The problems associated with schedule control in the prime development contractor structure contributed to the constraints and limitations previously described for the cost parameter by hampering the ability to perform cost and schedule trade-offs. The problems also created direct schedule control constraints. Correlation of RDT&E phase schedule data to the common WBS was difficult, determination of interfaces and interrelationships was complex, and integration of RDT&E phase schedule data with schedule data of other phases was inaccurate at other than summary level.

The issues involved in the problem were symptomatic of the same management philosophy that contributed to the cost situation. The prime development contractor took a firm position that the system of controls in use had evolved with the RDT&E program over a ten year period, that the system was consistent with the needs of the Army and the increasing scope of the prime development contractor's responsibilities, and that it was efficient and functional

[1]Mayo, "Use of PERT in the Safeguard Development Program," letter, 12 May 1970.

without being excessively burdensome.[1] These basic arguments applied to both the cost and the schedule control systems.

The prime development contractor's lack of demonstrated sensitivity to the broader needs of the Army was a reflection of the perspective with which the RDT&E phase was viewed by many directly associated with it. This view, in its most simplistic form, suggested that the RDT&E phase was essentially an end in itself. Given this view, a larger need to integrate RDT&E schedule data into production and deployment phase data assumed secondary importance.

Management Control Requirements

The conclusion that PERT was more a symbol than a reality ultimately resulted in its deletion as a requirement in the prime contract. The program manager's concurrent attempts to implement C/SCSC in the prime development contract met with less than full compliance. An analysis of the prime development contractor's control system revealed that full implementation of C/SCSC would be "...costly, disruptive, and require considerable negotiation."[2] The Army implementation of the DoD requirement[3] recognized that a contractor's financial and schedule control system might have been previously

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[1] B. McMillan, Vice President, Bell Laboratories, "Safeguard R&D Contract DAHC60-71-C-0005," letter to Brigadier General R. C. Marshall, 21 January 1971, Ballistic Missile Defense Organization Files, Washington, D.C.

[2] R. C. Marshall, Brigadier General, USA, Commanding, U.S. Army Safeguard System Command, "Limited Application of DODI 7000.2, Performance Measurement (PM), to Produced WECo/BTL R&D Contract, DAHC60-71-C-0005," letter to Safeguard System Manager, 11 June 1970, Ballistic Missile Defense Organization Files, Washington, D.C.

[3] U.S., Department of the Army, Performance Measurement Cost/Schedule Control Systems Criteria (Implementation Guide), Department of the Army Pamphlet No. 37-2 (Washington, D.C., February 1970).

accepted by the government under different criteria. As a consequence, the implementing instructions were conditioned with respect to ongoing contracts and only required compliance "insofar as possible." Due to the potential disruption to the RDT&E program that might have been occasioned by full implementation of C/SCSC and a conviction by the program manager that the intended purpose of the requirement could be achieved by alternative actions, he ultimately authorized limited application of C/SCSC to the ongoing prime development contract.[1]

The program manager used base-lined milestones as the primary quantified standard in schedule control. The milestones were, in general, at a summary level in program activity and it was anticipated that additional, more detailed, milestones would be maintained by participating agencies and their contractors. The milestones were established by the program manager. Planned dates for accomplishment were base-lined by the program manager as they were established.[2]

Milestones were established in terms of a hierarchic arrangement defined in descending order of importance as follows:

1. Key Milestones--any milestone designated by the program manager as being under his control.

2. Major Milestone--any milestone identified by the program manager as requiring intensified management and control by an agency commander.

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[1]Starbird, "Management of the Safeguard Development Effort," letter, 19 October 1970.

[2]U.S., Department of the Army, Milestone Report RCS SAFSM-3, Safeguard System Master Plan (SSMP) Part No. 2.06.01, Revision No. 1 (Washington, D.C.: Office Chief of Staff, 23 June 1969), p. 1.

3. Supporting Milestones--any milestone established by an agency commander with performance data provided to the program manager.

4. Minor Milestones--any milestone established by an agency commander or his representative for tactical control. These could be reported to the program manager, if desired, by the agency commander.

The first three levels of milestones could also be further identified, when applicable, as interface milestones.[1] Interface milestones were defined as those milestones that, upon completion, resulted in transfer of further action to another agency.[2]

The milestone levels, by definition, also defined the control thresholds and tolerances. As an example, only the program manager could establish or change a key milestone. In interaction with a corollary time-oriented hierarchy, the milestones also formed the foundation for emergency reporting requirements for accomplishment of and changes or proposed changes to specified milestones. Safeguard Emergency Action Reports (SEAR's) were used for this exception reporting and were required to be submitted within 48 hours of key milestone accomplishment or determination of out-of-tolerance milestone condition.[3] Control thresholds and requirements for exception reporting are depicted in

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[1] Ibid.

[2] For an interesting discussion on management of interfaces between major participants in a complex endeavor see John M. Schmissrauter, "Interface Management of Aerospace Systems," in The Management of Aerospace Programs, ed. by Walter L. Johnson (Washington, D.C.: American Astronautical Society, 1967), pp. 261-85.

[3] U.S., Department of the Army, Milestone Report RCS SAFSM-3, pp. 2-4.

Table 4. Routine monthly reporting was required for all key and major milestones as a minimum.[1]

Tactical Considerations

Tactical considerations centered on the need for sufficient schedule performance data with which to (1) manage the RDT&E program, (2) perform meaningful trade-offs analyses between schedule and cost, and (3) determine sequence and precedent interrelationships between events. Companion to the need for data was the requirement to implement PERT, followed by a shift to C/SCSC, with the prime development contractor and PERT with the participating government agencies.

Assessment and Definition

The prime mission for schedule control at the tactical level was analogous to that for cost control. The system in use, as it related solely to management of the prime development contractor, had historical precedence and acceptance, was viewed by tactical managers as consistent with the general tactical management philosophy, and it maintained the status quo of the management situation. Requirements to integrate schedule data from the RDT&E phase with schedule data from other phases were viewed as secondary to managing the RDT&E phase by RDT&E tactical managers.

It is interesting to note that the direction by the program manager to implement PERT and subsequently C/SCSC in the prime development contract was aimed at upgrading both strategic and tactical level schedule control. A great deal of effort was expended at the tactical level in this regard, with little

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[1] Ibid., p. 3.

TABLE 4

ESTABLISHMENT, CONTROL, AND EMERGENCY REPORTING CRITERIA FOR SAFEGUARD MILESTONES [a]

TYPE MILESTONE	ESTABLISHED BY	CHANGE APPROVAL	EMERGENCY REPORTING
KEY	PROGRAM MANAGER	PROGRAM MANAGER	ACCOMPLISHMENT OR ± THREE DAYS OR MORE FORECAST CHANGE [b]
MAJOR	PROGRAM MANAGER	AGENCY COMMANDER	FIFTEEN DAYS OR MORE DELAY [c]
SUPPORTING	AGENCY COMMANDER	–	SIXTY DAYS OR MORE DELAY
MINOR	–	–	NONE

[a] SOURCE: U.S., DEPARTMENT OF THE ARMY, MILESTONE REPORT (RCS SAFSM-3), SAFEGUARD SYSTEM MASTER PLAN (SSMP) PART NO. 2.06.01, (REV 1) (WASHINGTON, D.C.: OFFICE CHIEF OF STAFF, 23 JUNE 1969), P. 4.

[b] CHANGED TO 10 DAYS IN DECEMBER 1970.

[c] CHANGED TO 30 DAYS IN DECEMBER 1970.

actual success. During the entire period that this effort was underway, the method of management at the tactical level did not change materially.

The situation with regard to participating government agencies was generally different. A separate technical specification for participating government agencies[1] was prepared and implemented. It defined procedures for the preparation, updating, and submission of schedule control data in full accordance with the requirements specified by the program manager. Compliance with the technical specification by the participating government agencies fulfilled requirements for performance reporting to the program manager at the strategic level and for the proper degree of control by the appropriate agency commanders at the tactical level. The participating government agencies complied satisfactorily with the schedule control requirements.

Interrogation and Identification

One of the major benefits of using PERT at the tactical level was that it facilitated development of interface definitions. The PERT network logic formed the foundation for determination of interrelationships and the identification of the techniques of integration. PERT was also a communication link between participants. All performance data were submitted to a central point where networks were updated and distributed to the participants. Each participant was furnished his own updated network as well as updated interface data of other agencies. The networks applied not only to the RDT&E phase, but to the production phase as well. As a consequence, PERT provided a vital link

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[1]U.S., Army Safeguard System Command, Schedule Control Requirements for Safeguard Government Participating Agencies, SAFSCOM Technical Specification Number 715-51 (Huntsville, Alabama, 2 September 1969).

between agencies within a life-cycle phase and between agencies in different life-cycle phases. The quality and limitations of PERT data in the development contractor structure severely restricted its usefulness as either an integration or communication link in the program. It also hampered total system schedule review and analysis activity.

Management Control Requirements

Tactical managers tended to monitor the RDT&E schedule at the major milestone level. Milestones at the supporting level were monitored when they were also interface milestones. Submission of SEAR's to the program manager also provided a built-in exception reporting system at the tactical level. Typically, SEAR's had to be authenticated by the agency commander. The coordination required prior to his authentication normally assured careful and comprehensive analysis of the facts. Since SEAR's required follow-up reports within ten days,[1] they normally became management attention items until resolved.

Production Phase

The analysis now shifts from the RDT&E to the production phase. The two cells discussed in this section are differentiated only by the level dimension. The first portion of the analysis is focused on strategic considerations while the second portion concerns tactical considerations.

Strategic Considerations

At the outset, the production program was a time-emphasis program. As the number of planned sites diminished, the importance of cost increasingly

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[1]U.S., Department of the Army, Milestone Report RCS SAFSM-3, p. 4.

overshadowed the time element, and the production effort gradually became a cost-emphasis program.

Assessment and Definition

The external and internal influences affecting the production phase were similar to those affecting the RDT&E phase. Initial efforts, by the program manager, were directed at implementing PERT in the prime production contractor structure. Participating government agencies involved in the RDT&E phase also implemented PERT in the production phase. Government agencies participating primarily in the production phase implemented the PERT requirement without difficulty.

The two major elements of production presented different control situations. The construction activity of the site activation effort was a natural candidate for PERT while the repetitive aspects of hardware fabrication were not so natural. To support the site activation networks, however, the production contractors and participating government agencies were required to develop PERT networks. Production networks reflected key activities and events supporting interface points. PERT was not applied to the "level of effort" tasks of production such as Value Engineering, Quality Assurance, and System Engineering.

PERT continued throughout the production program as the vehicle for interfacing hardware, construction, installation and test, and allied support activities. It was supplemented and finally replaced by Line of Balance control systems in the hardware production area as that activity matured and became more repetitive in nature.

Interrogation and Identification

The widespread use and acceptance of PERT in the production phase provided a linkage of interdependencies throughout the total dimension of the hardware fabrication and site activation activity. Utilizing the program work breakdown structure as its foundation, the PERT networks provided an audit trail and depth of detail sufficient to support the milestones reported to the program manager. Assessment of the fidelity of the milestones was relatively straightforward.

Management Control Requirements

The program manager utilized the same concept of base-lined milestones used in the RDT&E phase for control of the production phase. Milestone definitions were the same. Hardware fabrication milestones were defined by major item of equipment. Site activation milestones stressed site construction, equipment installation and test, and on-site training. The milestones identified were common to each site and were to be reported for each site.[1]

The concept of management thresholds and tolerances defined above for the RDT&E phase was also applied to the production phase. Reporting requirements were similarly imposed without change.

Tactical Considerations

At this level information was required to develop and implement schedule plans and to monitor performance against those plans. Milestones were monitored down to the major milestone level, in general, although intensified

[1] Ibid., pp. C-1 - C-2, D-1, F-1, G-1.

management requirements occasionally demanded more detailed control. Development of properly sequenced interdependencies was of paramount importance.

Assessment and Definition

The schedule control system implemented at the tactical level to support strategic level reporting constituted an effective response to tactical level requirements. It was efficient, timely, and accurate. Participating government agency requirements were the same as for the RDT&E phase.[1] PERT requirements and methodology for contractors participating in the production program under the aegis of the prime contractor were defined in a separate contractor document.[2] The use of PERT, as noted previously, is most effective in nonrepetitive activities and in the early phases of a production program. The PERT requirement for hardware fabrication was ultimately replaced--and properly so--with a requirement for the more conventional Line of Balance system. Data, as required, were input into the appropriate milestones in the remaining PERT networks from the Line of Balance system.

Interrogation and Identification

One minor problem involving maintenance of two duplicative data bases existed for a time at the tactical level. One was maintained by the program manager and the other by the prime contractor. The situation stemmed

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[1]U.S., Army Safeguard System Command, Schedule Control Requirements for Safeguard Government Participating Agencies.

[2]Western Electric Company, Program Evaluation and Review Technique (PERT) System (Greensboro, North Carolina: Safeguard Project Division, 1 March 1969).

from the need of the prime contractor for selected participating government agency schedule data. Early in the program, the prime contractor had the ability to rapidly process raw PERT input data by computer and the program manager did not. As a consequence, participating government agencies submitted applicable input data simultaneously to both the program manager's data base and the prime contractor.[1]

Following development of a comparable capability for processing all PERT data by the Ballistic Missile Defense Organization (BMDO), the prime contractor was reluctant to accept processed data from the BMDO in lieu of raw data direct from the participating government agencies. This procedure, however, constituted a dual control and processing system for PERT data for networks developed, maintained, and reported on by all of the participating government agencies.[2]

The contractor's reluctance to accept processed data was primarily based on the reporting delay caused by the processing by BMDO, differences in the methods of processing, and differences in the interfaces incorporated in the two data bases. This issue was resolved rather rapidly in favor of the processing of all input data, including that of the prime contractor, by the BMDO. Outputs were returned to all participating government agencies and to the prime contractor.[3]

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[1]U.S., Army Safeguard System Command, Cost Reduction Recommendations on Safeguard System Command PERT Reporting and Processing Requirements (Huntsville, Alabama: Management Data Systems Office, February 1971), pp. 1-4.

[2]Ibid.

[3]Ibid., p. 11.

Management Control Requirements

Management control requirements for the production phase centered on the major milestones at the tactical level of management. Interface milestones were also highlighted for management attention. This was due, in large measure, to the typically higher potential for error at agency mission junctures of shared responsibility.

A unique capability of the Safeguard PERT processing system was a summarization/skeletonization model. The principal function of the model was to reduce large, integrated networks into smaller networks which were easier to study and analyze. The manager established the level of summarization or skeletonization by specifying the extraction criteria to be used for selecting the original network events or milestones that were to be retained in the smaller skeletonized network. The precedence relationships and time durations between connected milestones present in the original network were retained in the skeletonized network. This feature assured that the skeletonized network would retain the integrity of the original network.[1] The summarization/skeletonization model provided improved visibility of major milestone interrelationships and enhanced management analysis through retention of original or parent data fidelity.

Deployment Phase

The two cells contained in this portion of the PPL analysis matrix are the schedule parameter/deployment phase/strategic level cell and the schedule

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[1]U.S., Army Safeguard System Command, Design Specification for the Safeguard PERT Summarization/Skeletonization Module (Huntsville, Alabama: Computer Sciences Corporation, September 1972), pp. I-1 - I-3.

parameter/deployment phase/tactical level cell. Viewed in terms of the schedule parameter, the deployment phase was conceptually linked to the production phase, and schedule control requirements for the deployment phase were a natural extension of production phase requirements.

At the strategic and tactical levels, the deployment phase did not present any unique schedule control requirements. The two basic scheduling models (PERT and milestone planning and control) which were applicable to the production phase were equally applicable to the deployment phase. Milestones were separately established for the personnel training program and the logistics program. Milestones relating to the assignment of operating personnel were integrated into the site activation function that was integral to the production phase.

The deployment phase did not materially affect the schedule control parameter. Analysis of the management control situation revealed no new relationships or criteria beyond those already documented. In sum, the deployment phase was not a significant consideration in the schedule control situation.

Termination Phase

The cells of interest in this section of the chapter are the schedule parameter/termination phase/strategic level cell and the schedule parameter/termination phase/tactical level cell.

The termination phase triggered the initiation of actions aimed at phasing the deployed site out of the Army inventory. It also set in motion management actions designed to minimize costs and curtail management systems. The phase did not present any unique requirements. Rather, it suggested a gradual reduction in requirements as activities were terminated.

The termination phase did not add any new conceptual relationships or conditions to the schedule control situation. Termination activities and events were planned and controlled with the same interest and concern for sound management logic as the production and deployment activities and events. The primary difference was in the type and scope of activities and events being controlled rather than in the nature of the schedule control situation.

Schedule Control in Perspective

Time is both a resource in system management and a vehicle for measuring program performance. Time-reference schedules typically serve both as plans for future activities and as the control standard against which program progress is measured. Time-emphasis considerations that stress the temporal reference tend to highlight schedule control. Even cost-emphasis and technical performance-emphasis considerations frequently accentuate schedule control, due to its significance as an early warning indicator of undesirable program performance trends.

The schedule parameter demonstrates a fairly direct sensitivity to the RDT&E and production phases of the life cycle. The nature of program activity in these two phases is highly instrumental in determining the type or types of schedule control model or models most appropriate for implementation. On the other hand, the schedule parameter is relatively insensitive to the deployment and termination phases. This observation, with regard to the deployment phase, might be less valid if the deployment phase was the independent responsibility of another agency. This was not the case with Safeguard, however, where the deployment phase was a natural extension of the production phase.

It is also significant to note that the tools and techniques of schedule control relate readily to the life-cycle phases. In most instances this is because the tools and techniques were designed to cope specifically with the activities associated with the phases involved. This is in contrast to observations made concerning the cost parameter, where it was noted that control requirements were articulated by fiscal appropriation and not by life-cycle phase.

Schedule control lends itself very well to hierarchic levels of decision-making. Through the use of carefully selected milestones, a program manager may manage at whatever depth he desires. By setting his thresholds or tolerances properly, he may also insure that deviations are handled in differing manners. At one end of the spectrum, deviations might be ignored or simply noted as having occurred if falling within the tolerance or threshold band specified. At the other end of the spectrum, deviations might be cause for complete re-examination of control standards involving the same degree of management attention as the development of the existing standards. The type and level of management action would be dependent upon the criticality of the threshold breeched.

Properly developed, strategic level schedule control requirements should drive tactical level requirements. Strategic level requirements should be defined in terms that require increasing degrees of detail at successively lower levels of decision-making. The requirements should also be designed to insure logical audit or traceability of data down through lower levels. Given this observation, tactical level requirements must be subserviant to and supportive of strategic level requirements. They should not be permitted to be developed as ends in themselves.

CHAPTER VII

THE TECHNICAL PERFORMANCE PARAMETER

The technical performance parameter is concerned with system design objectives and specifications. The purpose of technical performance control activity is the anticipation or early detection of variances that require management attention and to provide visibility into technical performance accomplishments and status against the predetermined technical objectives. The goal of technical performance control is assurance of the continual technical integrity of the system.

This chapter addresses the technical performance parameter of management control. It begins with a synoptic description of the technical performance parameter. The next section delves into those properties which are common to all cells in the technical performance segment of the PPL analysis matrix. The next four sections relate to the four phases of the PPL analysis matrix. The strategic and tactical level cells are considered in each section. The final section summarizes the salient features of the technical performance parameter and places them in perspective in terms of the total parameter analysis.

Technical Performance Considerations

The technical performance parameter is a means of establishing objectives and determining program progress. For purposes of control, the elements tracked should be key indicators of technical achievement. In this particular the technical performance parameter is perhaps the most difficult of the three parameters to define. It is the purpose of this section to provide insight into the concept of technical performance.

The Nature of Technical Performance

This initial exploration of the major considerations of technical performance is intended to focus attention on critical characteristics. The theme is to reveal the nature of the parameter through exposure of its cardinal attributes.[1]

Definition and Description

The technical performance parameter may be broadly interpreted. In its fundamental context it may be considered, from a contractor's perspective, simply as "specification compliance," meaning all contractual requirements other than cost and schedule.[2] Murdick and Ross tend to equate technical performance to quantity and quality, citing manufacturing standards of performance as typical examples.[3] Roman suggests that technical performance is related to engineering and scientific activity involving such functions as product design, product development, testing, production control, quality control, and product

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[1]For an interesting analysis of the affect of the rapid progression of technology on the field of management see, Robert H. Roy, The Cultures of Management (Baltimore: Johns Hopkins University Press, 1977), pp. 155-62.

[2]E. L. Williams and G. A. Wilson, "Project Cost Control at Raytheon's Wayland Laboratory," IEEE Transactions on Engineering Management EM-10 (September 1963): 143.

