

*“the management of major R & D projects is one of the most complex and demanding management concepts in existence. . .”*

## **The Systems Approach to Project Management**

by

Alexander S. Cruz

### **Introduction**

One major idea lies at the root of the modern, scientific approach to management. That idea – the systems concept – has had a substantial impact on the planning and the implementation concepts of management. This effect is best illustrated in the planning context by the increasing emphasis which is being placed on the scientific analysis of managerial decisions. Increasingly, managers are relying on decision analysts, who may call themselves “operations researchers”, “systems analysts”, or “management scientists”, to aid in the selection of the best strategies from the myriad which are typically available. And, as they do, the basic framework by which decisions are made shifts away from the traditional pattern.

In the implementation phase of management, the manager has also become increasingly independent of traditional management thinking and principles. In an effort to “get the job done”, pragmatists have evolved new management approaches which are best exemplified by the current emphasis on project management in executing plans and decisions.

A System may be defined literally as “an organized or complex whole; an assemblage or combination of things or parts forming a complex or unitary whole.” The value of the systems concept to the management of an enterprise can be seen in terms of two elements of the manager’s job. First, he desires to achieve **overall effectiveness** of his organization – not to have the parochial interests of one organizational element distort the overall performance. Second, he must do this in an organizational environment which invariably involves **conflicting organizational objectives**.

The systems concept or viewpoint is the simple recognition that any organization is a system made up of segments, each of which has its own goals. The manager realizes that he can achieve the overall goals of the organization only by viewing the entire system and seeking to understand and measure the interrelationships and to integrate them in a fashion which enables the organization to efficiently pursue its goals.

Of course, this means that some functional unit within an organization may not achieve its parochial objectives, for what is best for the whole is not necessarily best for each component of the system. This simple realization is the essence of the systems viewpoint, which has led to more effective management decisions and to organizing for the efficient execution of those decisions.

The systems approach may be operationalized through a process of defining the organization in terms of its clientele and claimants, defining goals for each clientele and claimant group, making decisions using models which relate proposed actions to these objectives, and institutionalizing the overall process by creating and integrating management systems for dealing with similar situations should they arise in the future.

### **The Management Environment**

One of the important contexts within which project management ideas have been generated is that of traditional management thought. Hence, we shall seek to “position” project-management ideas within this framework of other modern management ideas which have resulted from the changes induced by the “horizontal culture”.

#### **A. Traditional Management**

To make a meaningful comparison of project management and traditional management, one must begin with the ideas behind traditional management theory. It should be recalled, however, that these ideas were developed for organizations that were smaller and environments that were simpler than those of today.

The traditional theory of management evolved slowly over a period of time from the charismatic leader-follower arrangement. Some of the basic assumptions of traditional theory are those of bygone times.

#### **Pyramidal Structure**

The organization is viewed as a vertical pyramidal structure functioning as an integrated entity on a scalar basis. Implicit in this thought is the gradation of value placed on the different levels in the organization. The vertical levels approximate the gradation of competency. Therefore, the decisive and salient business is conducted up and down the hierarchy. Goals are established by assigning them as the responsibility of an official in the hierarchy; this official exercises specific authority derived from the level of his organizational position. The more crucial and important decisions are made at higher levels in the or-

ganization. Strategic decisions are combined with strategic policies and planning; routine decision making is delegated downward to a lower echelon in the hierarchy. Authority to execute decisions is passed down the hierarchy; information and responsibility are exacted upward through the intervening layers of executives.

### **Superior-Subordinate Relationships**

Since the enterprise functions vertically, it relies almost entirely on superior-subordinate relationships. Therefore, a strong superior-subordinate relationship is required to preserve unity of command and ensure unanimity of objective. If healthy relationships exist in the recurring chain of superiors and subordinates in the organization, the objective will be attained and the participants in the organization will gain economic, psychological, and sociological satisfaction in their jobs. The superior located higher in the structure presumably has more authority. Peer, associate, and informal relationships are present, but do not interfere with the legal distribution of power and influence in the organization.

### **Departmentation**

The alignment of an organization is based on some technique of departmentation, such as functional homogeneity, similarity of product, territorial location, etc. In organization by functional homogeneity, certain functions are organic; i.e., they are basic functions whose performance are vital to the perpetuation of the activity. Separation of the business into organic functions encourages parochialism; each manager will be more concerned with his area of effort than with the overall coordinated effort. However, the functional manager will be able to maintain integrated staff action through lateral staff coordination.