[3]Murdick and Ross, Information Systems for Modern Management, p. 125.

standardization among others.[1] Sayles and Chandler emphasize the differences between technical goals and business requirements. They see the two as having divergent mission orientation. Technical goals are aimed at successful system performance--ostensibly without concern for business requirements; business requirements are concerned with successful fiscal management--allegedly a separate and dissonant interest.[2]

As used in the Safeguard program, the technical performance parameter was concerned with system design objectives, production and operations management, site activation and integration, system logistics support, and system operational availability and readiness. The importance of the technical performance parameter was underscored by Enthoven and Smith:

> Some of the most important program decisions in DOD concern the introduction of new equipment. Realistic estimates of performance must be available if the choices are to be good ones. Indeed, the problem of reliable performance estimates has become more significant in the past ten years, as complex electronic components have become key elements in the effectiveness of many new weapon systems.[3]

In the final analysis, equipment performance is not only the product of all other elements of technical performance, it is the measure of the weapon system when acquired under realistic operational conditions.

Placed in perspective, the technical performance parameter has a decided emphasis on engineering and scientific endeavors, the cost parameter has

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[1]Roman, Research and Development Management: The Economics and Administration of Technology, pp. 365-69.

[2]Leonard R. Sayles and Margaret K. Chandler, Managing Large Systems: Organizations for the Future (New York: Harper & Row, Publishers, 1971), pp. 272-97.

[3]Enthoven and Smith, How Much is Enough? Shaping the Defense Program, 1961-1969, p. 318.

a definite business flavor, and the schedule parameter represents a middle-ground blend of both.

Qualitative Materiel Requirement

Sentinel development effort was guided by the Qualitative Materiel Requirement (QMR), "Nike-X Missile Defense System." Ballistic Missile Defense (BMD) requirements for the Safeguard system were initially modified by the 1967 deployment. Requirements were further modified by the Presidential decision announced in 1969. The requirements statement of the QMR was modified through issuance of Development Concept Papers by the Secretary of Defense.[1]

Control of Technology

Control of technical performance[2] presents a more formidable control problem than either cost or schedule control, and it has been suggested that too much control will stifle technical creativity.[3] Technical control is difficult because of three factors. First, there is a general absence of a common denominator of performance measurement. As a consequence, each control requirement must be defined in the dimensions or units appropriate to the element being controlled. This lack of commonality of units of measurement

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[1]U.S., Department of the Army, Basic Objectives, Safeguard System Master Plan (SSMP) Vol. 1, Revision 2 (Washington, D. C.: Office Chief of Staff, 12 August 1971), p. 7-1.

[2]An excellent discussion on the management of technological complexity in a large-scale, complex military weapon system may be found in Harvey M. Sapolsky, The Polaris System Development: Bureaucratic and Programmatic Success in Government (Cambridge, Massachusetts: Harvard University Press, 1972), pp. 249-54.

[3]Robert N. Anthony, Management Controls in Industrial Research Organizations (Boston: Harvard University, 1952), p. 28.

also frustrates efforts to roll-up or summarize technical performance elements. Second, the selection of effective key control indicators of project success is more complex than is the case with the cost or schedule parameters. The intent is to select those technical indicators most susceptible to quantification, those that are readily measurable, and those that provide the earliest indication of variance from technical requirements.

Third, there is difficulty in identifying and defining acceptable levels of technical risk. "Technical risk" may be defined as the correlation of the state of the art of component design technology with the criticality of functional performance. For example, the highest level of technical risk results from using unproven component design for weapon system equipment that must perform functions essential to operational success. Technical risk decreases from this highest level as either more proven and technically authenticated component design from existing technology is used and/or operational criticality of the component diminishes.

The cost and schedule parameters are also subject to risk. There is a close relationship among these two parameters and technical risk. Cost risk is a function of the confidence level placed on completing all increments of planned work within the fiscal resources distributed for the effort. Similarly, schedule risk is a function of the confidence level which is placed on completing all increments of planned work within the time budget. Under typical conditions, the larger the technical risk, the larger the cost and schedule risk.

Cost and schedule risk may be reduced through intentional distribution of contingency fiscal and time allotments. Addition of these contingency cost and time budgets helps ameliorate technical risk. Addition of contingency, or "management reserve" as it is popularly named, permits coping with the unexpected while maintaining strategic program commitments.[1]

Trade-off investigations among the three parameters are frequently referred to as risk analysis studies. Such studies are a continuing part of the acquisition management process and are rigorous to perform.[2] Additionally, in practical terms, project achievement is measured by the progress against these three parameters and the relationship among them at any one time.[3]

Targets of Technical Control

Management control of complex technology is difficult.[4] It is usually concentrated on the "...written resources and the information which the scientific and technical personnel have for their use."[5]

While control is concentrated on information, the ultimate major targets of technical performance control are the tangible elements of the weapon system; i.e., the hardware, software, and facility components that comprise the operational system. As a rubric for focusing attention, the

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[1] Joseph F. Shea, "Observations on Defense Acquisition," Defense Systems Management Review I (Autumn 1977): 33.

[2] Jacques S. Gansler, "A New Dimension in the Acquisition Process," Defense Systems Management Review I (Autumn 1977): 10.

[3] W. J. Taylor and T. F. Watling, Practical Project Management (New York: John Wiley & Sons, Halsted Press, 1973), pp. 82-94.

[4] An informative treatment of the profound effect that rapidly increasing technological complexity is having on management may be found in James C. Stephens, Managing Complexity: Work, Technology, and Human Relations (Washington, D.C.: University Press, 1970), pp. 280-94, 311-20.

[5] Bartow Hodge and Robert N. Hodgson, Management and the Computer in Information and Control Systems (New York: McGraw - Hill Book Company, 1969), p. 69.

Safeguard generic elements are defined as system hardware, system software, and site facilities.[1] This portion of this section briefly touches on these three inanimate elements.

System Hardware

System hardware refers to that complex of system equipment that comprises the air vehicles, missile site and perimeter acquisition radars and ancillary equipment, command and control equipment, and various components of ground support equipment. Excluded, by definition, are system software and the permanent facilities at the operational site. In sum, system hardware is the "machinery" portion of the system and fulfills the "mechanization" purpose.

System Software

System software designates those data processor programs, data-processing tapes, data descriptions, and other data used to communicate with, operate, test, monitor, and maintain the system hardware. Thus, two major subsets exist within the software definition. The first is that system software associated directly with the system data processors integral to the two radars and the command and control central. The second pertains to conventional printed matter such as technical manuals, handbooks, and procedures used for manual operation and maintenance of the system. Excluded from this definition are design, fabrication, and performance drawings and specifications. The system software provides the data required by the system and performs an "integrative logic" purpose.

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[1]As a point of clarification it should be noted that Safeguard required an integration of hardware, software, facilities, and personnel in order to achieve operational readiness. Personnel added the dimension of "rationality" to the

Site Facilities

Site facilities refer to the brick and mortar type facilities and other special purpose type facilities necessary to achieve system operational status at the system site. By definition, the reference also includes the real estate, roads, interconnecting cables, and personnel support facilities required at the site. The facilities portion of the system, in essence, constitutes the "structure" portion of the weapon system. Site facilities provide the installation required for the fixed site weapon system.

A graphic conceptualization of a weapon system is depicted at Figure 13.

Execution of the Technical Program

Execution or implementation of the technical portion of a program does not necessarily follow a prescribed or highly structured format. The technical program, however, should be comprehensive and well planned, provide for reasonable management reserve as required and possible, and be dynamic permitting redirection due to changes in objectives and as a consequence of test results.

While the technical process may be unstructured, it should not be approached in a piecemeal manner. The over-all technical process might be thought of conceptually in terms of four functionally integrated tasks. These tasks are design, test, produce, and operate. These tasks may be repetitive. Any given component design may cycle through the process more than once. A fifth

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system. For purposes of this study, the personnel portion of the equation was not examined because it was not in the mainstream of technical performance control.

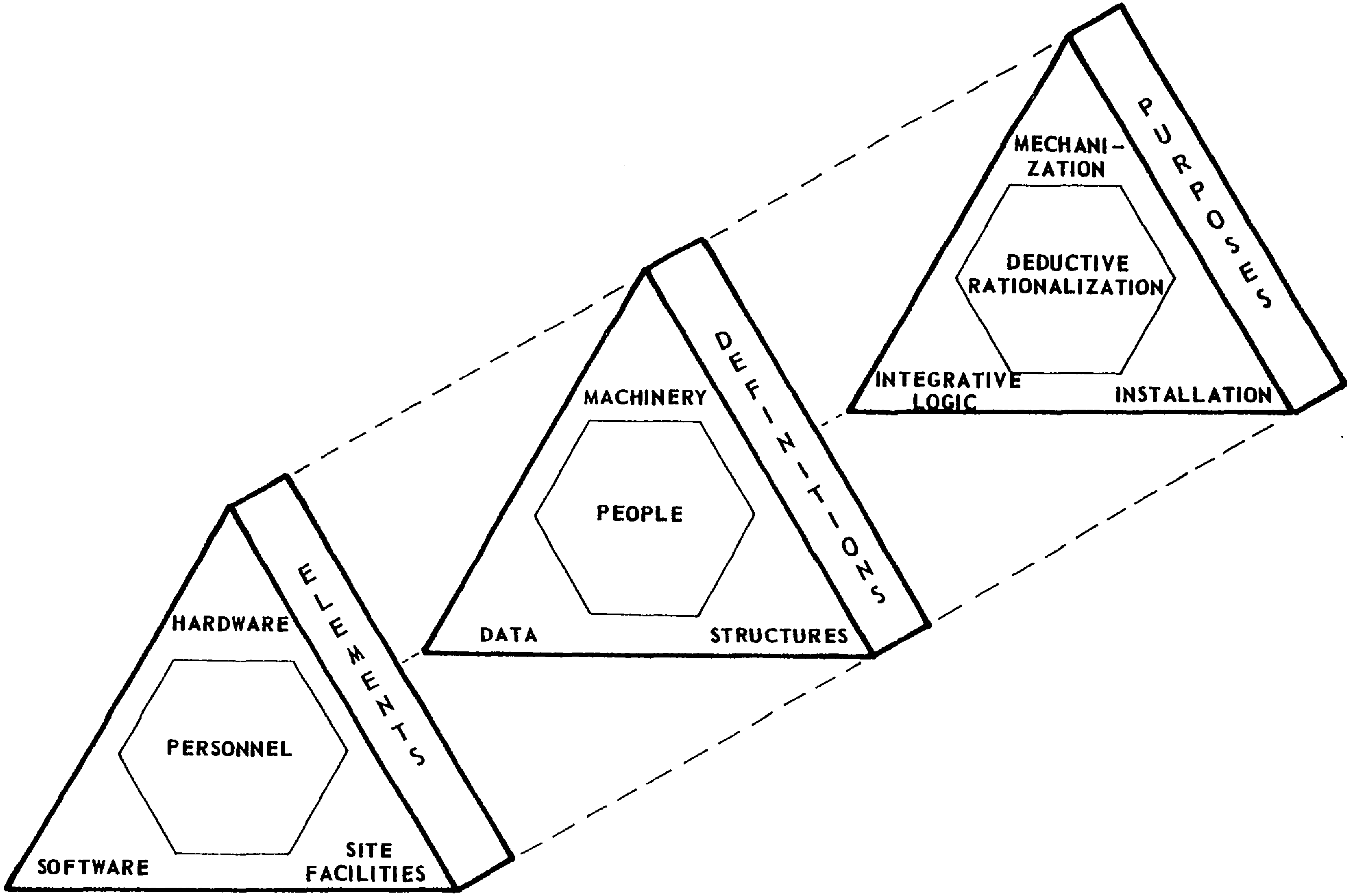

Fig. 13. Conceptualization of A Weapon System

task, assessment, is operative across the other four tasks. These relationships are depicted in Figure 14. Each of the tasks is significant for integrated control of technical performance. The major management aspects of each of the four tasks are highlighted in the following paragraphs.

Design

The design task is concerned with full engineering development and refinement of the specific hardware, software, and facility configurations of the components and elements to be produced. Designs should be fully representative of production items in terms of form, fit, and function.[1] Normally, the only permissible difference from the production item is in the manufacturing aspect. Development materiel typically may be fabricated on what is referred to as "soft" tooling, in lieu of the "hard" tooling used in the volume production phase.

Design is an iterative engineering process. The objective is to insure that stated requirements are successfully met. The design task emphasizes system integration and interface control, reduction of technical risk, and optimization of system technical performance. The product of the design task is comprehensive system definition accurately reflected in engineering drawings, specifications, and related engineering documentation.[2]

Design, particularly that associated with the RDT&E phase, is typically less rigorously controlled than the other tasks. Anthony, discussing

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[1] An excellent article on the desirability of designing for smooth and cost-effective production during the RDT&E phase may be found in Raymond Kendall and G. Wayne Talbot, "R&D and Production: The Artificial Barrier," Government Executive 9 (November 1977): 25.

[2] U.S., Department of the Army, Principles of Management, Sentinel System Master Plan (SSMP) Part 2.01 (Washington, D.C.: Office Chief of Staff, 13 April 1968), p. 22.

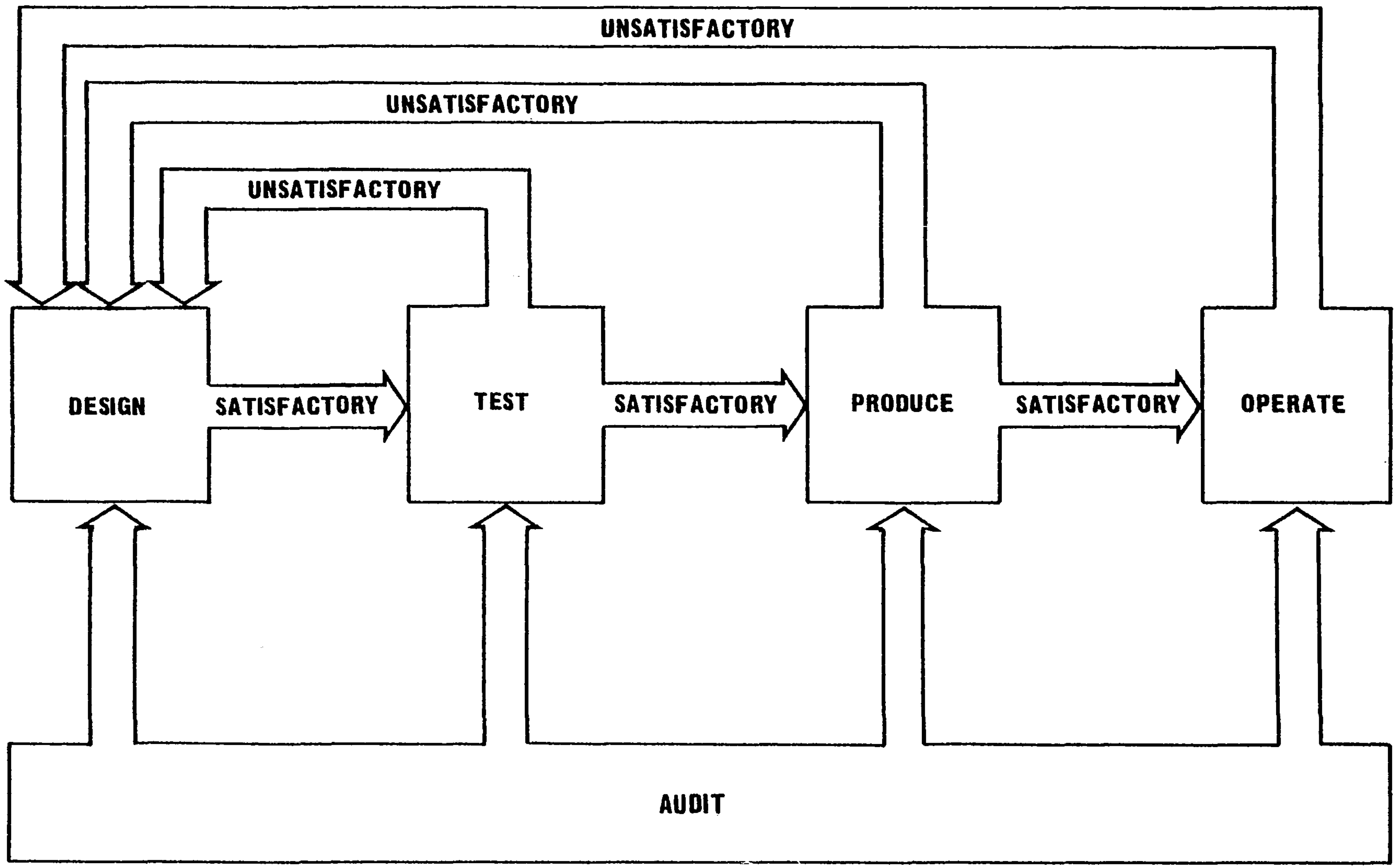

Fig. 14. Execution of the Technical Program

research projects in particular, suggests that formal written progress reports and data are secondary to informal conversations and meetings as vehicles for making decisions about technical work.[1] This thought suggests the flavor of the control process in the initial stages of the design task.

Test

The Safeguard test effort was divided into three discrete elements. The first was referred to as development engineering testing. It was conducted by the prime contractor under the direction of the development agency. It was integral to the design task and encompassed all development testing and evaluation required to assure that the proposed design met all technical performance and related characteristics of the system design specification.[2]

The second major aspect of the test program was the system acceptance testing conducted under the purview of the evaluation agency. The main thrust of this test effort was to assure that system characteristics were acceptable in a tactical environment, that the design released for production would satisfy military requirements, and that all system elements met performance specifications. This testing was independent of development engineering testing and represented an independent check and balance verification by the program manager[3] of the "pedigree" of the system design.

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[1] This view is suggested in Anthony, Management Controls in Industrial Research Organizations, pp. 193-7, 201 and George A. Steiner and William G. Ryan, Industrial Project Management (New York: Macmillan Company, Arkville Press, 1968), p. 43.

[2] U.S., Department of the Army, Principles of Management, p. 24.

[3] Ibid.

The third category of test was the operational testing conducted under the cognizance of the user. The purpose of the testing was to determine that operational site personnel could operate and maintain the system. This activity, as did all other test programs, stressed both hardware and software evaluation.[1]

Produce

This task is defined by the production phase described in Chapter IV. In sum, the primary objective was to produce the system design released to production from the RDT&E phase in a timely manner and at minimum cost. The effort also included construction of site facilities.

Operate

This task occurs during the deployment life-cycle phase described in Chapter IV. It refers specifically to that aspect of deployment concerned with actual operation and maintenance of the system by user personnel.

Appraise

The appraisal task is operative across the total spectrum of the other four tasks. Commonly referred to as "product assurance," the objective of this task is to insure that acceptable levels of quality, reliability, and maintainability are incorporated in the basic development of the system; that conformance with engineering requirements is attained during manufacturing; and that acceptable levels of reliability, availability, and maintainability are achieved in service.[2]

Significant activities of a typical product assurance program include preparation of basic concepts during the design task to assure compliance with

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[1] Ibid., p. 25.

[2] Ibid., p. 28.

quality criteria, testing to evaluate design, determination that production systems are acceptable, and continuing appraisal of equipment in the field to verify product quality and durability. A program for analysis and feedback of site maintenance and operational data was also established.

Models and simulations were used extensively throughout the program to supplement testing of actual system equipment and to reduce costs.

Additional Comments

Two final comments on technical performance considerations are germane at this point. First, a major concern of technical performance control activity is the anticipation or early detection of technical variances. This is the same requirement for proactive control expressed previously with the cost and schedule parameters. In essence, it is a statement of need for anticipatory preventative action in contrast to reactive remedial action. While technical performance control may be more difficult to achieve effectively than cost or schedule control, it is important that it be accomplished in a manner compatible with the two and on a continuing basis.[1]

Secondly, the ascertainment of valid fact is particularly important to successful technical performance control. Since it is difficult to integrate or correlate much of the independent technical data, it is essential that technical data be stripped of subjectivity and reduced to pure technical fact. An interesting theory on the selection of targets for management control has been advanced by Juran. Somewhat in contrast to management by exception, Juran

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[1] Martin, Project Management: How To Make It Work, p. 190.

states that there are, in many management control situations, a "vital few"[1] items or elements that should be managed individually. These "vital few" are to be isolated from the "trivial many" that should be managed as a class. This thesis is based on a Pareto distribution principle that suggests that the majority of the total value, utility, or other outputs of an endeavor result from a small percentage of the total resources or other inputs. While the principle is more evident in such areas as sales, inventory, and purchasing, it is also evident in the technical performance parameter. As an example, state-of-the-art components are in the "vital few" category.[2]

Technical Performance Analysis Overview

The technical performance parameter of the PPL analysis matrix is structured identically to both the cost and schedule parameters. It contains the following eight individual cells:

1. RDT&E Phase/Strategic Level
2. RDT&E Phase/Tactical Level
3. Production Phase/Strategic Level
4. Production Phase/Tactical Level
5. Deployment Phase/Strategic Level
6. Deployment Phase/Tactical Level
7. Termination Phase/Strategic Level
8. Termination Phase/Tactical Level

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[1]These elements are similarly described and referred to as the "critical few" in Louis A. Allen, Prefessional Management: New Concepts and Proven Practices (New York: McGraw-Hill Book Company, 1973), pp. 212-14.

[2]Juran, Managerial Breakthrough, pp. 43-54.

The relationships among these eight cells and the cells in the cost and schedule parameters were introduced in Figure 1 in Chapter I.

All cells in the technical performance segment of the PPL analysis matrix displayed common characteristics when subjected to examination of the assessment and definition factors and the interrogation and identification criteria. As was done with the cost and schedule parameters, these common traits are discussed in terms of the total parameter before the specifics of each individual cell are explored.

Assessment and Definition

The technical performance parameter is especially complex. It is affected by a number of external and internal influences. These influences help to mold the situational elements that define its scope. Technical performance encompasses a variety of engineering activities and a multitude of diverse efforts, all of which must be carefully integrated into a balanced and comprehensive technical program.

The feedback or cybernetic aspect of management control is particularly relevant in the technical area. This relevance applies both for purposes of program and/or control standard adjustment and for selective filtering of the less important data. Selective filtering permits passage of only that data of real significance.[1] Shorn of irrelevant detail, such data may be logically summarized for decision making.

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[1]Stafford Beer, Decision and Control (London: John Wiley & Sons, 1966), pp. 342-44.

The exogenous environment[1] in which the Safeguard program developed was, from the outset, a mixture of viewpoints. Initially, the mix was only partially antagonistic but predominately supportive. With the passage of time, the mix changed complexion and grew progressively more hostile, finally crippling the program. The external environment had an overpowering effect on the Safeguard program.

The most visible focus of the political debates surrounding ABM centered on the authorization and appropriation legislation each year. There was an undercurrent, however, of concern regarding the technical practicality and feasibility of the ABM system; in short, would it work in accordance with its specifications? There was also some concern relative to the strategic wisdom of deployment and the attendant reaction it might trigger in the U.S.S.R. or with other potential enemies. Escalation of the arms race was clearly not a desirable state. Finally, the validity of the design threat was questioned. The core issue was whether the threat was accurately defined or had been intentionally exaggerated in order to justify the deployment.

The economic issue, in large measure, was a surrogate for political and technology considerations, but affordability was also at issue. The principal concern was that the ABM deployment would divert money from domestic programs through reordering of budget priorities.

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[1] Two interesting vignettes on the effect of the external environment on R&D programs, the first contemporary with the deployment decision and the second current, may be found in T. K. Glennan, Jr., "Research and Development," in Defense Management, ed. by Stephen Enke (Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1967), pp. 269-89 and Neil V. Hakala, "Administration of Industrial Technology," Business Horizons 20 (October 1977): 4-10.

Public opinion, voiced primarily by the academic, intellectual, and scientific community, was highly spirited on both sides. The opponents of the program attempted to discredit the requirement or need for the system while the proponents argued its validity. The technology debate centered on the ability of the system to function satisfactorily in all particulars, the susceptibility of the existing system design to enemy penetration, the ability of the system to perform the mission assigned to it, and the real or imaginary dangers from close location of operational sites near population centers.

Endogenous influences also impacted the technical performance parameter. As mentioned in Chapter III, the ABM system had been under study for over a decade at the time of the deployment decision. As a consequence, the system development requirements, operational concepts, and system characteristics were well defined at the time the deployment decision was made. They were to change many times subsequent to the decision. Additionally, general Department of the Army management doctrine defined techniques for managing various aspects of the technical program such as the configuration management technique for control of engineering documentation and the product assurance program for assessment of product integrity. Other government agencies and participating contractors were generally familiar with existing technical requirements for acquisition of guided missile systems.

In addition to the use of existing U.S. Army management procedure, the Secretary of the Army established a permanent ABM (antiballistic missile) Review Group. Composed of the three Assistant Secretaries of the Army[1] and

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[1]ASA for Research and Development (R&D), ASA for Installation and Logistics (I&L), and ASA for Financial Management (FM).

the Chief, Office of Operations Research,[1] the group was chaired by the Assistant Secretary of the Army (ASA) (R&D). Each principal was directed to assign one professional-level individual from his office as a working representative, and the ASA (R&D) also provided a full-time secretary to the group. The ABM Review Group was specifically charged by memorandum signed by the Secretary of the Army with the responsibility of:

> ...isolating and analyzing major issues in the development, engineering, production, installation and operation of the system and in ABM advanced development, and presenting them to me so that I may render decisions within the guidance of the Secretary of Defense or make recommendations to the Secretary of Defense on matters not within Defense guidance.[2]

The central thrust of the group's mission was directed at assuring system cost effectiveness and performance reliability.[3]

The first program manager held a disciplined view of technical management and firmly believed in management by exception. While discussing the most significant ingredients a manager utilized in managing a large-scale complex endeavor such as Safeguard, he stated:

> The second ingredient, I guess is the ability to pick out places where there are problems and work in detail on those problems. That is the ingredient. People do it in different ways. I tend to try to do it by letting others handle things that are running all right, and then going

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[1]The Chief, Office of Operations Research was subsequently designated Deputy Under Secretary of the Army for Operations Research.

[2]Stanley R. Resor, Secretary of the Army, Memorandum for the Assistant Secretary of the Army (R&D), the Assistant Secretary of the Army (I&L), the Assistant Secretary of the Army (FM), and the Chief, Office of Operation Research, 5 October 1967, Ballistic Missile Defense Organization Files, Washington, D.C.

[3]<u>Ibid</u>.

> down personally, and in great detail, into things that aren't running right.[1]

This management philosophy of management by exception was, in large measure, perpetuated by succeeding program managers.

The objective of the technical performance control action was to isolate, define, analyze, and articulate specifications of the technical issues and system performance characteristics and to maintain the technical integrity of the total system design. This objective was operative throughout the total life cycle of the system. The goal of the technical performance parameter was an operational system.

Several key factors helped define the type of control action required for management of technical performance. First, all participants in the technical aspects of the Safeguard program were required to report specified technical data periodically. Additionally, all major participants reported technical progress periodically at program review meetings. Second, the technical data was used by the program manager to ensure achievement of a producible and operational system capability and high constancy of performance. Third, technical performance data were required from all participants in the engineering program. Fourth, the control situation contained both nonrepetitive and repetitive elements. The RDT&E activity was nonrepetitive and highlighted by a high level of technological complexity. The hardware fabrication element of the production program was predominantly repetitive while the missile site construction activity was nonrepetitive. Fifth, feedback was extremely

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[1] Alfred D. Starbird, Lieutenant General, USA, Retired, interview by Dean J. Stevens, Staff Historian, U.S. Army Safeguard System Office, Washington, D.C., 6 August 1971.

important in the technical program, and proactive control was essential to the practiced management philosophy. Sixth, the technical performance parameter is an excellent predictive device, but is frequently difficult to assess rapidly. As a consequence, the schedule and cost parameters are typically used in preference to technical performance. Seventh, the technical performance situation did not require one hundred percent measurement or tracking in all engineering activities. Some specific activities, such as configuration management, did, however, require one hundred percent tracking. Certain elements of the product assurance program also required one hundred percent measurement. Finally, as with both of the other two parameters, timeliness of reporting was an important factor in defining the technical performance control situation.

Interrogation and Identification

Three major constraints significantly affected the technical performance parameter. First, there was the difficulty of totally quantifying objectives and assessing performance. In a program as complex as Safeguard it was difficult, particularly early in the design, to specify all system design objectives in finite terms. The design process was an iterative one requiring repeated reexamination of the sensitivity of system performance to major item specifications and to changes in the design objectives and postulated threat. Periodic change was inevitable and it was essential to be prepared for changes and have the procedural initiatives available for controlling them. Simulation was utilized extensively in the design effort. Because of the importance of the simulation results, exhaustive efforts were made to validate them with actual test data.[1]

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[1]U.S., Army Ballistic Missile Defense Systems Command, Project History, pp. III-2 - III-3.

The second major constraint affecting the technical performance parameter was the lack of an inherent common denominator. The cost parameter has dollars as a common yardstick of measurement and the schedule parameter has time, but no such inherent dimension of commonality exists in the technical performance parameter. As an example, basic radar performance characteristics typically cited are average operating power measured in kilowatts, detection range measured in kilometers, signal to noise ratio measured in decibels, minimum target cross-section detection capability measured in square meters, and mean time between failure (MTBF) measured in hours. By comparison, basic missile performance characteristics include length and diameter measured in meters; weight measured in kilograms; acceleration and velocity measured in meters per second squared and meters per second respectively, maximum flight time and maximum range measured in seconds and kilometers respectively, and warhead yield measured in megatons. This diversity of dimensions added to the complexity of the control situation. "Roll-up" of data to increasingly higher levels of summarization is meaningless in the same sense that "roll-up" of dollars suggests ability to arrive at one cumulative total program figure.

The third and final major constraint attaches to the diversity of the engineering activities involved in the parameter. As an example, such individual activities as design engineering, test engineering, system support engineering, human factors engineering, value engineering, product and production engineering, safety engineering, maintenance engineering, and systems analysis must be carefully integrated into a balanced and comprehensive technical program. It is in the integration of these diverse activities that both intraparameter and interparameter trade-offs are explored to the fullest.[1]

Latent interdependencies are virtually nonexistent for intraparameter activities. The diversity of dimensions used in the technical performance parameter precluded any meaningful integration at the summary level.

Risk, uncertainty, and change are characteristic of technology-intensive activity. All three are directly related to the state of the art of the technology involved and tend to diminish as design matures through the life cycle, provided a comprehensive program is implemented. If a comprehensive program is not implemented, risk and uncertainty probably will remain at a high level. It is management's task to determine acceptable levels of risk and uncertainty and structure a program that will control them with the desired precision. It is here that technical control requires the highest level of managerial craftsmanship.[2]

The common characteristics of the technical performance parameter resulting from a generic examination of the assessment and definition factors and the interrogation and identification criteria are summarized for convenience in Table 5.

RDT&E Phase

This section of this chapter contains the first analysis of individual cells in the technical performance parameter and involves the RDT&E phase.

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[1] E. Oakley Drumheller, Jr. Forrest L. Godden, Jr. and John F. Schwegler, "System Engineering Process," Defense Industry Bulletin 7 (Winter 1971): 4-9.

[2] A brief introduction to the scope and spirit of technical risk and uncertainty may be found in Scott T. Poage, Quantitative Management Methods for Practicing Engineers (Boston: Barnes & Noble, Inc., 1970), pp. 20-29.

TABLE 5

EXAMINATION RESULTS COMMON TO ALL PPL ANALYSIS MATRIX CELLS IN THE TECHNICAL PERFORMANCE PARAMETER

EXAMINATION CONSIDERATIONS	SUMMARY EXAMINATION RESULTS
ASSESSMENT AND DEFINITION	
INFLUENCES	
EXOGENOUS	POLITICAL – SOME CONGRESSIONAL CONCERN REGARDING TECHNICAL FEASIBILITY, WISDOM OF DEPLOYMENT, AND VALIDITY OF DESIGN THREAT ECONOMIC – COST AFFORDABILITY USED AS SURROGATE FOR POLITICAL AND TECHNOLOGICAL CONCERNS; SOME CONCERN BMD WOULD DIVERT MONEY FROM DOMESTIC PROGRAMS PUBLIC OPINION – ACADEMIC – INTELLECTUAL – SCIENTIFIC COMMUNITY HIGHLY VOCAL, SPIRITED DEBATE PRO AND CON; OVERT ATTEMPTS TO DISCREDIT REQUIREMENT FOR SYSTEM TECHNOLOGY – ISSUE CENTERED ON ABILITY OF SYSTEM TO FUNCTION, SUSCEPTIBILITY OF SYSTEM TO PENETRATION, ABILITY TO PERFORM ITS ASSIGNED MISSION, AND LOCATION OF SITES NEAR CITIES
ENDOGENOUS	EXISTING U.S. ARMY MANAGEMENT DOCTRINE – DEVELOPMENT REQUIREMENTS, OPERATIONAL CONCEPTS, AND SYSTEM CHARACTERISTICS DEFINED; CONFIGURATION MANAGEMENT AND PRODUCT ASSURANCE PROGRAMS STRUCTURED; ABM REVIEW GROUP ESTABLISHED OTHER GOVERNMENT AGENCIES – CONFIGURATION MANAGEMENT AND PRODUCT ASSURANCE PROGRAMS STRUCTURED PARTICIPATING CONTRACTORS – UNSTRUCTURED BUT DISCIPLINED; FAMILIAR WITH U.S. ARMY REQUIREMENTS MANAGEMENT PHILOSOPHY OF PROGRAM MANAGER – DISCIPLINED; MANAGEMENT BY EXCEPTION; HIGH INTENSITY FOCUS ON PROBLEM AREAS
OBJECTIVES AND SCOPE	ISOLATION, DEFINITION, ANALYSIS, AND SPECIFICATION OF TECHNICAL ISSUES AND SYSTEM PERFORMANCE CHARACTERISTICS AND MAINTENANCE OF THE TECHNICAL INTEGRITY OF TOTAL SYSTEM DESIGN DURING THE SYSTEM LIFE CYCLE
KEY FACTORS	PARTICIPANTS REPORT TECHNICAL PERFORMANCE AS REQUIRED INFORMATION USED TO ENSURE ACHIEVEMENT OF A PRODUCIBLE AND OPERATIONAL SYSTEM CAPABILITY INPUT DATA FROM PARTICIPANTS IN REQUIRED FORMAT AND ON SPECIFIED TIMES CONTROL SITUATION CONTAINS BOTH NONREPETITIVE AND REPETITIVE ELEMENTS PROACTIVE CONTROL REQUIRED DATUM EXCELLENT PREDICTIVE DEVICE, BUT MAY BE DIFFICULT TO ASSESS 100 PERCENT MEASUREMENT NOT REQUIRED TIMELINESS OF REPORTING IMPORTANT
INTERROGATION AND IDENTIFICATION	
CONSTRAINTS	DIFFICULTY IN QUANTIFYING OBJECTIVES AND ASSESSING PERFORMANCE, LACK OF COMMON DENOMINATOR, DIVERSITY OF INDIVIDUAL EFFORTS INVOLVED
LATENT INTERDEPENDENCIES	VIRTUALLY NONEXISTENT FOR INTRAPARAMETER ACTIVITIES
CHARACTERISTICS	RISK, UNCERTAINTY, AND CHANGE ARE INHERENT IN TECHNOLOGY INTENSIVE ACTIVITY

Two cells in the PPL analysis matrix are analyzed in this section. Two each are analyzed in the next three sections, for a total of eight cell analyses in this chapter.[1]

The two cells examined in this section share the common phase dimension of RDT&E, but are differentiated by the level dimension. The first cell is defined by the strategic level; the second by the tactical level.

Strategic Considerations

Jay W. Forrester captured the flavor of the management of RDT&E activity in very concise and compelling terms. He wrote, some years ago, in his classic text on the behavior of industrial systems:

> ...research management is fraught with more uncertainty than most other parts of the management picture.[2]

While the uncertainty of RDT&E effort adds to the complexity of the task, it also underscores the intensity of the need for management control.[3]

The methodologies of engineering technology are fashioned in weapon system acquisition to enhance the creative effort required for successful

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[1]The quickening pace of technology has contributed significantly to the evolution of a dynamic and innovative environment surrounding RDT&E activity. Summarized accounts may be found in: John S. Foster, Jr., "FY 1972 Defense RDT&E Program: Research and Development in U. S. Defense Posture," Defense Industry Bulletin 7 (Summer 1971): 1-7; Paul E. Holden, Carlton A. Pederson, and Gayton E. Germane, Top Management (New York: McGraw-Hill Book Company, 1968), pp. 77-94; Joe C. Jones, "The Impact of Technology on Management," Defense Management Journal 6 (February 1971): 16-18; and Joseph A. Litterer, "Research Departments within Large Organizations," California Management Review 12 (Spring 1970): 77-84. A current descriptive account may be found in Philip H. Francis, Principles of R&D Management (New York: AMACOM, 1977), pp. 1-20.

[2]Jay. W. Forrester, Industrial Dynamics (Cambridge, Massachusetts: M.I.T. Press, 1961; New York: John Wiley & Sons, Inc., 1961), pp. 324-25.

[3]Ibid., pp. 324-29.

accomplishment of program objectives. While technology is frequently considered as a resource,[1] it is the control of the methodologies of engineering technology that is of interest in this study. The effectiveness of control at the strategic level is determined, in large measure, by the quality of technical competence available to the program manager,[2] the technical and managerial competence and corporate integrity of the prime contractor, and the formal and informal relationships between the program manager and the prime contractor. Control effectiveness is also influenced by the managerial response to the control situation and by the management philosophy employed in both the public and private participants in the endeavor.

Assessment and Definition

It was recognized very early in the RDT&E program that weapon system major item requirements or specifications had to be formulated as rapidly as possible. It was also recognized that the requirements had to be sufficiently definitive and unambiguous to guide the development effort without being overly restrictive. It was essential that interfaces be clearly delineated in order to assure the attainment of full synchronization of all major items into a total weapon system. Weapon system design integration was an enormously complex task involving a multitude of interrelated technical activities. As an example, it included such activities as accomplishment of total system compatibility and

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[1]Leikind and Miles, "The Nature of Science and Technology," in Science and Technology: Vital National Assets, eds. Sanders and Brown, p. 17.

[2]Technical competence may be available to the program manager by means of in-house military and civilian (civil service) personnel, through system engineering support contracts with private industry and academic institutions, or a combination of the two methods.

integration in terms of form, fit, and function; accomplishment of a system-wide parts standardization program; administration of an effective configuration management program; establishment of integrated production scheduling requirements; recommendations for repair parts provisioning; and accomplishment of technical documentation maintenance and control including operation of a technical documentation repository.

Overly restrictive technical requirements, on the other hand, have a tendency to unduly limit the range of available alternative solutions available to the designer. This reflects a process orientation as opposed to a goal orientation form of control--a focus on method rather than on outcome.[1] This is also a valid criticism and is to be scrupulously guarded against, particularly in design activity.

As a practical matter, timeliness and completeness of requirements are, typically, mutually exclusive objectives.[2] As a consequence, early requirements are frequently incomplete simply because all problems are not fully understood.

On balance, it would seem that the problems promulgated by lack of specificity may be more serious than the problems associated with overly detailed requirements. It is deemed prudent, therefore, to make requirements available as early as possible even though decisions may be made quickly and on

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[1]The concept of control of results as opposed to control of method is discussed in Gary Dessler, Management Fundamentals: A Framework (Reston, Virginia: Reston Publishing Company, 1977), pp. 334-35.

[2]This is fairly common in the weapon system acquisition process. An excellent discussion of the salient factors involved may be found in Merton J. Peck and Frederic M. Scherer, The Weapons Acquisition Process: An Economic Analysis (Boston: Division of Research, Graduate School of Business Administration, Harvard University, 1962), pp. 362-66.

incomplete analysis. As objectives change, analysis becomes more complete, and problems become more clearly defined and understood, the requirements may be updated as required. The desirable state would be detailed requirements for the end product without undue specification of the method or process for arriving at the final design.

The inevitability of change demanded close accounting and a comprehensive change control procedure; i.e., an effective configuration management system.[1] Change control insured that changes were tracked and that all designers were working with the most current set of requirements.

Interrogation and Identification

The technological complexity of the two radars in the Safeguard system coupled with the large number of changes experienced, particularly during testing, placed a severe strain on scheduling test time. It also necessitated very close coordination between hardware designers and software developers. While these complexities compounded an already difficult task and further complicated the control situation, they did not prove to be insurmountable. Configuration control of all changes represented a formidable management undertaking, but control of tactical software presented the greatest challenge.