### *The Bureaucratic Syndrome*

Historically, organizational values have been built around the vertical structure. Principles of organization were drawn from military or church models and characterized by a form of bureaucracy. Division of labor, specialization, a visible "chain of command", an objective system of policies and procedures – all these VESTIGES of the bureaucratic model are found in contemporary organizations and have as their purpose the assignment of subtasks to units of people who are "expert" and the creation of "departments" where people of similar skill, training, and attitudes are brought together. Under such an organizational arrangement, problems of EFFICIENCY and CONTROL in the CURRENT OPERATIONS can be dealt with decisively.

### *Line and Staff*

Organizational groups have a basic dichotomy, i.e., the LINE and the

STAFF. Line makes the salient decisions by exercising command prerogatives. Staff does the thinking and planning. The staff official advises and counsels; his authority to command is limited by his ability (based primarily on technical competence) to influence the line official, but facilitates and prescribes methods and procedures. Those in line positions plan and decide. Specialized activities apart from the line organization are staff functions. The nature of the line-staff relationships depends on a command-counsel parity. The staff is expected to influence the judgment of the line official; therefore, the staff exercises its authority by providing counsel to the line official.

### *The Scalar Chain*

The authority patterns in the traditional model of management follow the scalar chain of command. Authority flows from the highest to the lowest level, following every link in the chain. Subordinates receive orders from one superior only. Work is accomplished by relatively autonomous functional units of the organization. Individual authority is more or less constrained by the boundaries of the unit and by explicit delegation extended in the documentation. Everyday activities are set by the alignment reflected in the organizational chart. Horizontal relationships exist through informal organizations, committees, staff meetings, or formal coordination processes.

### *Goals*

Goals are established only by making them the responsibility of some official and some office. When a new task is evolved, it must be assigned to an appropriate unit in the hierarchical chain. Higher-level individuals exercise authority and do most, if not all, of the directing and guiding of important matters. Authority patterns between managers and technicians in different independent organizations are ignored.

### *Decision-Making*

Qualitative management theory has, in the main, approached decision making from the basis of several distinct phases:

- Defining the problem
- Analyzing the problem
- Developing alternative solutions
- Selecting the best solutions
- Converting the solution into effective action

Each of these phases has several steps and provides a framework for analyzing decision making in management. In the traditional approach, heavy

reliance is placed on developing executive judgment for decision making through careful selection, education, and training of the individual. The role played by experience in the decision process has been stressed; i.e., experience in various management positions sharpens one's ability to select the most favorable alternative from among the choices available.

### *Committee Action*

Meetings, outside organizations, and committees are the means for achievement of the horizontal and external relationships needed to maintain the integrity of the organization. Here, the traditional and time-consuming formal channels of communication are bypassed, and the organizational activities, both within the parent unit and between the parent unit and other organizations, are coordinated in the total managerial environment.

### *Organizational Position*

Each position within the organization has a fixed and official area of jurisdiction, and this area is delineated in authority patterns and evidenced in job descriptions, policy manuals, etc. The specific description of a position within the hierarchy includes the facilities necessary to perform a task or group of tasks except for an element of supervision held in the superior position. To each position, except the lowest, a degree of authority is given, and a reciprocal degree of responsibility is exacted. A clear distinction must be drawn between the duty assignments for different jobs. Responsibilities for each job should be clearly defined, thereby encouraging everyone to conform to his job specification. No one should be responsible for many different activities except those activities related to the achievement of a common objective.

### *Rewards and Punishment*

The system of rewards and punishment in organizations is copied from that of the church, the state, and the military establishments. This system relies on the assumptions stated by Fremont A. Shull in his book *Matrix Structure and Project Authority for Optimizing Organizational Capacity*:

. . . motives and attitudes of people are the same without regard to the collectivity in which they perform or the nature of the external environment in which the organization exists;

. . . leadership, communication, and participation needs of organizations are alike without regard to the nature of, and emphasis upon, specific survival and growth needs; and thus . . . the nature and type of the coordination and inducement systems in different organizations should be more similar than dissimilar.

### *Management Principles*

Proponents of the traditional form of organization tend to explain and justify their organizational forms and their modus operandi in terms of principles of the organization. The principles relating to the management function apply to the management of any kind of enterprise. They provide the conceptual framework for the theory and are used as fundamental truths, applicable to any given environment and valuable in predicting results. The body of related principles is referred to as the "theory". A bureaucracy is guided by a set of rules and principles which determine all conduct. The individual and the bureaucratic person are separated, with an impersonal, routine, rational result.