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[1]The following references contain informative treatments of the nature, function, and procedures of configuration management: Chester P. Buckland, "Configuration Management: Creative Catalyst?" Defense Industry Bulletin 7 (Winter 1971): 1-3; National Aeronautics and Space Administration, Configuration Management Office Manual (Washington, D.C.: Apollo Program Office, n.d.); and T. T. Samaras and F. L. Czerwinski, Fundamentals of Configuration Management (New York: Wiley-Interscience, 1971). Regulatory requirements pertinent to the Safeguard program may be found in: U.S., Department of the Army, Safeguard Configuration Management Operating System Manual, Safeguard System Master Plan (SSMP) Supplement No. 3.10.A, Revision 2 (Huntsville, Alabama: U.S. Army Safeguard System Command, 1 July 1973).

This was due primarily to the fact that configuration management procedures for hardware and site facilities were far more mature than corresponding procedures for software.[1]

The wide diversity of activities in the RDT&E phase offered little in the way of linking threads that might permit development of a common technical denominator. As a general rule, design and test activity were interrelated technically by means of integrated system engineering plans. Further, all technical activity was interwoven by means of the schedule parameter. As previously mentioned, however, the dimensions of measurement reflected a wide range of technical units.

During the RDT&E phase, the program was technology-intensive, with schedule and cost of secondary and tertiary importance respectively. Program changes and design changes were inevitable, and the control situation was marked by highly unstructured, nonrepetitive work. Technologically, the RDT&E program operated almost continuously at the leading edge of the state-of-the-art.

Management Control Requirements

The primary plan used to guide the RDT&E program was the approved Technical Development Plan (TDP). The U.S. Army Ballistic Missile Defense Systems Command (BMDSCOM) was assigned responsibility for management of the missile system development contractors and other development agencies' efforts in accordance with the plan. Subordinate plans such as major item performance and design specifications, the coordinated test plan, the tactical

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[1]This paragraph is based partly on U.S., Army Ballistic Missile Defense Systems Command, Project History, p. III-3.

communications plan, and the nuclear weapons plan were used as specific control standards, even though the degree to which various elements were quantified varied substantially.

The mission assigned BMDSCOM encompassed the design and development engineering testing of the components and elements of the weapon system to assure that the system met the technical performance and system safety requirements specified in the component plans and technical specifications. BMDSCOM utilized engineering support contractors and appropriate government agencies for design support to achieve optimal trade-offs of technical considerations. Independent or system acceptance testing was conducted by the Safeguard System Evaluation Agency (SAFSEA) under the direction of the program manager.[1]

The management thresholds and tolerances established for the technical performance parameter were tailored primarily to the technical requirements of the system. The major item specifications delineated design objectives, but generally did not specify requirements for methods of achieving the results. Control of design and development test activity was not extended or rigidly controlled by the program manager below the level of the program manager approved specifications. The program manager also used cost and schedule thresholds as proxy technical performance thresholds because of their convenience and ease of application.

Performance reporting took a number of forms and involved both written and oral reporting. Some of the more meaningful forms are discussed in the following paragraphs.

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[1]U.S., Department of the Army, Principles of Management, p. 22.

The monthly progress report prepared by the prime contractor contained status information on all elements of program interest, including unique issues not explicitly referenced. A Weekly Activity Summary was also required to be submitted by electrical transmission to the program manager by all subordinate commanders. It was an information document containing concise statements of fact regarding such significant issues as results of interagency meetings or briefings, test results, milestone accomplishments, status of results of ongoing studies, contracts awarded, and special interest items. The report format specifically precluded inclusion of opinion, conclusions, or recommendations.[1]

Two separate major test reports were required. The first, the Quarterly Testing Report, was prepared quarterly to provide a periodic consolidated report on the progress gained during the quarter toward achieving the detailed test programs specified in the Consolidated Test Plan and more detailed, lower-level plans. The report also served as a means for periodic "closed-loop" review of test accomplishments against test plans. The coordinated report was prepared by BMDSCOM with input from appropriate test activities.[2] The second major periodic test report requirement pertained to reports prepared by SAFSEA. The reports were both Single Topic Evaluation Reports covering a single subject or area of consideration and Quarterly Evaluation Reports for periodic summarization of final Single Topic Evaluation

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[1]U.S., Department of the Army, Weekly Activity Summary RCS SAFSM-7, Safeguard System Master Plan (SSMP) Part 2.06.06 (Washington, D. C.: Office Chief of Staff, 23 June 1969).

[2]U.S., Department of the Army, Safeguard Test Reporting, Safeguard System Master Plan (SSMP) Part 2.06.10 (Washington, D.C.: Office Chief of Staff, 12 February 1970).

Reports. These two forms of report were limited to the independent evaluations performed by SAFSEA.[1]

Perhaps the most effective means of communicating status on technical performance was the use of periodic in-process program reviews. These reviews consisted of oral presentations or briefings by the principals involved and facilitated one-on-one dialogue between the program manager and, typically, the manager responsible for the technical aspects of the system element involved. These encounters were commonly used as a vehicle for redirection of program plans. The forum for proactive management control afforded by in-process program reviews was one of the most effective and important characteristics of the Safeguard program.

Tactical Considerations

Management control of technical performance at the tactical level is where the real visceral technical issues are resolved. While strategic considerations occasionally take on an aura of abstract detachment, tactical considerations are typically more tangible. Tactical considerations focus on detailed, hard-core engineering and scientific problems. They involve the decisions essential to conversion of input requirements into output designs, simulation and testing to determine performance capabilities, and analysis to confirm design fidelity.

Management control of this matrix cell is perhaps the most challenging of all of the cells. It offers almost unlimited opportunity for management

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[1] U.S., Department of the Army, System Evaluation Reports, Safeguard System Master Plan (SSMP) Part 2.06.05 (Washington, D.C.: Office Chief of Staff, 12 April 1969).

creativity involving new control initiatives. It is truly an area where "...management requirements...go beyond the proved capabilities of present forms and methods."[1]

Assessment and Definition

The tactical portion of the RDT&E phase is, in effect, the vehicle of implementation of the decisions made at the strategic level. The tactical cell is marked by greater informality and less guarded dialogue. This is not to suggest that dialogue at the strategic level is less than candid, but the mandatory formality frequently carries with it a concommitant prerequisite for selective filtration of some of the more speculative information.

This phenomenon is also a consequence of the summarization process, which attempts to eliminate detail to an increasingly greater extent with each higher level of reporting. This predigestion of data also eliminates or minimizes differences of opinion that frequently are highly significant. In a large-scale complex endeavor, oversimplification of complicated issues and elimination from consideration of divergent and conflicting views may mask attractive technical alternatives at the strategic level. Unfortunately, there does not appear to be an easy solution to this dilemma.[2] It is possible, however, that a sufficiently perceptive manager will, through probing, bring needed details to the surface.

The development of open and frank technical discussion and debate at the technical level tends to ameliorate the negative effects of oversimplification

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[1]Webb, Space Age Management: The Large-Scale Approach, p. 5.

[2]The loss of meaningful detail in the summarization process is highlighted in early missile system activities in John B. Medaris, Countdown for Decision (New York: G. P. Putnam's Sons, 1960), pp. 141-46.

and predigestion. This requires a great deal of technical excellence and professionalism at this level of decision making. It also requires a high degree of engineering discipline. Technical problems must be analyzed and clarified; theories tested; causes discovered, isolated, and confirmed; and solutions developed and validated. Technical actions must be based on solid technical fact rather than on opinion. Each of these actions gives rise to peculiar control requirements which must be fulfilled if discipline is to be implemented and maintained.

Interrogation and Identification

The constraints, potential for latent interdependencies, and predominant characteristics of the technical performance parameter at the tactical level are similar to those described for the strategic level. Differences, where they existed, were more differences of degree than differences of substance.

Perhaps the situation is best illustrated by example. At the strategic level a primary concern relative to system software was articulated as concern that the software would function and function properly with the associated hardware. At the tactical level this same concern was thought of more in terms of integrating the outputs of approximately twelve hundred software programmers, all working simultaneously, into a comprehensive and synchronized software package. The strategic concern was primarily goal oriented in this case, while the tactical concern contained elements of both goal orientation and process orientation.[1]

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[1]A brief overview of the major considerations associated with general software integration may be found in Robert L. Paretta and Stephen A. Clark, "Management of Software Development," Journal of Systems Management 27 (April 1976): 21-27.

Management Control Requirements

Probably no other two cells in the strategic-tactical cells pairs combination demonstrate more clearly or conclusively the compelling need for fitting control to the task[1] than the cell under discussion and the preceding cell. Where other tactical cells in the strategic-tactical cells pairs tended primarily to be concerned with providing input data for strategic reporting, the RDT&E tactical cell had unique requirements. In addition, the relationship between the strategic manager (the program manager) and the tactical managers was also unique. The relationship could best be described as one of a manager managing managers, since much of the RDT&E activity extended the state of the art and no historical standard of performance existed.[2]

The management control requirements at the tactical level were concerned formally with input of data for the preparation of reports required for strategic reporting. Of far greater significance and utility were the informal and frequent exchanges of technical status by telephone and personal visit. These exchanges were normally between contractor and government counterparts. They typically were very candid encounters and centered on technical problems as they arose. Consequently, on the day-to-day issues, little time was lost setting priorities and determining the significance of technical problems.[3]

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[1]For a brief discussion on the benefits of fitting control to the task, see Gary Dessler, Organization and Management: A Contingency Approach (Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1976), pp. 361-62, 378-86.

[2]The manager managing managers relationship is briefly analyzed in Jerry Dermer, Management Planning and Control Systems (Homewood, Illinois: Richard D. Irwin, Inc., 1977), pp. 243-59.

[3]U.S., Army Ballistic Missile Defense Systems Command, Project History, p. III-4.

One disadvantage of the informal exchanges was the possibility that decisions and agreements would not be properly documented. This void was normally filled with confirming letters, trip reports, or other forms of written documentation. The strategic level reports and special technical reports also helped provide the necessary management audit trail.

The advantages of this type of informal management control were discussed earlier in this chapter and do not require elaboration here. Suffice to say that the methodology was generally employed throughout the Safeguard program. It was an unstructured, but recognized requirement and was one of the most useful control techniques employed in the management control of the technical portion of the program.

Production Phase

The transition of a weapon system from the RDT&E phase to the production phase bench marks the transition of weapon system design from the relatively flexible to the relatively rigid. It also triggers a tightening of engineering change procedures coupled with more formality and greater government voice in the approval process. The transition process may be accomplished smoothly or it may be a source of severe turbulence in program progression.[1] It was a relatively smooth process in Safeguard since most of the major RDT&E contractors were also the manufacturing contractors. Thus, the expertise of the original designers was captured in the production phase.[2]

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[1]An interesting contemporary account of the RDT&E to production transition of weapon systems may be found in Frederic M. Scherer, The Weapons Acquisition Process: Economic Incentives (Boston: Division of Research, Graduate School of Business Administration, Harvard University, 1964), pp. 394-96.

[2]U.S., Army Ballistic Missile Defense Systems Command, Project History, pp. III-10 - III-11.

The two cells examined in this section share the common phase dimension of production. The first cell concerns the strategic level of decision making while the second cell concerns the tactical level.

Strategic Considerations

The government-contractor relationship that evolved with the Safeguard program found formal expression in the production program, but had its roots deep in the RDT&E program. The U. S. Army placed heavy reliance on the prime contractor and the subcontract structure for the successful accomplishment of the production program.[1] In keeping with this heavy dependency on the prime, the production program assignment included total responsibility for system integration and over all management of the diverse production program. System integration was perhaps the single most intricate, complex, and challenging engineering and management task involved in the technical performance parameter.[2] It was managed, on a day-to-day basis, at the tactical level of decision making.

The responsibility assigned the weapon system prime contractor included "voting" participation in many of the critical technical decisions affecting program progress and direction. The management philosophy inherently maximized contractor participation and influence in the decision-making

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[1]A compelling discussion on the importance of the United States industrial production base to United States military deterrence may be found in Jacques S. Gansler, "Let's Change the Way the Pentagon Does Business," Harvard Business Review 55 (May-June 1977): 109-18.

[2]Precisely this same area was a source of concern in the U.S. Navy Fleet Ballistic Missile (FBM) Program. For a discussion of the issue see Sapolsky, The Polaris System Development: Bureaucratic and Programmatic Success in Government, pp. 249-54.

process. In essence, the program manager managed prime contractor management of its contractually binding responsibilities. In some respects, the government-contractor relationship was closer to a partnership than the more familiar customer-contractor relationship suggests. The program was so immense and geographically dispersed and government in-house technical capability so limited that no other alternative appeared practical at the time. In retrospect, the arrangement stands the test of time and still appears prudent.

Assessment and Definition

At the strategic level the production phase was viewed as an integration of several allied yet distinct processes. First, the production phase involved the process of manufacturing the hardware for the weapon system. Hardware designs developed during the RDT&E phase were base lined, released to production, and manufactured by the prime contractor-subcontractor industrial structure in accordance with established production schedules. Secondly, the production phase included tactical site construction. The U.S. Army Corps of Engineers was responsible for the execution of the construction program in accordance with technical criteria provided by the program manager. Actual construction was performed by private industry under administration of the U.S. Army Engineer Division - Huntsville, an organizational entity of the U.S. Army Corps of Engineers, but under the operational control of the program manager. The third major process of the production phase was that of site activation. This was the vehicle which the program manager used to integrate the activities of the industrial sector, the U.S. Army Corps of Engineers, and all other government agencies assigned responsibility for any aspect of the establishment of the BMD site. Site activation management for any individual site began with the selection of the site location and continued through the release of the site to user personnel.[1]

The production phase was a complex management control situation. There were a number of major industrial firms involved, direct administration of the activity was split among several government agencies, and the number of things happening simultaneously was enormous. The merger of hardware, software, and site facilities was followed by the addition of operation and maintenance personnel in the deployment phase. All elements had to be integrated into a fully synchronized operational site. The enormity of the task presented a very complex management control problem.

Interrogation and Identification

A portion of the basic problem was purely scheduling in nature and was resolved through the schedule parameter as discussed in Chapter VI. There still remained as a part of the technical performance parameter problem, however, the vast technical job of assuring that all major items not only fit together, but that they functioned properly together as well. These factors did not surface so much as constraints as they did pure management complexity.

With regard to the potential for latent interdependencies, the statements made earlier for the overview and RDT&E analyses apply fully here. There just was not any direct potential.

While the degree of risk and uncertainty diminished somewhat in the production phase from the RDT&E phase, change was inevitable due to the concurrency problem mentioned earlier. Coordination of all technical activity,

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[1]U.S., Department of the Army, Principles of Management, pp. 32-34.

and particularly changes, became a significant task in the production phase. As in the RDT&E phase, the mainstream of activity was technology intensive, with schedule performance being next most important. Cost, while of concern, was of lesser consequence than either of the other two parameters.

Management Control Requirements

The Army Materiel Plan (AMP) was the master planning document for the production phase. It was the basic source document for development of the Safeguard PEMA (Procurement of Equipment and Missiles, Army) fiscal appropriation. It was the Safeguard input to the Army five year financial program input to the Program Objective Memorandum (POM). It provided a medium through which the program manager projected his PEMA program. It was a comprehensive document covering eight fiscal years; i.e., the immediate prior, the current, and the succeeding six fiscal years. The purpose of the plan was to document a means of achieving materiel objectives and maintaining balanced inventories. The AMP integrated those elements of production planning that directly affected Army materiel acquisition such as objectives, assets, losses, procurement, manufacturing schedules including administrative and production lead times, identity of producers, and fiscal obligation and expenditure levels.[1] The responsibility for preparation of the AMP was assigned to BMDSCOM. Approval authority was vested in the program manager based upon Department of Defense and Department of the Army program guidance. The AMP was also the root quantified standard for the control of the technical performance parameter of the production phase at the strategic decision-making level.

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[1] Adapted from William C. Wall, Jr., "Production Planning," address at the Defense Weapon Systems Management Center, Wright-Patterson Air Force Base, Ohio, 17 November 1967.

The Product Assurance Plan, a component plan of the TDP, set forth the major objectives of the product assurance program and the procedures necessary to attain the objectives. The plan expanded the objectives outlined in the TDP and established the organization, the techniques of assessment and inspection, and the specific management and technical controls required to assure the deployment of a reliable weapon system. While operative to a limited extent in the RDT&E phase, the product assurance program was fully operative across-the-board in the production and deployment phases. It was the primary technique of control over the manufacturing process and tactical site construction activity.[1]

The Integrated Site Activation Plan was a compilation of policy statements, instructions, and detailed procedures applicable to all agencies. It governed all actions involved in the activation of Safeguard sites. The plan was a composite of several component plans and delineated the responsibilities of all participating agencies and defined interfaces.[2]

The Configuration Management Plan was similar notionally to the Product Assurance Plan. Configuration management procedures were operative in the RDT&E phase, but the full potential was not realized until implemented in the production phase. The plan specified the scope and purpose of the Safeguard configuration management program, the policies of the program, and the requirements that had to be satisfied for effective implementation and operation

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[1]U.S., Department of the Army, Product Assurance Plan, Safeguard System Master Plan (SSMP) Part 3.07 (Washington, D.C.: Office Chief of Staff, 13 April 1970), pp. 1-9.

[2]U.S., Department of the Army, Principles of Management, p. 32.

of the configuration management program. Configuration management was the technique utilized to control changes to the technical base line.[1]

The establishment of management thresholds and tolerances was accomplished primarily through means of the individual plans just described. They were tailored to the tasks and requirements outlined in the plans. As a general rule, management thresholds and tolerances were reflective of the level of interest specified by the program manager for the cost and schedule parameters. Major item technical specifications delineated the design objectives, and changes to the base line were controlled through the configuration management program. As a matter of interest, the program manager reserved to himself approval authority of all changes estimated to increase costs in excess of $1.0 million within the current fiscal year or $3.0 million total for the approved program. Similarly, the program manager was the sole approval/disapproval authority for changes estimated to decrease costs in excess of $3.0 million within the current fiscal year or $10.0 million total for the approved program.[2] This tolerance band is interesting because it demonstrates clearly that the managerial indifference zone of the program manager had both a cost increase (upper boundary) and a cost decrease (lower boundary) limit. One might have intuitively assumed that no lower limit would be established in this specific case.

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[1]U.S., Department of the Army, Configuration Management Plan, Safeguard System Master Plan (SSMP) Part 3.10, Revision 1 (Washington, D.C.: Office Chief of Staff, 3 March 1971), pp. 1-1 - 1-4.

[2]U.S., Department of the Army, Safeguard Configuration Management Operating System Manual, Safeguard System Master Plan (SSMP) Supplement No. 3.10.A, Revision 1 (Huntsville, Alabama: U.S. Army Safeguard System Command, 4 November 1971), pp. 6-15 - 6-16.

Reporting requirements were similar to those discussed above for the RDT&E/strategic cell and will not be repeated here. One point deserves reiteration, however. As was the case with the RDT&E situation, the one-on-one encounters with the program manager in in-process reviews and special sessions were clearly the most beneficial. The forum provided for discussion, rapid communication and response, and the potential for rapid affirmative action.

Tactical Considerations

Management control at the tactical level in the production phase was a more structured process than used in the RDT&E phase. It was also a more rigid process, essentially devoid of the flexibility enjoyed in the RDT&E phase. Volume production forces greater management discipline and formality for three major reasons. First, it is essential that an engineering base line be fully documented to assure systematic communication between engineers. This facilitates technical visibility and provides the requisite audit trail for problem resolution. Secondly, the potential cost impacts are higher since a defective design is much more costly to correct once a design is in production. For example, changes to production tooling are typically expensive, as is retrofit of equipment already delivered. Third, a defective design delivered to the user could result in an inoperative weapon system. This is certainly not a desirable state.

These management control requirements of this cell presented a sizable challenge because of the multifaceted scope of the activity. The synchronization of all of the effort was an enormous undertaking in itself even without the technical complexities involved. The inherent technical complexity, coupled with the schedule and deployment concurrency issues, increased the magnitude of the management control task significantly. The impact of the deployment concurrency issue abated as the number of sites in the program was incrementally decreased, but the other did not attenuate as rapidly.

Assessment and Definition

Analysis of this element revealed that the discussion recorded for this element in the RDT&E/tactical cell applies equally well here. Many of the managers were different, the technical problems had a production orientation in lieu of an R&D orientation, but the technical management relationships were quite similar.

The fidelity of the engineering documentation released to production is the key to smooth transition from RDT&E to production. Even though incremental releases of items to production may occur, the documentation must be technically complete in all particulars. Detailed end item engineering documentation is essential in order to accurately describe specifically what is being procured both in the buying cycle and in the materiel acceptance cycle. Control of hardware and site facility documentation and system software is effected through the configuration management program, while control of materiel quality is accomplished through the product assurance program. Both programs are critical to success in the production phase and are stressed accordingly.