### *Span of Control*

Since areas of responsibility in the organization are limited and fixed, and since each area of responsibility has its limits of authority, the number of subordinates that a supervisor controls must be correspondingly limited. Each organizational position (except, of course, the last one in the chain of echelons) has responsibilities that cannot be delegated; thus, the responsibilities of a position increase with the number of subordinate units it controls. In traditional theory, this "span of control" has received much attention, directed toward showing how restricting the span of control can improve executive effectiveness. Recent literature on the span of management (span of control) reflects a growing disenchantment with the concept and recognizes that many variables in the management environment affect the number of subordinates one can supervise effectively.

### *Component View*

Traditional theory tended to emphasize the components (finance, marketing, production) of the organization and neglected an analysis of the interfaces and the "systems" nature of the business organization. Management theory was taught in much the same way, with the role of integrating finance, marketing, etc., left to the student. Problems in industrial organizations were dealt with from a component basis, without an explicit evaluation of the total systems effect.

### *Industrial Parochialism*

Most traditional management theory developed in the industrial setting; hence, a form of parochialism developed. Although church and military models provided a reference point, the theory reflected the industrial milieu, and, unfortunately, many of the developing principles did not find early acceptance in educational and ecclesiastical organizations. Even today, management books

are written using industrial systems as the primary focus.

### *Horizontal Dimensions*

Traditional theory recognized the existence of horizontal relationships through the “informal” organization, in the operation of the manager’s coordinate responsibilities, and in the doctrine of “completed staff action”. Formal matrix organizations did not exist, although there was the forerunner of project techniques found in military operations, e.g., in the naval task force organization.

### *Unilateral Objective*

Traditional management, in portraying the industrial complex, tended to emphasize the satisfaction of a single objective — the stockholder’s claim — profitability. This claim was based on the belief that stockholders were the residual owners and thereby had a more direct claim on the management of the business than did other groups. Today, much of this belief still exists, but the business firm today must recognize that its success depends not only on stockholder and customer satisfaction, but also on discharging responsibilities to its employees, communities, and society in general. The objectives of today’s business firm extend to a range of “clientele”, each having its parochial objective, yet overall organizational effectiveness must be maintained.

### *Neglect of Long-Range Planning*

Long-range planning, as an activity arising from the organic management function of planning, had its early development in the military establishment. Although concepts of long-range planning in business circles existed long before businessmen began writing about it, a conceptual framework for long-range planning was not developed in management literature until the 1950’s. Traditional management theory neglected this aspect of organizational survival. Whatever long-range planning existed was responsive in nature; today’s long-range planning techniques and philosophies tend to be contrived, i.e., a deliberate process of developing a sense of long-range direction and purpose for the organization.

## **B. Bureaucracy**

A primary element of traditional management theory is the Bureaucracy. The bureaucratic organization is an easy object of ridicule, but this is somewhat ironic since bureaucratic organizations provide a significant proportion of today’s employment. Bureaucratic organizations run our government and manage our military forces. Some religious organizations contain vestiges of a bureaucracy, and heads of bureaucratic organizations shape our economic, social, and industrial worlds.

### *Characteristics*

An organization can be considered bureaucratic when it exhibits characteristics such as the following:

1. It is so large that the individuals cannot know all the other members.
2. Its members pursue a career in the organization and depend on it for most of their income. Individuals have a serious commitment to the organization and its provincial viewpoint. They feel restricted in voicing personal views, particularly if these views run counter to the prevailing modes of thought.
3. It includes many levels of management in the hierarchy, and promotions are based on how well the individual performs the organizational role. The individual's personal objectives are subordinated to the organizational goal. Efficiency, integrity, loyalty, and individual motivation are expected of the employee. Within a given bureau, however, are many types of officials – ranging from those who are motivated by self-interest to those few motivated by loyalty and self-sacrifice.
4. It tends to perpetuate itself, to expand, regardless of whether or not there is any real need for its services. This phenomenon is aptly described in C. Northcote Parkinson's famous first law: "Work expands so as to fill the time available for its completion." An organization's propensity to expand is in direct proportion to its ability to attract and retain capable personnel. An expanding organization normally provides its leaders with increased power, income, and prestige, so that leaders encourage growth. The growth of an organization is also a deterrent to internal conflict since it enables the new members to improve their status without lowering that of the old.

### *Organization Size*

Increasing the size of an organization may very well improve the quality of its performance and its chances for survival. Therefore, the organization leaders may seek expansion to reduce internal dissension and improve the morale of the organization. Large organizations have a better chance to survive than small ones. Large organizations are harder to destroy and harder to change than small ones (because they embody greater sunk costs); so they tend to be more resistant to external pressures. They also spend more on research and development (both in total and per employee), hence they can better develop new techniques useful in augmenting their power. Very large organizations can impose a certain degree of stability upon their external environment, whereas smaller ones cannot. Increased environmental stability reduces uncertainty and anxiety and solidifies the control of high ranking officials.



Other characteristics of bureaucracies can be summarized as follows:

1. A bureaucracy does not outlive its usefulness. It shifts its functions in order to survive and thus perpetuates the need for its existence.
2. There is a heavy dependence on formal policies and rules to motivate and guide behavior. An informal authority structure and an informal communications network, however, may exist side by side with the formal network, and this informal structure may result in the development of intense personal loyalties and deep involvements among the members, particularly among officials in the higher echelons of the hierarchy.
3. Officials near the top of a bureaucracy have a greater breadth of information about affairs in the organization than those below. Individuals at lower levels, however, have more detailed knowledge about their particular activities. Therefore, no one knows everything about what is going on in the organization.

### C. Project Management Versus Traditional Management

The form of a bureaucracy is almost universally hierarchical. The management of activities such as those that exist in a research and development organization, however, requires horizontal and diagonal relationships. In such an organization, managers and technicians deal horizontally with peers and associates at different levels in the same organization and with outside organizations. To follow the "chain of command" would be unwieldy, time consuming, and costly and would disrupt and delay the work. Horizontal and vertical contacts grow out of the necessity to get the job done; they are seldom charted, and yet they are necessary to a smooth flow of work in the organization. These relationships have been called the "informal organization", but this is a misnomer. There may be little informality; the standards of performance may be just as stringent as those in the formal (hierarchical) structure. In many cases, these relationships have sufficient strength and permanency to become de facto the modus operandi of the organization.

The acceptance of horizontal-vertical relationships between members of an organization requires changes in the organizational form. The realignment of tasks, the restructuring of the formal hierarchical structure, and the de jure recognition of a hybrid organizational form have been accomplished in many of today's corporations. In weapons-systems management, rigid hierarchical structuring has been abandoned in favor of closely integrated project groups. An informal structure to manage the "stream of projects" has its pitfalls, however, since the administration of a project raises unique problems that preclude a "laissez-faire" coordination, communication, and control. As a project grows,

the system of working through informal contacts becomes inadequate to cope with the severity and frequency of management relationships. Large projects require close coordination, since seemingly insignificant errors can boomerang into large costs and schedule slippages. The project organization must reflect how all things fit together, but this fitting together must not become a sacred organizational chart, with its job descriptions and task divisions, that turns into a "fence" rather than serving as a guide for accomplishing the job. Too often the manager thinks of his organization as an independent entity, completely self-sufficient in its environment. The manager of large projects must have a new approach to his job:

His way of thinking must permit him to utilize new knowledge in management literature which recognizes that a strictly vertical approach to management is not necessary.

He must become reoriented away from the purely functional approach to the management of human and non-human resources.

He must be able to visualize his role beyond his company's internal operations and to understand how the project relates to its environment and to other projects in it.

He must understand that purposeful conflict may very well be a necessary way of life as he manages his project across many vertical organizational lines.

He must recognize that project management is a dynamic activity where major changes are almost the order of the day.

Many companies now derive a considerable part of their total income from products that did not exist a few years ago. Other companies are changing in other directions; they are revising their organizational structure, eliminating unprofitable products, or opening new facilities. A company in a growth situation is constantly reshuffling facilities, markets, and products in an effort to remain competitive. Inevitable as these changes may be, they nevertheless cause anxiety and disrupt the established order of business. A project approach to the organizational structure can smooth the path considerably in accomplishing these projects.

To understand the concept of project management, one must first understand the framework of the project environment and the phenomena found in it. This framework points up the salient differences between the role of the project manager and that of the traditional functional manager. While these differences are possibly more theoretical than actual, differences do exist, and they affect

the manager's modus operandi and philosophy. The differences in the viewpoints of the project and the functional managers are outlined in Table 1. This comparison highlights a singular characteristic of the project manager; i.e. he must manage activities that include extensive participation by organizations and people not under his direct (line) control.