The engineering doucmentation "released to production" pertained solely to the hardware portion of the weapon system. The technical documentation for the site facilities was "released" from the RDT&E phase to the production phase, but the documentation was the basis for a construction process, not a manufacturing process. Similarly, system software was "released" from the RDT&E phase to the production phase, but there was not a manufacturing or construction process associated with system software. In other words, system software possessed the unique quality of being able to transition directly from the RDT&E phase to the production phase without having to go through a manufacturing process. When released from RDT&E, it was equivalent to the output of the manufacturing process, and required installation and integration only. As a result, system software was transmitted directly from the developer to the tactical site for installation and integration with the system hardware.[1]

Interrogation and Identification

The constraints, potential for some form or dimension of common denominator, and major characteristics of the technical performance parameter at the tactical level were strikingly similar to those described for the strategic level.

While no major differences in substance were noted, the characteristics of risk, uncertainty, and change were more discernible at the tactical level than at the strategic level. This was due fundamentally to the summarization and predigestion of data that occurred as it moved up the program management chain of command. It was also a function of the length and frequency of exposure of tactical level managers to the near-term realities of the production phase. In other words, tactical level managers were closer to the major sources of production risk, uncertainty, and change than the strategic level manager,

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[1]A broad study of Safeguard system software is contained in J. D. Musa and F. N. Woomer, Jr. "Software Project Management," Bell System Technical Journal (Special Supplement) (1975): S245-S269.

both hierarchically and functionally. Consequently, the characteristics of risk, uncertainty, and change were more evident at the tactical level than at the strategic level.

Management Control Requirements

In large measure the management control requirements at the tactical level were associated directly with implementation of strategically driven requirements. Two tools, configuration management and product assurance, are worthy of brief elaboration, however, due to their relevance specifically to the tactical level situation.

The principal objectives of the configuration management program were to establish a configuration base line, control all changes to that base line, define the approved product configuration, and document actual product configuration. The program also had an "early warning" feature to assure that all activities concerned were notified in advance of major changes being considered that affected their product.[1]

The configuration management procedure specified three time-phased formal reviews of system design. First, a Critical Design Review (CDR) was required before the design could be released to production. The CDR was the vehicle used to permit the U.S. Army to assure that the design met system requirements and was ready for release to production. The First Article Configuration Review (FACR) was conducted to compare initial production hardware with the documentation that described the production configuration. This second review was used to confirm the validity of production

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[1]U.S., Department of the Army, Configuration Management Plan, pp. 1-1 - 1-3.

documentation. The FACR was authorized to be conducted as a product assurance function instead of a configuration management function. Third, the Documentation Validation Audit (DVA) was required for tactical hardware after sufficient quantities of the item had been produced to permit stabilization of the manufacturing processes. The purpose of the DVA was to evaluate and confirm the fidelity of the engineering documentation of the production base line.[1]

A separate time-phased review process was required for site facilities. The Review of Facilities Design (RFD) was required on the design of site facilities when design was 30 percent complete, 60 percent complete, and 90 percent complete. The purpose of these reviews was to assure that design was progressing satisfactorily and that all requirements were being considered during the design activity.[2]

The configuration management program also provided mechanisms for processing changes to the base line and for processing waivers and deviations. Criteria were defined for determining which of four established hierarchic approvals was appropriate in any given circumstance. Specific requirements also defined the regular and special reports required and the form of mandatory historical files and records.[3]

The unique qualities of system software discussed previously permitted it to be base-lined later than the hardware and site facilities designs. It was also determined that a departure from the concepts of a CDR, FACR, and DVA was required since the procedures for those formal reviews reflected a typical

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[1]U.S., Department of the Army, Safeguard Configuration Management Operating System Manual, pp. 5-1 - 5-30.

[2]Ibid., pp. 5-30 - 5-31. [3]Ibid., pp. 4-1 - 4-32, 6-1 - 10-26.

hardware approach not appropriate for system software.[1] Configuration management, as a process, originated as a means of controlling documentation and hardware, but the principles are also applicable to system software.[2]

The configuration management approach adopted for Safeguard system software was referred to as a "Stages of control" method. Under this concept, the controlled documentation passed through two stages. The first stage involved contractor control only. The second stage occurred after base-lining and involved joint contractor/U.S. Army control. The documentation base-lined included the performance/design specifications; documentation related to tactics, software operation and test, and necessary support functions; and the source code[3] for the actual system software end-product used at each site.[4]

The primary objective of the product assurance program was to achieve the highest weapons system reliability and availability levels possible, within the time and cost constraints, consistent with materiel need. Each of the more than two million components used in the system had to be tested to assure that they conformed to the design parameters stipulated in appropriate engineering drawings and specifications. Product assurance data were used to

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[1]U.S., Army Ballistic Missile Defense Systems Command, Safeguard Software Configuration Management Plan and Software Local Configuration Control Board Charter, Revision 2 (Whippany, New Jersey: Bell Laboratories, 2 August 1974), pp. 5, 22.

[2]For an enlightening discussion on Safeguard system software configuration management, see D. Van Haften, "Software Change Control," Bell System Technical Journal (Special Supplement) (1975): S231-S244.

[3]Source code is the original symbolic language statements in which software is prepared prior to assembly or compilation.

[4]U.S., Army Ballistic Missile Defense Systems Command, Safeguard Software Configuration Management Plan and Software Local Configuration Control Board Charter, pp. 5-13.

define a realistic picture of system reliability and availability. More importantly, the program was meant to provide early warning of potential problem areas.

The product assurance program was operative across the total life cycle of the Safeguard weapon system and was composed of several subprograms. The quality assurance effort was designed primarily to assure the requisite degree of quality in all materiel and to prevent quality failures. The Corrosion Control and Deterioration Prevention Program was aimed at protecting the weapon system components from corrosive environments. The Standardization Program established a means of minimizing the introduction of new components, items, processes, and practices into the weapon system. Its major objectives were to enhance interchangeability, to conserve resources, and to improve the operational readiness of the weapon system. The Reliability Program was aimed at assuring that established reliability characteristics of the weapon system were not degraded during manufacture, operation, maintenance, and storage of the weapon system. Finally, the prime objective of the Maintainability Program was to assure that the maintainability considerations developed during the RDT&E phase were not permitted to degrade during operation, maintenance, and storage.[1]

A number of periodic and special reports were required. In addition, special investigation and audit reports were stipulated on a regular and an as-required basis.[2]

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[1]U.S., Department of the Army, Product Assurance Plan, pp. 1-2, 27-48.

[2]Ibid., p. 9.

Deployment Phase

As with previous sections, the two cells discussed here are identical except for the level dimension. The first cell is the technical performance/ deployment phase/strategic level cell, while the second is the technical performance/deployment phase/tactical level cell.

Strategic Considerations

As indicated in previous chapters, the assignment of responsibility for operation of the tactical site was not a normal responsibility of a program manager. While the phase was of short duration, it was a dichotomous situation. On one hand it represented an added burden to the program manager and his staff. It broadened the program manager's sphere of direct responsibility and added an exposure to new and different problems. On the other hand, one of the primary purposes of the deployment phase was to gain operational experience of a deployed ABM site. The assignment of responsibility to the program manager for deployment enhanced his ability to accomplish this aspect of the technical performance parameter.

Assessment and Definition

Three major technical activities were highlighted in the deployment phase. The first, the operation of the logistics program, is a normal function of the program manager. The second, the training of instructors, operating, and maintenance personnel, is usually the sole responsibility of the U.S. Army training community. In the case of Safeguard, the program manager exercised executive authority over the training program. Finally, the operation of an activated site is normally the mission of the U.S. Army user community. The operation of the Safeguard site was conducted under the purview of the program manager.

The over-all responsibility for the establishment of policy and guidance for logistic support of the Safeguard system was assigned to the program manager. The mission of developing, implementing, and operating the logistics system was initially assigned to the U.S. Army Safeguard Logistics Command (SAFLOG), a subordinate command of the U.S. Army Materiel Command.[1] The SAFLOG had the sole task of providing system mission essential logistics support of tactical equipment at the site. This responsibility included development of quantitative and qualitative logistics support requirements, operation of the logistics depot, procurement and distribution of repair parts inventories, and periodic evaluation of the results of logistics efforts. The size and complexity of the Safeguard program required substantial levels of manpower and equipment resources for its support and justified establishment of independent Safeguard dedicated institutions such as SAFLOG.

Responsibility for non-mission essential support of the tactical site was the responsibility of the U.S. Army Continental Army Command.[2] This non-mission support included common services, administration of contracts awarded in the geographical proximity of the site, and special transportation required occasionally for evacuation of weapon system equipment to manufacturing facilities or the depot.[3]

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[1]The U.S. Army Materiel Command was subsequently redesignated the U.S. Army Materiel Development and Readiness Command.

[2]The U.S. Army Continental Army Command was subsequently abolished. Its mission was divided between two newly established commands: the U.S. Army Forces Command and the U. S. Army Training and Doctrine Command.

[3]U.S., Department of the Army, <u>Principles of Management</u>, p. 31.

In October, 1972, the Secretary of the Army concurred in a program manager conclusion that logistic support for a single deployed ABM site could be provided more effectively by the prime contractor than by a fully dedicated logistics system while maintaining the same reliability, availability, and system effectiveness objectives.[1] As a result, the U.S. Army system, which was not fully operational, was deactivated and conversion to a contractor logistics support system was accomplished.[2]

The training mission included three major segments. First, the New Equipment Training (NET) responsibility was assigned to BMDSCOM. NET is required for the training of military and civilian training school instructors and other selected key personnel. This training is the initial transfer of required technical knowledge from the designer to the training school instructor cadre that form the off-site resident training base and other key personnel that conduct and evaluate engineering and service tests and occupy staff positions that require a basic understanding of the weapon system. The second element of the training mission was associated with the off-site resident training of operating and maintenance personnel. This provided requisite training for the operation, maintenance, and support of the weapon system at the tactical site. This training program was the responsibility of the U.S. Army Continental Army Command. The third element of the training mission concerned the on-site

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[1]A study of contractor logistics support in comparison to U.S. Army logistics support was performed in 1972 at the direction of the program manager. Results are documented in U. S., Army Safeguard System Command, Safeguard Site Maintenance Study Evaluation (Huntsville, Alabama, 7 August 1972).

[2]U.S., Department of the Army, Integrated Logistics Support Plan, Safeguard System Master Plan (SSMP) Part 3.15, Revision 3 (Washington, D.C.: Office Chief of Staff, 7 November 1973), pp. 1-1 - 1-2.

training of operating and maintenance personnel primarily by prime contractor personnel. This training was designed to qualify personnel to meet the operational requirements of each site through on-the-job training. This training was the responsibility of the user community.[1]

The decision by the Secretary of the Army to adopt contractor logistics support also caused a change in the training philosophy. NET and off-site resident training were conducted for a limited number of personnel, and the scope of course offerings was drastically reduced. All other required training was accomplished on-site through joint U.S. Army/prime contractor training.[2]

Planning for both the logistics support and training programs was initiated early in the RDT&E phase. While the planning was accomplished as a concommitant off-line product of the main-stream design effort, it was updated as major design changes occurred. Plans were solidified for both tasks early in the production phase, and preliminary implementation was initiated. Both tasks were time phased to achieve full realization in the deployment phase, but both had to be modified substantially from their original form to provide for adjustment from a multi-site program to a one-site program.

In early 1973, the Secretary of Defense directed that the Safeguard site mission include operation for the purpose of gaining experience relative to the installation, test, and operation of a deployed ABM site. This objective was in addition to the basic objective of defense against ballistic missile attack or

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[1] U.S., Department of the Army, Principles of Management, pp. 34-35.

[2] U.S., Department of the Army, Ballistic Missile Defense (BMD) Integrated Training Plan, Safeguard System Master Plan (SSMP) Part 3.17, Revision 1 (Washington, D. C.: Office Chief of Staff, 21 August 1973), pp. 1-1 - 1-4.

accidental launch. The purpose was to secure vital data for use in the future development and deployment of ballistic missile defense systems, should that become a reality. Operating experience was gained and a data base developed during the period that the Safeguard site was operational.[1]

Interrogation and Identification

The change from a U.S. Army logistics support to contractor logistics support for Safeguard in 1972 represented a mid-course steering control correction to the planned course of action. It was triggered by control feedback and was an excellent example of proactive management. The management initiative that resulted in the deactivation of the dedicated U.S. Army logistics support system and concurrent establishment of a contractor logistics support activity was a prudent program decision. It resulted in a substantial cost avoidance and simplified the management control situation.

The diversity of activities in the deployment phase presented a situation, with regard to latent interdepencies, similar to that found in the RDT&E and production phases. There was not an easy method of linking technical performance data without the use of a surrogate. As before, the surrogate was the schedule parameter.

During the deployment phase, the program continued to be technology-intensive. The development of operational experience unique to a tactically deployed system was considered critical. Cost became a more critical parameter than schedule, however, as the resource crunch began to affect the program.

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[1]U.S., Army Ballistic Missile Defense Systems Command, Safeguard Operational Experience Program (SOEP) Report Part-I (Huntsville, Alabama: PAR Management Office, February 1977), pp. 1-1 - 1-9.

Management Control Requirements

The logistics support program was driven by the Integrated Logistic Support Plan. It served as the fundamental reference for the logistic support effort. It established procedure, designated responsibilities, and described required time sequencing of major activities. Two component plans were specified. The first, the Safeguard Maintenance Support Plan, was a planning document outlining the concepts of maintenance for Safeguard equipment. The second, the Safeguard Supply Support Plan, set forth guidelines for all applicable participants to follow in the implementation and use of the supply system.[1]

The training program was described in the Integrated Training Plan (ITP). It consisted of three major sections compatible with the breakout of the mission; i.e., NET, off-site resident training, and on-site on-the-job training. Responsibility for consolidating, coordinating, publishing, and maintaining the ITP was assigned to the U.S. Army Continental Army Command. The program manager also established a BMD Training Committee to coordinate and review all training matters prior to presentation to him for disposition.[2]

Requirements for the Safeguard Operational Experience Program were documented in a report by the same title.[3]

Once the individual plans cited above had been approved, the program manager monitored progress through schedule and cost control technique and

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[1]U.S., Department of the Army, Integrated Logistics Support Plan, pp. 1-1, 5-1, 6-1 - 6-4.

[2]U.S., Department of the Army, Ballistic Missile Defense (BMD) Integrated Training Plan, pp. v, 1-1 - 1-4.

[3]U.S., Army Ballistic Missile Defense Systems Command, Safeguard Operational Experience Program (SOEP) Report Part-I.

tools. In addition, periodic performance reports, both regular and special, and oral and written reports were rendered by key managers of the plans.

The management activities covered in this matrix cell were not suitable for the use of technical performance management thresholds or tolerances. Exception reporting was driven primarily by the schedule parameter. In general, management thresholds and tolerances were not utilized for control purposes in this matrix cell.

Tactical Considerations

The technical performance/deployment phase/tactical level cell is a very significant cell in the PPL analysis matrix. It is here that the first technical feedback from the user community occurs. The initial operation of a typical weapon by the user is frequently a turbulent period. It is the period when the system is fully "wrung out" by the personnel that may have to operate it during actual hostilities. As a result, the weapon system is tested to the limit and often beyond the limits of its specifications.

In the Safeguard program the organizational separation between the user and the developer was not nearly as distinct as it typically is in classic U.S. Army project management. Furthermore, the prime contractor maintained technical personnel at the site throughout the total period of deployment. These two factors tended to minimize the impact of the transition from the production to the deployment phase.

Assessment and Definition

The three major technical activities discussed in the analysis of the strategic level were implemented at the tactical level. The management control situation at the tactical level was atypical for all three activities. Two were unusual because of the conversion from U.S. Army logistics support to contractor logistics support. The third activity was atypical because it was a mission normally reserved to the user community.

The control situation for the logistics support activity was characterized as a "manage" function under the U.S. Army logistics support system. The mission essential logistics support function was performed by SAFLOG and managed by BMDSCOM. The non-mission essential support was performed by the U.S. Army Continental Army Command and managed by BMDSCOM. Under the contractor logistics support concept, a portion of the "doing" function was assigned to BMDSCOM and a portion was contracted to the prime contractor. Under this arrangement, BMDSCOM was assigned responsibility for performing Base Operations Support at the tactical site, which included such tasks as nontactical supply, pay of personnel, family housing, operation of nontactical site facilities and equipment, and non-tactical facilities maintenance. These tasks were far removed from normal program management tactical level responsibilities, since Base Operations Support is usually the mission of the U.S. Army Continental Army Command in the continental United States.

The change occasioned by the change in training concept was not as great. There was a shift of emphasis from off-site training to on-site training, but not a shift in responsibility or mission. Task assignments remained essentially as planned, but task execution was modified consistent with a single site program.

The assignment of responsibility for operation of the tactical site to the program manager was a mission foreign to a developer/producer organization. At the tactical level it represented a totally new management control situation for BMDSCOM.

Interrogation and Identification

In a broad sense, the use of contractor logistics support services, the contractor presence on-site throughout the deployment phase, and the assignment of site operation responsibility to the designer/producer cast an aura of continuing development on the deployment phase. In essence, these factors tended to "demilitarize" the activities of the deployment phase in comparison to American combat units deployed outside the continental United States. These factors, however, did not detract from the utility of the operational experience data gathered.

Probably the cardinal characteristic of the deployment phase for an air defense weapon system is an obsession with weapon system availability and readiness. The nature of the ballistic missile threat is such that a defensive weapon system must be in a high state of readiness twenty-four hours a day, seven days a week. This places a severe strain on the hardware, software, site facilities, and personnel comprising the system. It also mandates that a great deal of management emphasis be directed toward assuring that all factors contributing to weapon system reliability and availability be highly effective.

Management Control Requirements

The Integrated Logistic Support Plan and its component plans--the Safeguard Maintenance Support Plan and the Safeguard Supply Support Plan--were the standards for management control of the logistics support function. Additionally, the prime contractor was directed to develop an Integrated Logistics Support Management Information System for collecting, processing, storing, manipulating, and retrieving logistics support management information. This management information system provided the required degree of visibility for the total logistics support activity for the Safeguard BMD System. Contractor effort was defined in a contractually binding definitive scope of work. This scope of work was the standard for contractor performance and was controlled through normal U.S. Army contract administration procedures.

The training activity was controlled through the Integrated Training Plan, and management of training was integrated with the management of the Safeguard program. The Integrated Training Plan outlined the requirement for all three major segments of training and identified the requirements for instructors and administrative personnel, training aids, equipment, and facilities. It also specified curriculum, schedule, and student loads.

Two techniques were used in the management control of the Safeguard Operational Experience Program. The first was a detailed plan that defined a systematic methodology for obtaining, analyzing, and reporting information to assure that maximum benefit was obtained. The second was the establishment of a Safeguard Operational Experience Program Steering Committee. The committee's primary charter was to develop and implement the plan. It also included such specific tasks as review of experiments proposed for accomplishment and identification of critical issues for resolution by appropriate agencies.

Even though the activity represented by this cell in the PPL analysis matrix represented atypical functions for a designer/producer agency, the management control activity was taken in stride. In large measure, control was exercised through the cost and schedule parameters.

Termination Phase

The termination phase is the final phase in the life cycle. For Safeguard it meant the transfer, storage, and/or disposal of the hardware, software, site facilities, and personnel that constituted the weapon system. It also precipitated the abolishment of Safeguard dedicated management activities and conclusion of all contract activity.

The two cells discussed in this section are identical except for the level dimension. The first cell discussed is the technical performance/termination phase/strategic level cell. The second is the technical performance/termination phase/tactical level cell.

Strategic Considerations

Most military projects ultimately move into the termination phase. Some projects evolve from deployment to termination only after attainment of complete stabilization and satisfaction of full military usefulness in earlier phases. Other projects evolve after experiencing truncated activity in prior phases. The latter occurred in the case of the Safeguard program. Although its full military potential was never realized or demonstrated, the program termination phase began in February, 1976, and ended in September, 1977.

Assessment and Definition

The management control situation was defined by three major activities: (1) transfer, storage, and/or disposal of all weapon system components other than the Perimeter Acquisition Radar (PAR); (2) transfer of the PAR to the U.S. Air Force; and (3) preparation of lessons learned.

The transfer, storage, and/or disposal of weapon system components had been anticipated for several years prior to receipt of actual direction to proceed. As a consequence, the activity had been thoroughly analyzed, alternatives studied, and plans prepared. The technical requirements of those components destined for long-term storage were prepared and approved.