## **Organizational Forms**

In this section we shall explore a variety of organizational forms. At one extreme is the pure project organization, where the project manager is given full authority to run his project as if it were a one-product company; at the other is the pure functional organization departmented on a traditional basis, reflecting the traditional hierarchy. In the middle lies an infinite variety of project-functional combinations -- the matrix organization. Each of these forms has certain advantages and disadvantages; no one form is best for all projects, or even best for one throughout its lifetime. The essence of project organization is versatility -- the project can be built around the task; as the task changes, so must the scope of the organization.

The characteristics of the different organizations are discussed below.

### **A. Pure Functional Organization**

The pure functional organization provides flexibility in the use of manpower. Personnel can be used on many different projects; Specialists can be grouped so that knowledge and experience gained on one project are transferred to another. The company has a broad manpower base to work with, and a continuity exists in the functional disciplines, procedures, and policies from one project to another. One disadvantage of the functional organization acting alone, however, is that it does not provide the emphasis necessary to accomplish project tasks. No one individual is responsible for the total project; there is no customer focal point. Since no one person functions as the "champion" of the project, responsibility will be difficult to pinpoint, coordination unduly complex, response to customer needs slow, and motivation and innovation decreased. Ideas may tend to be functionally oriented, and approaches to the management process will tend to perpetuate the functional organization without regard for ongoing projects.

### **B. Pure Project Organization**

The major advantage of the pure project organization is that it provides complete line authority over the project; the project participants work directly for the project manager. One of the strongest disadvantages of this type of organization is that the cost in a multi-project company would be prohibitive

because a duplication of effort and facilities would be required among the projects. Since there would be no reservoir of specialists in a functional element, there might be a tendency to retain personnel on the project long after they were needed. Then, too, there would be no functional group to look toward the future and work to improve the company's capability for new programs.

### C. Matrix Organization

A mixed project and functional structure, or "matrix" organization, is desirable for producing large projects within desired cost, schedule, and performance standards. The mixture can lie anywhere between the two extremes, the exact structure being determined by the particular task requirements. The matrix, or mixed, organization has many advantages:

1. The project is emphasized by designating one individual as the focal point for all matters pertaining to it.
2. Utilization of manpower can be flexible because a reservoir of specialists is maintained in functional organizations.
3. Specialized knowledge is available to all programs on an equal basis; knowledge and experience can be transferred from one project to another.
4. Project people have a functional home when they are no longer needed on a given project.
5. Responsiveness to project needs and customer desires is generally faster because lines of communication are established and decision points are centralized.
6. Management consistency between projects can be maintained through the deliberate conflict operating in the project-functional environment.
7. A better balance between time, cost, and performance can be obtained through the built-in checks and balances (the deliberate conflict) and the continuous negotiations carried on between the project and the functional organizations.
8. Interfunctional competition tends to be minimized by the intervention of the project manager.

Within the matrix organization many advantages of the functional organization are retained. Each functional manager supervises a pool of functional talent to fill the shifting needs of the various projects; he directs assignment and reassignment and arbitrates conflicting project demands; and he is in a position (because of the employee's long-term career dependence on his functional manager) to promote adherence to desired technical standards.

Of course, there are some disadvantages to a matrix organization. The balance of power between the functional and the project organizations must

be watched so that neither one erodes the other. The balance between time, cost, and performance must also be continually monitored so that neither group favors cost nor time over technical performance.

Each of the forms of organizational structure has certain advantages, but none can be considered best for all applications. The form to be used depends on the environmental requirements, which change continually as the project goes through its life cycle and as the number of projects and the products mix of the company change. The organization must be changed as the environment changes. Rotating personnel between projects and functions can be a valuable technique in executing development. Individuals gain perspective in the project and functional ways of thinking; they develop an understanding of the other fellow's problems.

Changes in organizational structure are often necessary and can have a more far-reaching effect than merely rotating people from one position to another. Structural changes sometimes affect the human element adversely, however; they strike at the core of human motivation – status, security, acceptance. Informal working arrangements can be broken up and morale damaged, to the extent that the general efficiency of the organization declines. Regardless of these problems, change is necessary, and the flexibility is desirable.

### **Planning the Matrix Organization**

Any undertaking requires some degree of organization. In some instances, the organization may be informal but inherent to the situation. As the number of individuals engaged in an enterprise increases, however, and inter-organizational and interpersonal complexities increase, more formality is required to achieve the desired objectives. Project management is not unlike other management in this respect. Organization is necessary to establish a framework, not only to produce the desired results, but also to clarify individual responsibilities, privileges, and authority.

#### **A. Why Matrix Organization**

The project manager accomplishes the project objectives by working with functional groups of the company and with outside organizations. The total project organization has no discrete boundaries; it is a complex structure that facilitates the coordination and integration of many project activities. While the project manager uses many traditional organizational principles in planning his structure, he must be guided by some considerations that go beyond traditional theory, such as:

**How shall the parent and outside organizations be aligned to accomplish the multilateral objectives of the project?**

How applicable are traditional principles of organization such as span of management, the scalar principle, unity of command, parity of authority and responsibility, unity of direction, and functional homogeneity?

Are the authority and responsibility relationships subject to alignment in a scalar chain, or will the flow of authority and responsibility form a “web of relationships” in the total project environment?

As project manager, will his first responsibility be to plan and to organize and control his subordinates, or to provide the environment in which others can accomplish the project themselves successfully?

How should the organization be aligned to give contributors due recognition?

What will the organization consist of – the blocks on the organizational chart or something greater?

Are conditions such that a simple bureaucratic organization will not suffice for the technological progress and the interdependencies between complex organizations?

What effect will technology have on the project organization structure?

If these questions are answered in a fashion which emphasizes the need for flexibility, a project model is probably indicated.

## **B. Developing the Project Organization**

Once a need for a project model has been established, the project manager may be charged with the development of the project organization.

Selecting a project organizational model requires an understanding of the work and the kinds of activities needed to reach the project’s objective. The project manager must visualize the total project environment in selecting an organizational philosophy, not just the locale of his project office. This process of visualizing the total project environment will require an identification and alignment of the relative roles of all the project participants. The project participants include any individual or assembly of individuals in the project office, in the functional organizations, or in an outside organization – in short, anyone who has an interest in the project affairs. Thus, this concept of the project environment is the same as the concept of the clientele of the overall organization. Those with a vested project interest represent the project’s clientele.

In performing the function of planning, the project manager defines the tasks, suggests organizational alignments, and assigns activities, so that the members of the organization can build, develop, and maintain a structure and process of working relationships to accomplish the project objectives. The broad matrix organization becomes the structural and process framework through which all the project efforts are coordinated and integrated into the common objective. The project organization may therefore not be thought of as an independent entity operating in a vacuum; it is part of a larger matrix system.

### C. Aligning Organizational Elements

Having considered the nature of the organization and the general role of the project in the matrix organization, we may now turn our attention to the individual components which must be aligned to form an effective project organization.

#### 1. *The Project Team*

The most effective project organization would be developed by assigning a project manager with perfect qualifications and giving him clear-cut authority and responsibility. This situation would be ideal, but it is not realistic. The best manager available should be assigned, and the necessary human resources to support him should be provided. To select the human resources requires that the overall project be divided into subtasks, and so on, until the project is represented by an alignment of rational, related, recognizable work units. This dividing should be accomplished by the project manager in collaboration with the functional managers who will be supporting the project.

For a project within an aerospace firm, for example, the representative elements of functional responsibility which might be integrated by the project manager for the objectives of the project include:

- Engineering
- Operations (manufacturing)
- Marketing
- Financial management
- Procurement
- Product assurance
- Contracts
- Engineering operations

Because of the importance of the project control function, the project manager might have a staff of key individuals to assist him in this area, some assigned to him directly and some supporting him from the functional organi-

zations. The remaining elements, however, are normally the responsibility of the appropriate functional managers. Each functional manager normally has assigned a key individual within his organization for liaison with the project manager and his staff. This key individual, although reporting to the functional manager, represents the project manager within that functional organization, and is the focal point for the authority on that project within that organization.

One of this individual's main functions will be the planning of all his organization's responsibilities for the project, in consonance with the total project plan, and ensuring that all organizational effort satisfies the requirements of the project. He thus becomes the "alter ego" of the functional manager for that project. His planning role is an important and continuous one, since he is required to maintain and update his portion of the total project plan as the project matures. His inputs and changes to the total project plan must be through the project manager, who ensures that all plans and changes thereto are in harmony and consistent with the total project objectives.

Depending upon the nature, size, complexity, schedule, current phase, and potential of the project, certain specialized functional personnel may be organizationally assigned to the project manager for the duration of his project, or for as long as required to ensure successful passage through its most critical phases. The "borrowed" members of the project management organization shall represent their functional organization's responsibilities on the program, such as financial operations, contracts, etc. These project management organization personnel, who are provided by their functional "home" organizations on a loan basis, charge their time to the appropriate project, or overhead account, as specified by the project charter or as mutually agreed upon by the loaning (functional), borrowing (project), and financial organizations.