Transfer of the PAR to the U.S. Air Force involved reassignment of total responsibility for all aspects of PAR operation, maintenance, and technical control from the U.S. Army to the U.S. Air Force. A detailed plan[1] was developed by the program manager to provide for a smooth and orderly transition. The plan described the program manager's method of operation for the PAR site, identified specific issues requiring resolution, and scheduled activities and milestones associated with the transfer.

The preparation of lessons learned is normally associated with the termination phase. The process is widely used throughout the U.S. Army management structure as a vehicle for documenting significant positive and negative experiences. Contributions to a lessons learned document are usually solicited from all major participants. Contributors are encouraged to be candid in their comments and screening of submissions is minimized. Taken in perspective, lessons learned can be a major input and transfer of knowledge to the management decision-making process of subsequent managers in allied endeavors.

Interrogation and Identification

The termination phase for a large-scale complex endeavor is typically cost constrained. Every effort must be made to maximize alternate usage of salvageable materiel and facilities. Transfer of knowledge must be accomplished effectively where required. Technical and program files must be put in order and retired to records holding areas. Last, but certainly not least, the management personnel associated with the program must be considered and appropriate personnel actions taken.

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[1] U.S., Army Ballistic Missile Defense Systems Command, Proposed Army Input: PAR Transfer Plan (PARTP).

Schedule control assumes a position of secondary importance in the termination phase. This is due, in large measure, to its relation to the funding cycle. In other words, funds for the project are typically budgeted only through the year in which the termination phase is planned to be concluded. As a consequence, any time extension of schedules opens a possible exposure to a requirement for additional funds in a period in which none are budgeted.

Technical performance control drops to third priority in the termination phase. It is concerned primarily with the transfer of knowledge and development of technically adequate storage procedures for materiel going into long-term storage.

Management Control Requirements

At the strategic level, the deactivation of the tactical site was controlled by the termination and deactivation plans, with cost and schedule control as the primary control techniques. The transfer, storage and/or disposal of applicable weapon system components involved national government agencies within and without the DoD, state governments, and local governments. Every effort was made to reutilize all available elements.

The transfer of the PAR to the U.S. Air Force was controlled through the PAR Transfer Plan; i.e., the PAR Transfer Plan was the standard for control activity. Critical milestones were developed and used to assess status of actions taken in accordance with the plan. The total effort was coordinated with the Air Force to assure orderly and timely transfer of the PAR.

The preparation of lessons learned actually began prior to the official commencement of the termination phase. This action was taken in this manner to capture as much management experience as possible before it was lost to the program. Since phase-out of management organizations and principal subcontractors began prior to the termination phase, it was necessary to initiate activity in this regard while the participants still had an obligation to the Safeguard program. The effort was beneficial and resulted in a published report that compiled lessons learned into the three areas of program control, BMD weapon system, and BMD tactical site.[1] The report presumes that individuals using it will be familiar with the topics covered and favors brevity over detail.

Tactical Considerations

The technical performance/termination phase/tactical level cell in the PPL analysis matrix did not add any materially different considerations to the technical performance control situation beyond those described for the strategic level. The detail in which tactical level managers operate is at a lower level in the work breakdown structure, but solution of the strategic level technical performance problem resolves the problem at the tactical level as well. In sum, this cell did not influence the technical performance problem or its solution significantly. As a result, further discussion of the cell is unnecessary.

Technical Performance Control in Perspective

It is important that the differentiation between the "process" of technical performance and the "demonstration" of weapon system performance be understood. The "process" of technical performance involves the design, test, produce, operate, and appraise cycle which is at the core of the technical performance parameter. The "demonstration" of system performance characteristics involves such specifics as kill probability, system detection range,

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[1]U.S., Army Ballistic Missile Defense Systems Command, Safeguard Lessons Learned (Huntsville, Alabama, January 1976).

engagement range, multiple target handling capability, and similar features of weapon system capability. The "process" of technical performance is subject to the management controls discussed in this chapter. The "demonstration" of system performance characteristics is measured through direct testing and statistical inference techniques. The values so determined are characteristic of the weapon system, just as certain qualities are characteristic of individual human personality. Lack of attainment of or a degradation in attained system performance may result--and frequently does--in the re-energization of the technical performance parameter.

One of the most difficult tasks of the technical performance parameter is the quantification of specific requirements without overshadowing the purely qualitative aspects. There is a compelling need, particularly with the technical performance parameter, to quantify requirements to assure that progress toward their attainment can be accurately measured. By the same token, however, there are qualitative elements that defy quantification, but must not be overlooked. The relevance of quantitative and qualitative considerations was stated with great clarity in a U.S. Air Force Management Manual published over twenty years ago:

> When we judge the effectiveness of an operational system, the number and importance of the strictly qualitative criteria far outweigh the number of quantitative criteria. To close our eyes to these qualitative criteria and to rely completely on the purely quantitative is to court disaster. A manager of an operational system cannot afford to overlook the highly important qualitative aspects by taking refuge in the meager information made available to him by numerical data which constantly flow over his desk.
>
> On the other hand, a manager simply cannot operate without running head long into the need for quantitative standards of performance. He must know how long it will take to complete a given job, how many working days of how many people will be required, how much of what materials it will be necessary to use, and how much it will cost. Answers to these questions are based on performance standards and have one significant point in common: They all deal

> with "How many and how much" -- that is, with quantities. Need for answers to questions of this type leads to the drive for quantification of data which managers can use.[1]

While the philosophy described is true of the cost and schedule parameters, it is particularly applicable to the technical performance parameter. The management control tools and techniques used must be oriented to the quantitative without loosing sight of the need for and value of the qualitative.

The role of the manager in technical endeavors is becoming increasingly important. Stephens expressed it in these terms:

> Just as the engineers translate the discoveries of scientists into workable and practical applications to improve our lives, the manager is a multiplier of both the efforts of scientists and engineers in bringing forth and spreading the use of technology. It is through organization and management that the fruits of labor and progress of science are coalesced into modern society. Increasingly, management is as much the factor advancing technology as the application of discoveries and the diffusion of knowledge.[2]

The technical management of large-scale complex endeavors is a demanding and compelling task involving a multitude of interrelated activities. The technical manager has both the opportunity and the challenge to develop and implement management and technical initiatives that will have synergistic effects upon the total endeavor.

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[1]U.S., Department of the Air Force, The Management Process, Air Force Manual 25-1 (Washington, D.C.: Government Printing Office, September 1954), pp. 48-49.

[2]Stephens, Managing Complexity: Work, Technology, and Human Relations, p. 281.

CHAPTER VIII

SUMMARY AND CONCLUSIONS

This study examines management control as it was performed in a large-scale complex endeavor. The preceding analysis assesses the application of integrated management control in the program and examines changes both in the management control situation and in the associated managerial response. The technique used for the analysis was the PPL analysis matrix. Each of the three major parameters of cost, schedule, and technical performance are examined throughout the program life cycle at the strategic and tactical decision-making levels. This chapter is a summary of this study effort and contains conclusions drawn from the analysis.

Scope of Chapter

The specific objectives of this final chapter are threefold. First, the need for integrated management control in large-scale complex endeavors is addressed. The reality of integrated control as experienced in the Safeguard program is considered in the same context and so is the relative importance of the three cardinal program parameters over time. Secondly, having completed the critical examination of the individual cells in the PPL analysis matrix, the matrix is reassembled and refined in a manner dictated by the results of the analysis. This has resulted in a reconfiguration of the matrix that differs from the original model. Finally, it is proposed that management can and should have a base line for management control that is transferable, adaptive, and dynamic. This discussion centers on the interrelationships among the cost, schedule, and technical performance parameters and the compelling need for proactive management control in large-scale complex endeavors.

It is not suggested that the conclusions drawn in this chapter are the "one best way" in which to accomplish the management control function. To the contrary, the conclusions here recorded are intended to serve as guides and to stimulate the development of new and advanced management initiatives that enhance integrated management control of large-scale complex endeavors.

Need for Integrated Management Control

The urgent need for integrated management control seems clear. While it is a convenience to the examination process to analyze the three program parameters in isolation, they cannot be controlled in that manner. The development of alternatives and trade-offs among cost, schedule, and technical performance is a consuming activity in program management. Effective means for accomplishing rapid and accurate forecasting of the effect of proposed changes to any two of the parameters on the third parameter are required.

The Cost Parameter

Money is simultaneously both a resource to be utilized by the program manager in the advancement of his program objectives and a critical means of measuring program performance. It is probably the most important of the three parameters to the general public in major matters of substance involving government spending. Following initiation of the production phase of a military weapon system, cost is probably the most important parameter in the conventional judgement of Congress as well. The principal concern by both groups appears to be that fiscal support to one program will divert money from more favored programs. The relative importance of cost tends to increase as the system progresses through the life cycle in the view of the U.S. Army, becoming paramount in the termination phase. Because of these differing views of the relative importance of cost between the U.S. Army and its environment, the development of pragmatic alternatives involving trade-off analyses assumes added importance.

Management control requirements for the cost parameter at the strategic decision-making level should be derived independently of requirements for the tactical level and should be established first. Tactical level requirements realistically should be an extension of strategic level requirements--reaching several layers lower in the work breakdown structure (WBS). Establishment and maintenance of a fiscal audit trail down through the WBS is imperative. It is an essential of sound financial management. It is an automatic benefit of a WBS related financial management and cost control system. Properly structured, the financial management and cost control system can be made to transcend the boundaries of the strategic and tactical decision-making levels with ease.

Dollars are the yardstick of measurement for cost control and are the obvious integrative linkage in the cost parameter. Care must be used in exercising this linking thread due to the effect of inflation on dollars. Inflation is a function of time, and while a compilation of figures in current-year dollars reflects the differences in actual money by year, the "real" difference in terms of purchasing power due to inflation must be reconciled. As a result, true comparisons of dollars in different years must be equated to some selected base year, and all other year dollars must be inflated or deflated accordingly.

The Schedule Parameter

Time, like money, is concurrently both a resource in program management and a convenient and effective vehicle for measuring program performance. Time differs from money in that it is constant, certain, and cannot be stored. Schedule may be changed by the addition or diminution of money, personnel, or other resources, but time cannot be changed. Schedule concurrency occurs through excessive overlapping of the research, development, test, and evaluation (RDT&E) phase and the production phase. In the Safeguard program, deployment concurrency involving extensive overlap of site construction and installation at many sites was evident in original planning. The effect of concurrency is schedule compression. Concurrency is generally regarded as a major contributor to cost overruns in the weapon system acquisition process.

It appears that the schedule parameter is second in importance only to the cost parameter as viewed by the general public. The schedule parameter assumes the same level of importance for the Congress after initiation of the production phase. Viewed by the U.S. Army, the schedule parameter seldom assumes higher than second place in a rank ordering with the other two parameters. An exception would typically occur in a time-emphasis period of national urgency that creates pressures for schedule compression.

Schedule control lends itself very well to hierarchic decision-making levels. Through use of carefully selected milestones, a program manager may manage the program schedule to whatever depth of detail he desires. As an example, the uncertainties of the RDT&E phase suggest that the milestones selected be at a reasonably high level in the WBS. As the degree of uncertainty diminishes in the maturing system, the milestones may be selected lower in the WBS. Through the proper setting of management control thresholds and tolerances, the program manager may also assure that deviations are handled in differing manners, depending upon the criticality of the threshold or tolerance breeched. Properly developed, strategic level schedule control requirements should drive or determine tactical level requirements.

Time, as a common reference of measurement, is a clearly meaningful integrative thread in the schedule control parameter. Time is simple, constant, and certain. Time units may be mathematically manipulated and are not subject to inflation. Also of significance is the fact that time, unlike dollars, does not normally require 100 percent measurement or tracking. Time is an effective linking thread, both horizontally and vertically, in the WBS.

The Technical Performance Parameter

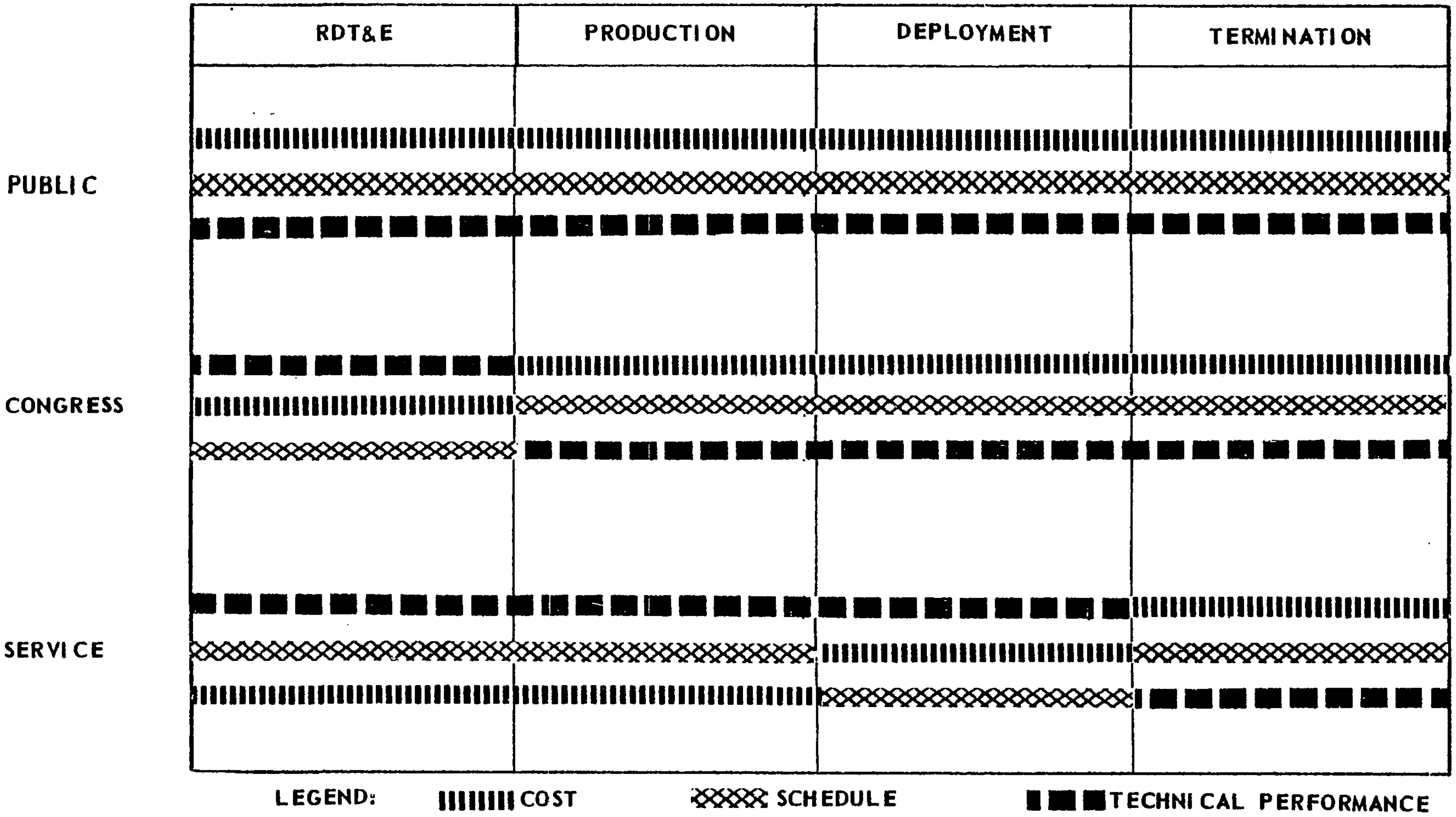
The process of technical performance, involving the design, test, produce, operate, and appraise cycle, is concerned with system design objectives and specifications. Its goal is assurance of the continual technical integrity of the weapon system. The technical performance parameter has a decided emphasis on engineering and scientific endeavors and the advancement of technology. Technical performance control is a demanding and compelling task involving a multitude of interrelated engineering and scientific activities. Of the three major program parameters, technical performance is the most difficult to quantify.

The technical performance parameter is probably the least important of the three program parameters in the eyes of the general public. While there is an inherent national pride in the attainment of new plateaus of technology, the general public is not as sensitive to technical performance as it is to cost and schedule. With the exception of RDT&E activity, the Congress views the matter in essentially the same light. The U. S. Army generally holds a perspective that places technical performance ahead of cost and schedule through the deployment phase.

Management control of technical performance presents a more formidable challenge than either cost or schedule control. There is virtually no common denominator of performance measurement, and each control requirement must be defined in units appropriate to the element being controlled. There is also difficulty attached to identifying and defining acceptable levels of technical risk. As a result, the establishment of management control thresholds and tolerances is exceedingly complex. The difficulties associated with identification of effective key control indicators that provide the earliest possible indication of variance from technical requirements compounds this complexity. Because of the difficulties associated with the technical performance control situation, cost and schedule control are frequently used as surrogates for technical control.

Relative Importance of the Parameters During the Life Cycle

Figure 15 depicts the relative importance of the three program parameters during a weapon system life cycle for the public, Congress, and service. It graphically portrays the thoughts discussed in the preceding paragraphs of this chapter section. With the exception of the RDT&E phase, it is suggested that the public and the Congress are in harmony in their respective views. It is also suggested that the U.S. Army view and the Congressional view are similar in the RDT&E phase and that all three views are identical in the termination phase.



NOTE: PARAMETERS ARE RANK ORDERED FROM MOST IMPORTANT (TOP) TO LEAST IMPORTANT (BOTTOM) IN EACH SET

Fig. 15. Relative Importance of the Cost, Schedule, and Technical Performance Parameters for the Public, Congressional, and Service Communities Over Time

The implications of Figure 15 on the control situation underscore the need for integrated management in large-scale endeavors. The control situation is especially complex during the production and deployment phases. The program requirements tend to dictate a strong emphasis on technical performance; i.e., a technical performance-emphasis priority. External influences, however, reflect a cost-emphasis and, to a lesser degree, a time-emphasis environment. Integrated management, based on fully developed interrelationships among all three parameters, would permit analysis of any single parameter in terms of the other two parameters. Integrated management would also facilitate trade-off analyses involving all three parameters. In sum, integrated management would greatly enhance the ability to manage a program as a technical performance-emphasis program, while responding to a generally cost and time-emphasis exogenous environment.

Safeguard Experience

The Safeguard BMD program fit this mold perfectly. It was basically a technically intensive program in a cost and time intensive environment. It was the most massive, complex, defensive weapon project ever undertaken by the U.S. Army. It represented a significant challenge to the DoD management process and maximized centralized management within the U.S. Army organizational structure. The Safeguard BMD program did not achieve full integration of cost, schedule, and technical performance, but it was a well managed program.

Two management concepts, fixed at the time of the deployment decision, were of paramount importance to the Safeguard program. First, the program was designated by the Secretary of the Army for system management. Under this concept, the system manager exercised coordination and directive authority over participating government agencies and private industry as a Vice Chief of Staff of the Army. He was totally responsible for the program and was given the full authority available to the U.S. Army to discharge his responsibility. The second concept attaches to the relationship between the U.S. Army and the weapon system prime contractor. Heavy reliance was placed on the prime contractor for the successful accomplishment of the total program. The prime contractor was assigned full responsibility for system integration and management of the production program. This philosophy maximized contractor participation and influence in the program direction. In many particulars, the government-contractor relationship was closer to a partnership than the more typical U.S. Army customer-contractor relationship. Both decisions were critical to the technical and management successes enjoyed by the Safeguard program.

The Safeguard management process resulted in an excellent definition of the scope of the management control problem, identification of the essential elements of the problem, assessment of total management control requirements, and establishment of meaningful quantitative and qualitative control standards. The major weakness of the process was the lack of positive follow-through. This resulted in ineffective integration of RDT&E management data with data from the other phases. Although management control of the RDT&E phase was effective at the tactical level, it lacked the broader perspective. The lack of full integration with other phases hampered efforts, at the strategic level, to track total program progress against a common System WBS. While not a fatal flaw in the management control system, the inability to accurately integrate the RDT&E program data detracted from the otherwise high fidelity system data available at the strategic level.

Accountability of individual responsibility was also a flaw in Safeguard management. Specifically, individual responsibility in accordance with the organization chain of command was not reconciled with accountability of individual responsibility in accordance with the System WBS. In some cases the organizational structure and the System WBS were not compatible and the differences were not fully recognized or corrected. Unfortunately, the System WBS was accurate, but did not totally coincide with assigned organization responsibilities. Refinement of the organization and minor redefinition of missions would have eased the inconsistencies, but these corrections did not occur.

The minor flaws in the implementation of management control in the Safeguard BMD program were totally overshadowed by the positive aspects. Safeguard management control was effective, pragmatic, and consistent with demonstrated need. The management of Safeguard was not an issue in the termination of the program. It was the gradual erosion, and ultimate loss of the political base upon which the program was founded, that led to the curtailment of resources and termination of the program.

Management Control Throughout the Life Cycle

The primary purpose of this section is the restoration of the PPL analysis matrix originally portrayed in Figure 1. The original model contains a total of twenty-four individual cells, all of which are assumed to be of equal importance in the analysis of the control situation. The three-dimensional analysis matrix developed in Chapter IV is consistent both with program management of the Safeguard BMD program and with similar large-scale endeavors. The matrix rows or horizontal planes are defined by structured, functional parameters of cost, schedule, and technical performance. The parameters encompass those critical elements of program activity essential to determination of project status. The matrix columns or vertical planes are defined by time sequenced, program life-cycle phases. The use of a time dimension for column definitions is an assist in evaluating management control dynamics during the life cycle of the Safeguard BMD program. The matrix files or depth planes are defined by hierarchic decision-making levels. This dimension provides insight into the influence of the organizational chain of command on the management control situation. It also underscores the significance of a macro management view of the program in contrast to a micro management view.

In this section, the matrix is reassembled based on the results of the analysis of the Safeguard BMD program. The PPL analysis matrix model is depicted in an open perspective in Figure 16. The original portrayal of the matrix in Figure 1 was in closed perspective. The model is shown in open perspective in Figure 16 to facilitate the graphic presentation of conceptual changes to the matrix in later illustrations. Other than the graphic change, Figure 16 is conceptually identical to Figure 1 in all particulars.

Conceptual Approach to Model Restoration

The restoration and refinement of the PPL analysis matrix took into consideration several aspects of the analysis results. First, the degree to which an individual cell contributed to definition of the management control situation was assessed. Specifically, this consideration centered on whether an individual cell was instrumental in defining the management control problem. Secondly, each cell was considered in terms of its potential for identifying essential elements influencing the problem, its solution, or both. Finally, the analysis

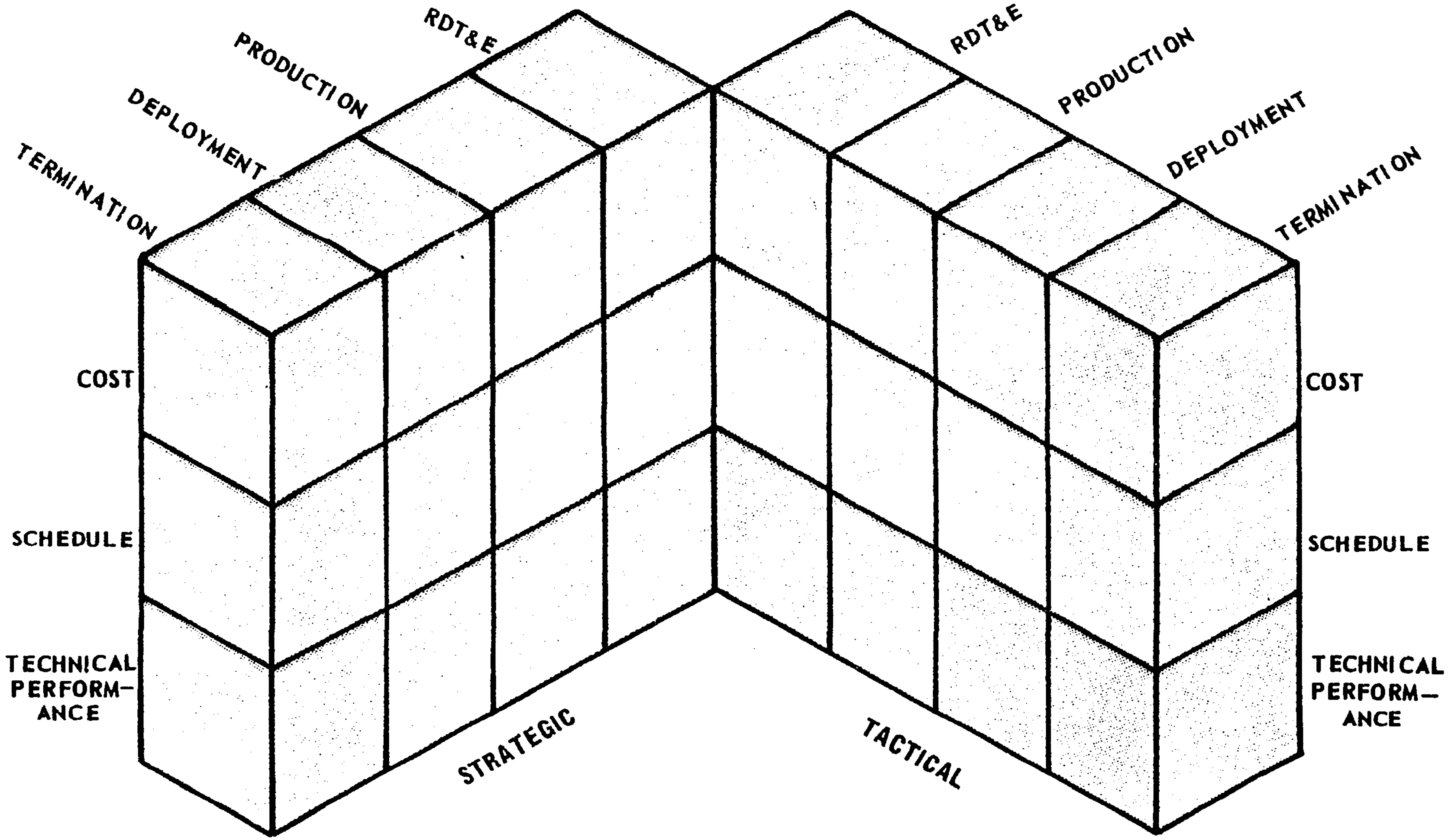


Fig. 16. Open PPL Analysis Matrix

results were examined to ascertain whether the cell had been pivotal in the establishment of actual management control requirements. If the answers to these considerations were affirmative, the cell was significant to the analysis. Cells so categorized were identified as major cells.

Matrix cells not fulfilling the requirements of major cells were of secondary importance to the management control situation. Cells in this category were labeled minor cells. The division of the matrix cells into these two categories resulted in a refinement of the PPL analysis matrix. The reassembled PPL analysis matrix depicts those elements contributing to specific definition of the Safeguard BMD management control situation.

PPL Analysis Matrix Major Cells

Figure 17 is an illustration of the major cells of the PPL analysis matrix as determined by the individual cell by cell examination. It will be noted that this reassembled matrix has only nine cells in the strategic level of decision-making in lieu of the original twelve. Similarly, the tactical level has only seven in lieu of the original twelve. In other words, the examination revealed that only sixteen of the original twenty-four cells are of constructive significance in evaluating the total management control situation.

Analyzed in terms of the program parameters, seven of the original eight cells in the technical performance parameter are significant. This results from the diversity of the technical performance management control situation. The technical performance parameter is especially complex, encompassing a variety of engineering activities and a multitude of assorted efforts. As a consequence, the total parameter reflects a great deal of variation throughout the life cycle. The cost and schedule parameters have five and four major cells

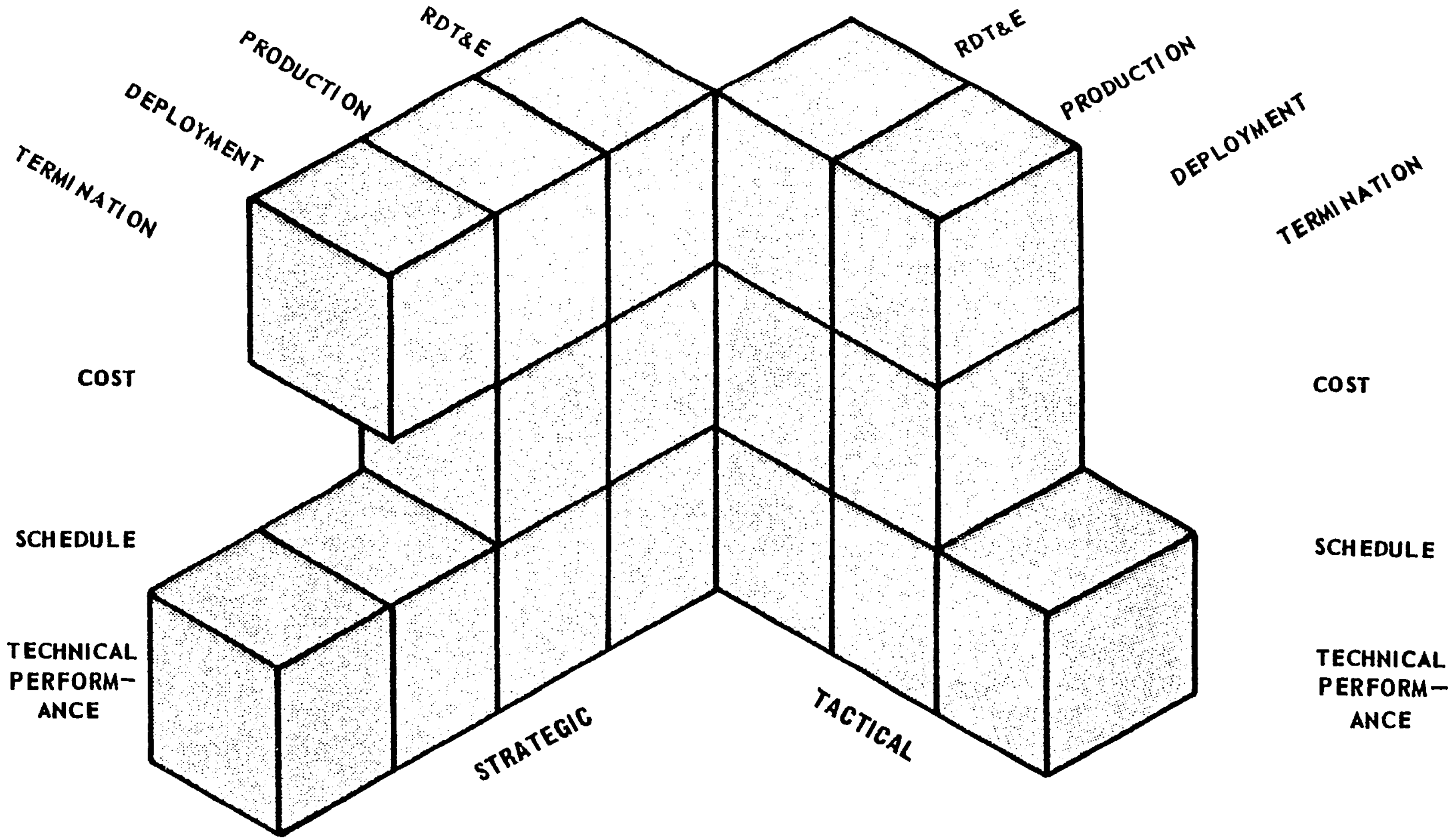


Fig. 17. PPL Analysis Matrix Major Cells

respectively, out of an original eight cells each, for the two parameters. In total, only nine of the original sixteen cells for the cost and schedule parameters are meaningful in the analysis. This is because the cost and schedule control systems developed for early life-cycle phases may be implemented with little change in subsequent phases. In other words, there is a higher degree of commonality among phases for these two parameters than with the technical performance parameter.

All six cells in the RDT&E phase as well as all six cells in the production phase are considered major contributors to definition of the total management control situation. This attests to the significance of these two phases to the management control situation. In the deployment phase only three of the original six cells are genuinely significant. These are the cost and technical performance cells at the strategic level and the technical performance cell at the tactical level. The termination phase is basically an extension of earlier life-cycle phase activity, with only the technical performance cell at the strategic level being of major consequence. The major cells depicted in Figure 17 identify the general areas that should be highlighted for special management attention when considering management control of large-scale complex endeavors.

PPL Analysis Matrix Minor Cells

Figure 18 illustrates the minor cells of the PPL analysis matrix. The eight minor cells identified were not necessarily less important from a total management control perspective than the major cells depicted in Figure 17, but minor cells are considered to have had only secondary influence on definition of management control requirements. In large measure, the specific management

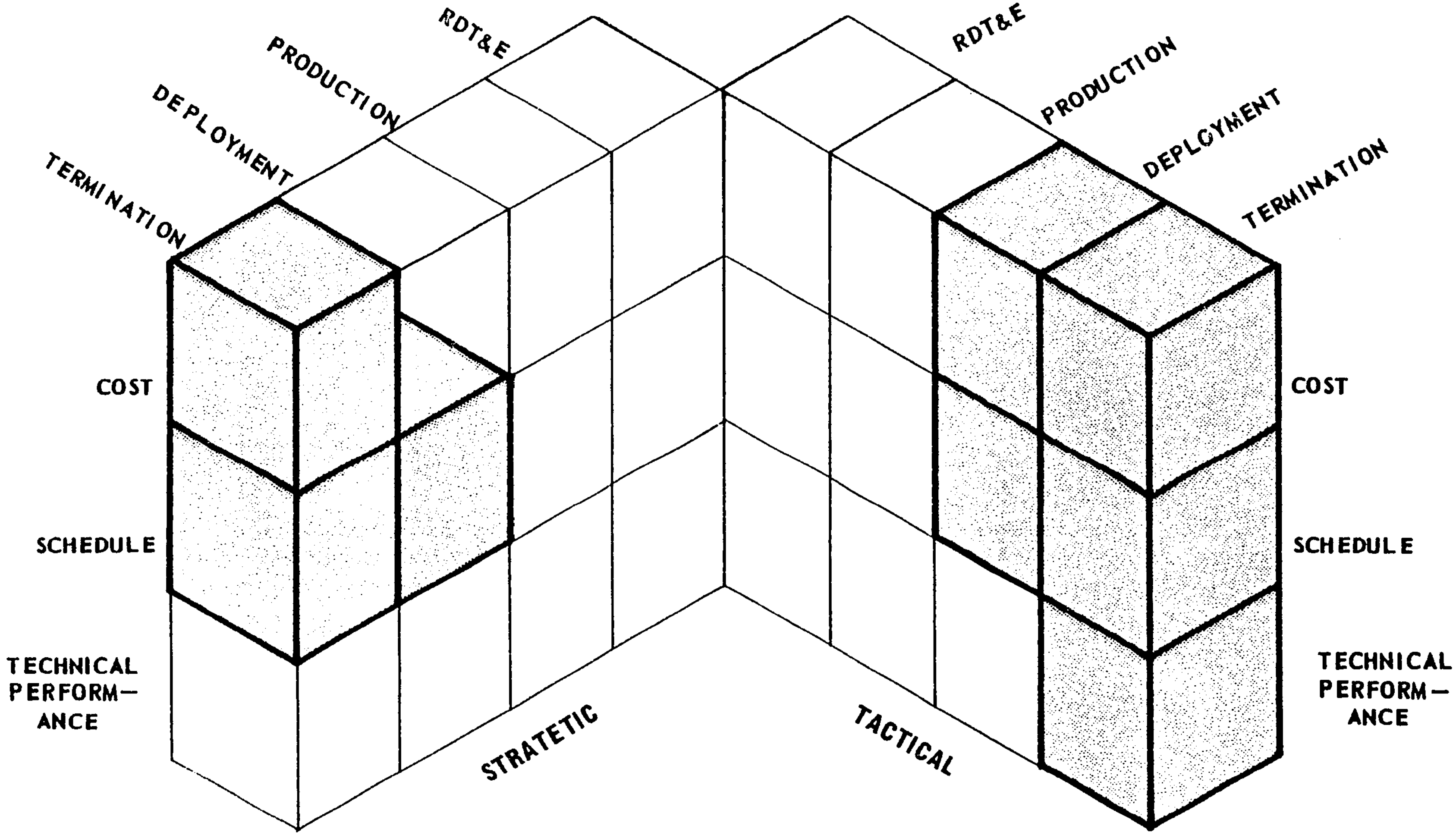


Fig. 18. PPL Analysis Matrix Minor Cells

control situation representative of each minor cell was an extension of earlier life cycle phase activity. As a result, management control tools and techniques employed in the earlier phases were extended to the minor cells. This extension of control systems into subsequent phases was more prevalent in the cost and schedule parameters than it was in the technical performance parameter.

Management Control Base Line

Management can and should have a base line for management control of large-scale complex endeavors. The base line should reflect a systems perspective and should integrate the three major program parameters of cost, schedule, and technical performance. It should be transferable, adaptive, and dynamic, and the conceptual base should focus on proactive management control tools and techniques.

The concept of integrated management control may be illustrated graphically. The Venn diagram depicted in Figure 19 portrays the three major program parameters, the three subsets of each pairs combination among the three parameters, and the single subset of all three parameters. The subset common to both the cost and schedule parameters is typically identified as cost performance reporting. The subset common to the cost parameter and the technical performance parameter is labeled work package budgeting. The subset common to the schedule parameter and the technical performance parameter is referred to as quantitative milestones. The single subset common to all three parameters is integrated program management.

Cost Performance Reporting

The basic premise upon which DoD cost performance reporting is founded is that schedule data are converted to and expressed in dollars. The

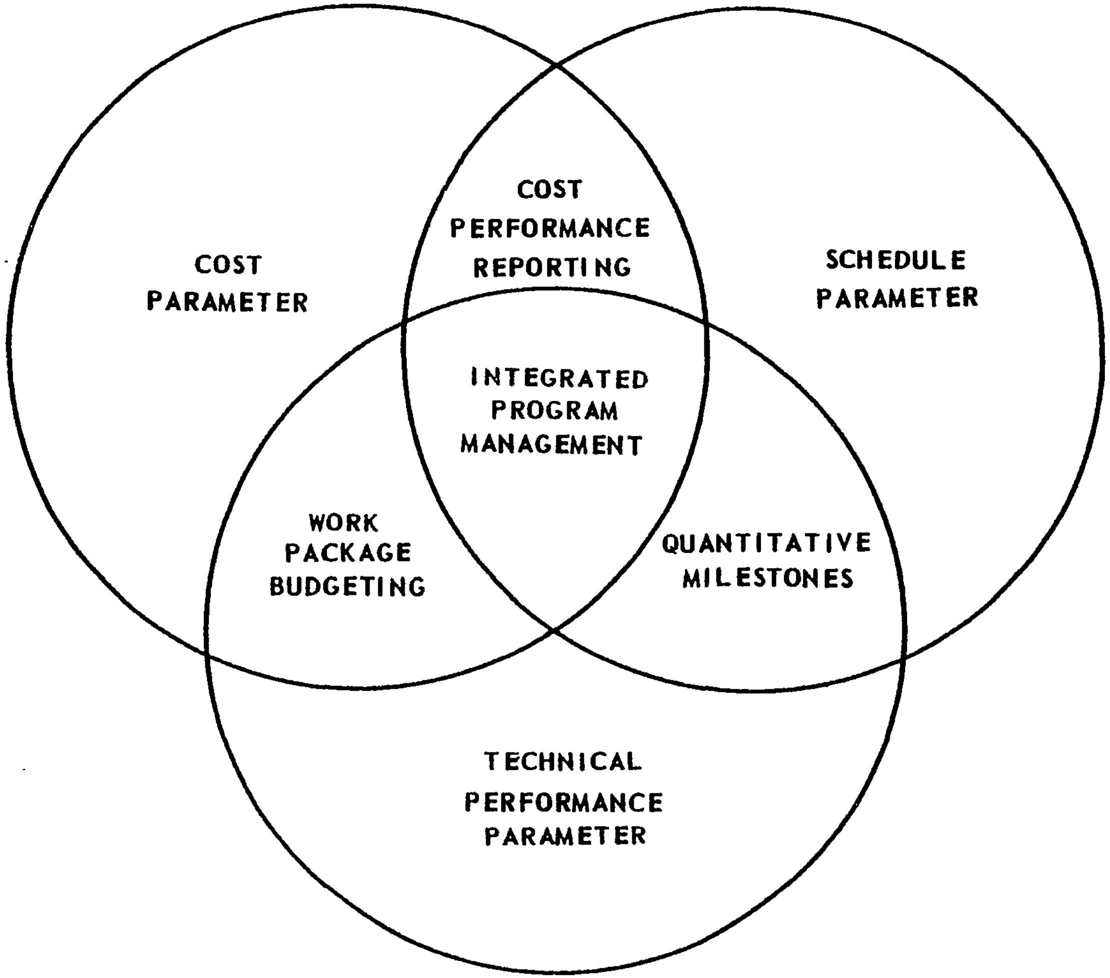


Fig. 19. Major Elements of Program Management

conversion process involves a time-phased fiscal budget plan reflecting the budgeted cost of work scheduled. The technique employs the WBS as the tool for identifying discrete elements of the program effort, whether they be goods or services.