Assignment to a project team may be too parochial for the man who wishes to maintain his technical status and his identification with his technical reference group. These are important to the development of a technical capability in the organization, since the functional organization is where functional know-how is advanced, expertise is developed, standards of performance are established, and manpower and facilities assignments are made. The project staffs can be drawn from the functional departments and are returned to them when the project or task is completed.

## 2. *The Project Office*

The size and composition of the project office depend on many factors. The size of the project, its importance to the organization, the degree of decentralization required, and the nature of the project, whether development or production, are some of the many factors that dictate the size and composition. The responsibilities of the project office include the direction, coordination, and



control of all the project activities, wherever located in the supporting functional elements.

Criteria that give a hint as to the size and composition of the project office center around the responsibilities of the project manager in planning for and utilizing organizational resources to satisfy project objectives. Size and composition of the office should be such that the project manager is able to establish and maintain an effective line of communication between the customer-supporting organizations and the parent organization during the life cycle of the project.

In this connection, the collective responsibilities of the project office should make it possible to determine:

That the customer is advised of all tasks, schedules, and costs necessary to the success of the project.

That all tasks being performed on the project are authorized and funded by contracts or work-breakdown-structure documentation.

That deviations from the contract and the project plan and/or specifications are authorized by and communicated to all concerned parties.

That the customer and the supporting functional elements are continuously advised of project progress, as required by the contract and project documentation.

Given these collective responsibilities, the typical project-office size and composition will include the complement of skills necessary to be able to provide strategic project planning and control for the following categories of effort:

- Business operations
- Engineering
- Manufacturing
- Product reliability
- Procurement
- Integrated logistic support
- Marketing and contracting

The point should be kept in mind that we are not advocating the bringing in of skills into the project office to expend all this effort; these categories of skills are to be drawn from the supporting functional elements. There must be people in the project office, however, reporting in a **Line** capacity to the project manager, who have the necessary complement of skills to function as the “alter ego” of the project manager in providing strategic direction and evaluation for the project manager in the above categories of effort.

### 3. *The Manager of Projects*

The emergence of many projects in the organization and their importance to the long-term survival of the organization suggest the need for a separate “functional organizational entity” to facilitate the development of the projects. Such an organization may be called a “manager of projects” and is appointed at the same executive level as the major functional heads of the company. Projects that emerge in the R & D side of the organization will grow in maturity; at some point in maturity these projects will come under the jurisdiction of the “manager of projects”, who is responsible for providing an environment whereby the stream of projects flowing through the company can be facilitated. The manager of projects is responsible for directing and evaluating all the individual project managers’ activities, as well as planning, proposing, and facilitating the implementation of project management policy. He is the focal point for assuring project compliance with commitments and for advancing the state-of-the-art as far as project management theory and techniques are concerned. Other specific activities of the manager of projects are as follows:

Provide an added “check and balance” to measure the consistency of emerging projects with the strategic objectives of the organization.

Work with other functional heads to allocate the projects and resources employed. Problems that arise concerning conflicting priorities among the projects can be resolved by the manager of projects and the appropriate functional head, thereby relieving the chief executive of this task and giving the chief executive time to think through the long-range strategy of the organization.

Resolve problems between the individual project managers concerning the allocation of resources.

Define and assist in the development and operation of project management systems, such as information systems, technical performance measurement techniques, and project control measures.

Ensure management consistency between projects, and assure that changes in one project are integrated with the cost, schedule, and technical performance objectives of all the other projects.

One real advantage of using a manager of projects is the opportunity it provides for the chief executive to delegate to the manager of projects much of the detail – resolution of conflict, routine allocation of resources, etc. – which goes on in the project-oriented organization. If the chief executive becomes embroiled in too much of this activity, it can seriously detract from the time

that he has available for strategic planning, an important element of his responsibility. By placing a manager of projects in the organization, he simply recognizes that the project-management activity is a major thrust of the organization activity, just as finance, production, and marketing are also major thrusts of activity.