In the WBS, work packages are the lowest level individual breakout of program effort, and the sum of all work packages must equate to total program effort. The cost parameter is related to work packages by allocating program dollars appropriate to the definition of the task to be performed. Any of a number of accepted cost estimating techniques may be used for this purpose. Since the individual work packages sum to total program effort, the fiscal budget allocation should sum to total program dollars less that amount designated for management reserve. The fiscal budget held for management reserve is a contingency to minimize program risk. Cost performance is assessed by measuring the actual cost of work performed.

The schedule parameter is related to work packages through the use of PERT, milestone planning and control, or similar scheduling techniques. All work required by work packages must be scheduled in a manner that will permit accurate evaluation of performance against plan. Work package schedules must permit roll-up into succeedingly higher level schedules, ultimately linking to the summary master schedule. The conversion of schedule data to dollars is accomplished by determining the fiscal budget applicable to the work scheduled to be performed within the specified time frame. Management control is exercised by determining the budgeted cost for work actually accomplished. This technique permits schedule variance to be expressed in dollars.

Cost performance reporting is a DoD management control technique for assessing cost and schedule performance in terms of a common denominator.

Properly implemented, it identifies the discrete elements of work to be accomplished down to the work package level, the organization or individual responsible for the work package, the dollar and schedule resources budgeted, and the resources expended in the accomplishment of the effort. The major deficiency of the technique is that it does not provide for direct management control of the technical performance parameter.

Quantitative Milestones

Quantitative milestones integrate the schedule and technical performance parameters. Quantitative milestones represent major decision points in the accomplishment of the program. They are events of technical significance strategically placed throughout the program. Properly established, quantitative milestones occur at sensitive points in the program life cycle and provide a quantified means of measuring and evaluating technical performance.

The quantitative milestone technique utilizes the WBS for definition of work packages. Because of the developmental nature of the programs normally associated with this technique, however, it is normally advisable to apply it at a higher level in the WBS. Typical application levels might be two to three levels higher in the WBS than the work package level.

The thrust of quantitative milestones is to emphasize technical performance. The schedule data are used primarily to determine where to locate the quantitative milestones. The key to the technique is the accurate quantification of technical requirements at strategic points in the project or task being controlled. The dimensions of quantification must be minimum essential capabilities of mandatory technical characteristics. The dimensions must be so defined that failure to demonstrate ability to meet objectives is sufficient cause to curtail further work until the performance capability can be successfully demonstrated or an adequate work-around plan formulated.

Quantitative milestones assure that technical decisions are consciously based on hard technical fact rather than omitted inadvertently and made by default merely through passage of time. The technique requires that objectives be predetermined prior to work initiation. The bases for quantification are the design and performance specifications and allied technical documentation. Quantitative milestones used in conjunction with basic schedules serve both as the plan for accomplishment of the technical program and as the standard against which achievement is measured.

Work Package Budgeting

Work package budgeting is a means of interrelating the cost and technical performance parameters. It also uses the WBS as the tool for identifying discrete work packages. Both the cost and the technical performance parameters are related to the WBS work packages by the same techniques described above in the cost performance reporting and the quantitative milestones subsections.

Work package budgeting is a disciplined but convenient technique for relating cost and technical performance. The technique employed may be as fundamental or as sophisticated as the endeavor warrants. Use of the WBS as a base permits summation of fiscal resources and program activity at varying levels of detail. The technique has utility both as a plan of action for future activities and as a major standard against which to measure progress. The primary deficiency of this technique is that it does not embody schedule control considerations.

Integrated Program Management

Integrated program management is at the core of the management control of large-scale complex endeavors. Its primary objective is to integrate the three major parameters of cost, schedule, and technical performance. In large measure, it demands that the program manager think in three dimensions. The concept is practiced typically by holding one of the three parameters constant.

Figure 20 depicts integrated program management in the perspective in which it is normally practiced. The program manager attempts to control the program boundaries as they are influenced directly by the endogenous environment, which tends to be rational. This environment is less controllable than the program. The least controllable environment is the exogenous environment which is normative. The endogenous environment may occassionally act as a buffer between the program and the exogenous environment.

Integrated program management is not a reality. Initiatives in this regard in the Safeguard program were terminated as the program was reduced in scope. While the activity that was accomplished showed promise, it was far from complete. It did suggest that the concept of integrated management, given sufficient time, interest, and development effort, is achievable.

Management Control in Perspective

Management control is an integrative force in the management process and a vehicle for feedback in the management cycle. The control function introduces the element of closure to management action, enhances rationality in the decision-making process, and underscores the search for order in large-scale complex endeavors.

Homeostasis is typically cited as the perfect biological example of an "ideal" control system. Homeostasis is concerned with self-regulation in the human body and it suggests a tendency toward a relatively stable state of

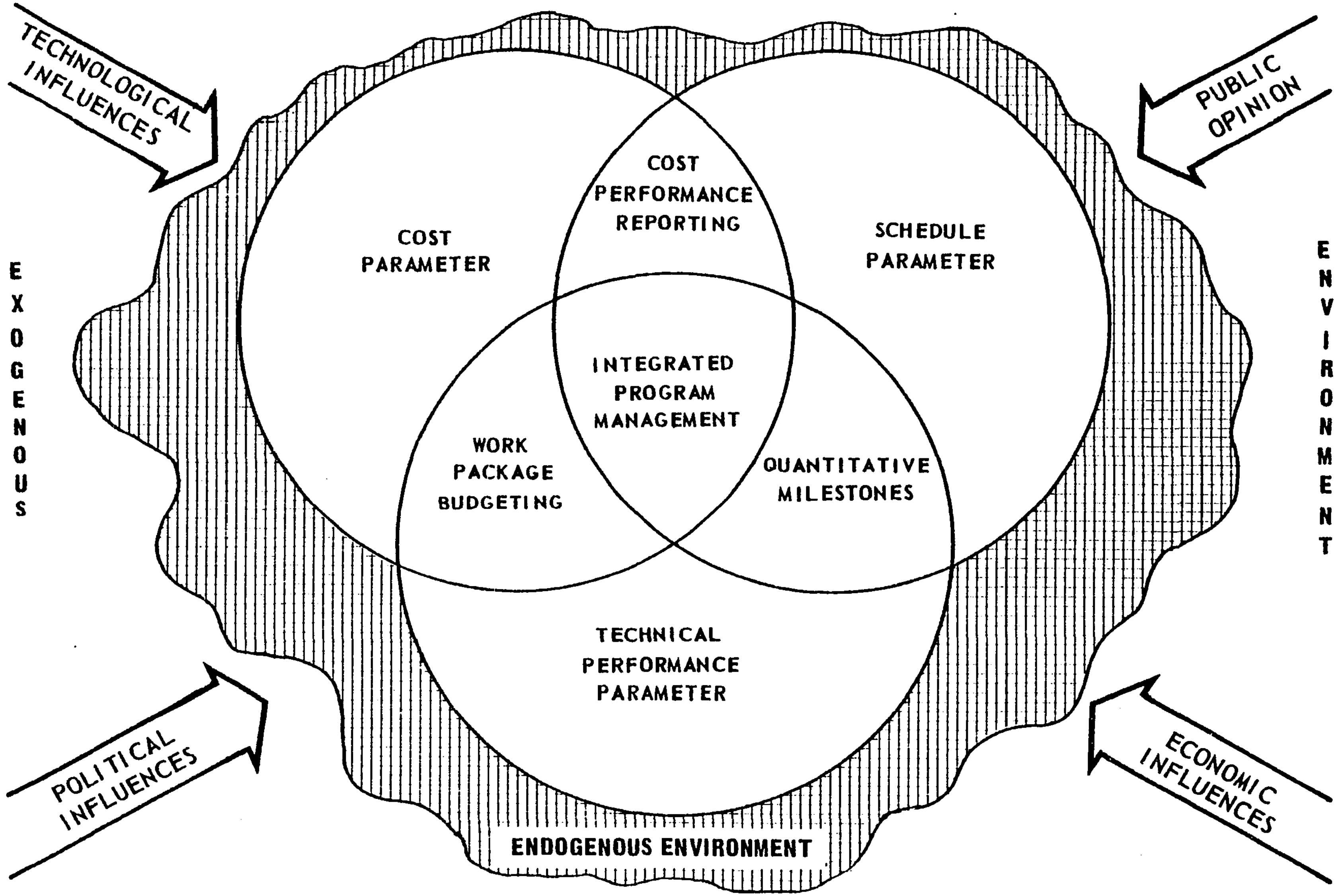


Fig. 20. Integrated Program Management in Perspective

equilibrium. It is a reactive mechanism as opposed to a proactive mechanism. As an example, homeostasis is the property of the human body that begins, without conscious thought, to coagulate the blood and close the wound of a cut finger. It is also the property that causes more rapid breathing as a reaction to strenuous exercise.

It is the fundamental conclusion of this study that such examples illustrate a satisfactory reactive system but not an "ideal" system. Quite to the contrary of the examples, an "ideal" control system would be sufficiently proactive to prevent the wound from being inflicted. Such a proactive system would be sensitive enough that movement from the status quo would be detected sufficiently early that infliction of a wound would be avoided. Similarly, proactive control would suggest that the human organism engage in deep breathing to enrich the blood with oxygen before the fact, much as swimmers and runners do, immediately prior to an athletic event. Rapid breathing during or following strenuous exercise would occur as a secondary control mechanism rather than a primary mechanism. Reactive or homeostatic control is an illusory primary protection and occurs as a secondary control tool in a proactive control system.

The concept of proactive management control is operative in a changing and dynamic environment. Adjustments or corrective steering may affect operational factors, control standards, or both. Proactive management control suggests adaptive tools and techniques used by cognitive human managers in a participative management environment involving all resources associated with the endeavor. The concept assures the inclusion of human beings in the control process without denying the possibility of automated, automatic controls and control techniques. Proactive management underscores the prospective rather than the retrospective acpect of the control process. The essence of proactive management control is the regulation or ordered progression of an endeavor toward its desired goals based on total situational assessment and optimal corrective action.

Integrated management control, interrelating the three major parameters of cost, schedule, and technical performance, must also become a reality. It is through this initiative that trade-off investigations, or risk-analysis studies, involving all three parameters, will become less rigorous to perform and more meaningful in application as a management technique. The attainment of integrated management will bring the ability to realistically predict the future behavior of any one of the three parameters as a function of change in the other two parameters. Independent analysis of individual parameters serves an important management control purpose, but total program risk is reduced and total program success is enhanced, when the three parameters are brought together in an integrated fashion. Integrated management will also enhance the determination of program progress, because progress is typically measured, at any given time, in terms of achievement against the three primary parameters and the relationship among them.

Management control should be offensive rather than defensive, should be preventative in preference to curative, and should favor preview before the fact in lieu of review after the fact. It should be equally sensitive to quantitative and qualitative management information, should satisfy management needs, and should enhance the decision-making process. Integrated and proactive tools and techniques are the preferred foundation for management control of large-scale complex endeavors.

APPENDIX I

GLOSSARY

ABM	antiballistic missile
ABMA	U.S. Army Ballistic Missile Agency
ABMDA	Advanced Ballistic Missile Defense Agency
ABMDA-H	Advanced Ballistic Missile Defense Agency - Huntsville
AMC	U.S. Army Materiel Command
AMP	Army Materiel Plan
AMS	Army management structure
AOMC	U.S. Army Ordnance Missile Command
ARADCOM	U.S. Army Air Defense Command
ARGMA	U.S. Army Rocket and Guided Missile Agency
ASA	Assistant Secretary of the Army
BMD	ballistic missile defense
BMDATC	Ballistic Missile Defense Advanced Technology Center
BMDMP	Ballistic Missile Defense Master Plan
BMDO	Ballistic Missile Defense Organization
BMDPM	Ballistic Missile Defense Program Manager
BMDSCOM	U.S. Army Ballistic Missile Defense Systems Command
CDR	Critical Design Review
CPM	Critical Path Method

C/SCSC	Cost/Schedule Control System Criteria
DA	Department of the Army
DOD	Department of Defense
DVA	Documentation Validation Audit
ERD	equipment readiness date
FACR	First Article Configuration Review
FY	fiscal year
FYDP	Five Year Defense Program
GAO	General Accounting Office
GNP	gross national product
ICBM	intercontinental ballistic missile
ITP	Integrated Training Plan
JATO	jet-assisted takeoff
LOB	Line of Balance
MCA	Military Construction, Army
MICOM	U.S. Army Missile Command
MIPA	Missile Procurement, Army
MPA	Military Personnel, Army
MTBF	mean time between failure
NASA	National Aeronautics and Space Administration
NCA	National Command Authority
NET	new equipment training
NICP	National Inventory Control Point
NMP	National Maintenance Point
NORAD	North American Air Defense Command
OMA	Operation and Maintenance, Army

OMB	Office of Management and Budget
OML	Ordnance Missile Laboratory
PAR	perimeter acquisition radar
PEMA	Procurement of Equipment and Missiles, Army
PERT	Program Evaluation and Review Technique
POM	Program Objective Memorandum
PPBS	Planning, Programming, Budgeting System
RAMMSO	Redstone Anti-Missile Missile Systems Office
RDT&E	research, development, test, and evaluation
RFD	Review of Facilities Design
RV	re-entry vehicle
SAFSCOM	U.S. Army Safeguard System Command
SAFSEA	U.S. Army Safeguard System Evaluation Agency
SAFSM	Safeguard System Manager
SAFSO	U.S. Army Safeguard System Office
SALT	Strategic Arms Limitations Talks
SDR	system design review
SENSCOM	U.S. Army Sentinel System Command
SENSEA	U.S. Army Sentinel System Evaluation Agency
SENSM	Sentinel System Manager
SENSO	U.S. Army Sentinel System Office
SSMP	Sentinel System Master Plan; Safeguard System Master Plan
TDP	Technical Development Plan
USA	U.S. Army
U.S.S.R.	Union of Soviet Socialist Republics
WBS	work breakdown structure

APPENDIX II

WORK BREAKDOWN STRUCTURE

The work breakdown structure (WBS) is a product-oriented hierarchic structure or family tree that totally defines a specific project or program. It identifies all work packages or tasks to be performed in the successful deployment of the weapon system. The WBS is similar in concept and appearance to an engineering generation breakdown, with one major exception. In addition to the hardware items depicted in the engineering generation breakdown, the WBS also includes software, site facilities, services, and all other work tasks associated with the research, development, test, and evaluation (RDT&E); production; and deployment phases of the weapon system. The WBS typically does not include the personnel element of a total weapon system.

The System WBS reflects the total weapon system breakout down to the work package level. The Project Summary WBS consists of only the top three or four levels of the System WBS. Other subsets reflecting specific portions of the program such as an RDT&E WBS or Contract WBS are also possible spinoffs of the System WBS.

The WBS is a tiered structure with each level subordinate to the level above it. Furthermore, all elements at a given level sum to the element of which they are a part at the next higher level. As an example, five levels and one complete breakout are illustrated in Figure 21. The elements shown at level 5

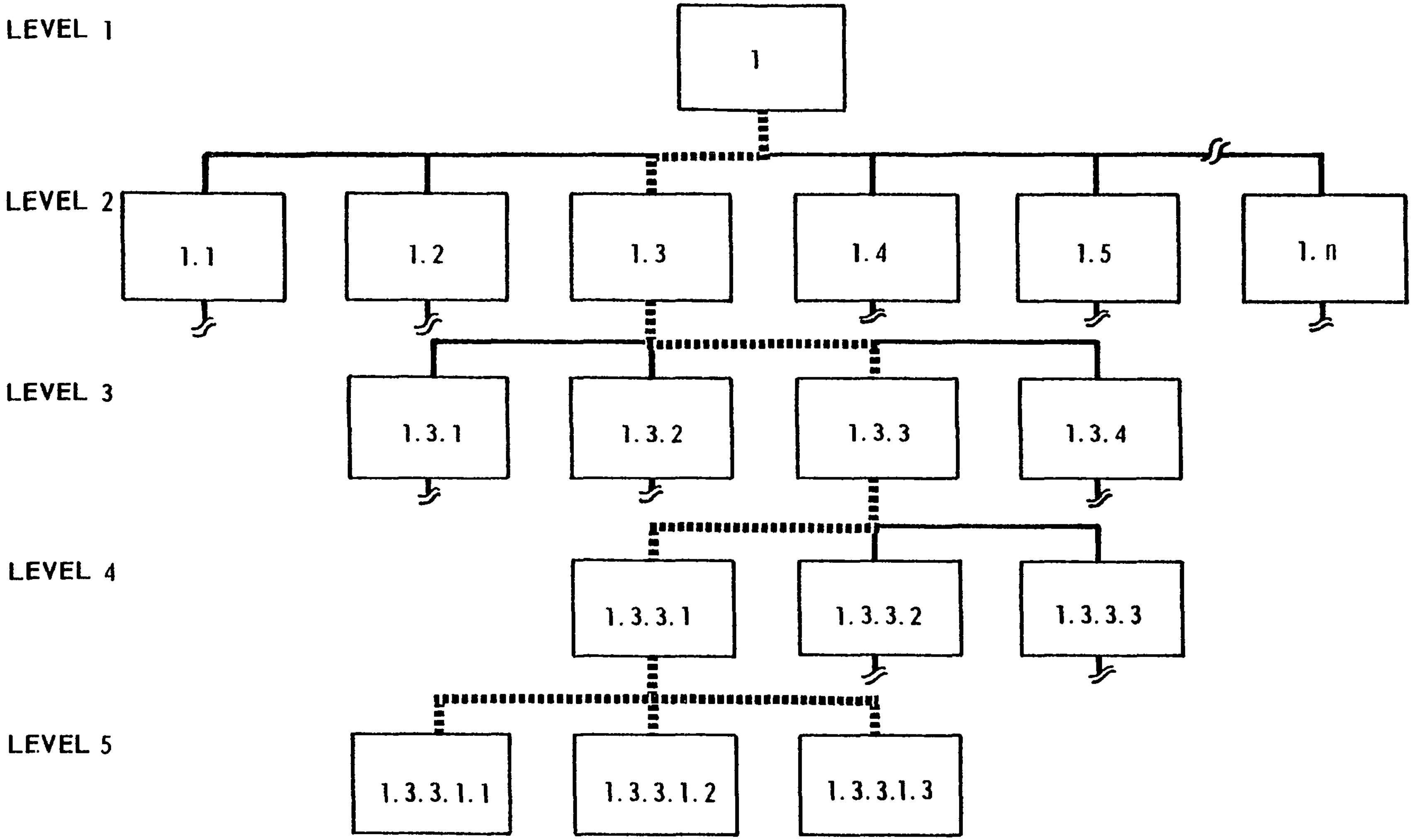


Fig. 21. Work Breakdown Structure

are work packages 1.3.3.1.1, 1.3.3.1.2, and 1.3.3.1.3. These three work packages completely define and sum to level 4 element 1.3.3.1. At level 4, elements 1.3.3.1, 1.3.3.2, and 1.3.3.3 completely define and sum to level 3 element 1.3.3. Similarly, at level 3, elements 1.3.1, 1.3.2, 1.3.3, and 1.3.4 totally define and sum to level 2 element 1.3. Finally, at level 2, elements 1.1 through 1.n sum to level 1. All elements are similarly defined, but the only complete breakout depicted is that illustrated by the family associated with level 4 element 1.3.3.1. The dashed line in Figure 21 shows how it is possible to selectively audit specific elements of the program down to the work package level.

The WBS has no predetermined size in terms of time, dollars, or activity. It is defined by the scope of the program it portrays. As an example, the Safeguard program at one time defined eighteen level 2 elements and seventy-seven level 3 elements in the Project Summary WBS. Level 4 and level 5 elements numbered in the hundreds and thousands respectively. Work packages were frequently located at level 8 in the System WBS.

Work packages are the terminal nodes in the structure and are the building blocks upon which the management control system should be founded. Work packages should describe discrete work tasks with easily defined beginning and ending events. Level-of-effort activity is not easily quantified and may be measured simply by noting passage of time or expenditure of funds.

Selection of work packages is critical. Too fine a division of work packages causes management information to become overly detailed, with an attendant loss of management control relevance. Too coarse a delineation of tasks in work packages, on the other hand, causes management information to become inordinately gross. Under these conditions management control initiatives may suffer from lack of data refinement. Problems associated with work packages being too bulky or too minute or with defining either an excessive or inadequate amount of effort are normally resolved early in the program life cycle. Typically, the degree of management control exercised or desired at each level of decision making is a pivotal factor in determining the WBS configuration.

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