#### 4. *The Functional Organization*

Functional organizations emerged out of workers specialization and the need to pool workers of common occupational activities into a cooperative effort. Thus, engineers are placed in an engineering organization, financial people in the finance department, etc. Functional organizations, according to Howard M. Carlisle (“Are Functional Organizations Becoming Obsolete ? ”), reflect some weaknesses:

1. Functional organizations tend to emphasize the separate functional elements at the expense of the whole organization.
2. Under functional departmentation there is no group that effectively integrates the various functions of an organization and monitors them from the “big picture standpoint”.
3. Functional organizations do not tend to develop “general managers”.
4. Functional organizations emphasize functional relationships based on the vertical organizational hierarchy.
5. Functional organizations tend to fragment other management processes.
6. Functional organizations tend to be closed systems.
7. Functional organizations develop a strong resistance to change.
8. Functional segregation through the formal organization process encourages conflict among the various functions.
9. The emphasis on the various operating functions focuses attention on the internal aspects and relations of the company to the detriment of its external relations.

While these weaknesses may be found in functional organizations, the primary purpose of the functional organization is to provide a pool of expertise that can be applied to the various projects that are in the organization. It should again be mentioned that the **Project** and **Functional** organizations are interdependent – one cannot survive without the other.

There are difficulties in bringing together project team members drawn from different organizational functions and levels within the organization. Distance is often a complicating factor. Hostility of traditionally oriented managers who suspect an interference in their “territory” can be a problem.

Functional managers often feel that the project could be handled better within functional units – preferably their own. Also, functional managers may feel that their authority is being undercut.

### System Dynamics Life Cycles

The primary reason for the complexity of the implementation function has to do with the dynamic nature of systems. Solutions to complex problems, once decided upon, are not immediately available. Transportation systems, for instance, go through long years of detailed design and development after the planning process is completed. Thus, the systems which are the proposed solutions to problems go from state to state as they evolve from idea to proposal to fruition.

The same dynamic evolution is descriptive of a wide variety of systems – whether they are thought of as problem solutions or not. For instance, new products, management information systems, and social programs share this same dynamic evolutionary characteristic.

#### *A. Sales Life Cycle*

Every dynamic system has natural phases of development. Recognition of these phases permits the manager to properly control what is happening and to use characteristics of the various phases to advantage. A product, for example, moves through various phases of sales life cycle after it has been placed on the market. William R. King, in his book *Quantitative Analysis for Marketing Management*, has referred to these life cycle phases as establishment, growth, maturation, and declining sales phases. Figure 1 shows these phases in terms of the sales revenue generated by the product during its period of slow establishment in the marketplace, followed by a period of rapid sales increase, a peaking, and a long, gradual decline. Virtually every product displays these dynamic characteristics, although some may have a sales life cycle which is so long or short that the various phases are not readily distinguishable. Many such products will have a long, slow decline after an initially rapid decline from the peak. With other products, the maturation phase is very long and the declining sales phase very gradual. But the general life cycle concept is virtually unavoidable for a successful product, for without product improvements its conception will eventually lure away customers because customers' attitudes, habits, and needs will change as time passes.

Of course, the sales portion of the life cycle of a product is really only one aspect of its entire "life". Indeed, only products which are marketing successes ever get to experience the sales life cycle of Figure 1. Most new customer products have from the beginning of their sales period an infinitely

descending curve. The product not only doesn't get off the ground; it goes quickly under ground – six feet under.

## B. Systems Development Life Cycle

All products – sales successes or otherwise – begin as a gleam in the eye of someone and undergo many different phases of development before being marketed and subjected to the sales life-cycle consideration of Figure 1.

New products, services, or roles for the organization have their genesis in ideas evolving within the organization. Typically, such “systems” ideas go through a distinct life cycle, i.e., a natural and pervasive order of thought and action. In each phase of this cycle, different levels and varieties of specific action and thought are required within the organization to assess the efficacy of the system. The “phases” of this cycle serve to illustrate the systems development life-cycle concept and its importance.

### 1. *The Conceptual Phase*

The germ of the idea for a system may evolve from other research, from current organizational problems, or from the observation of organizational interfaces. The conceptual phase is one in which the idea is conceived and given preliminary evaluation.

During the conceptual phase, the environment is examined, forecasts are prepared, objectives and alternatives are evaluated, and the first examination of the performance, cost, and time aspects of the system's development is performed. It is also during this phase that basic strategy, organization, and resource requirements are conceived. The fundamental purpose of the conceptual phase is to conduct a “white paper” study of the requirements in order to provide a basis for further detailed evaluation. Table 2 shows the details of these efforts.

There will typically be a high mortality rate of potential systems during the conceptual phase of the life cycle. Rightly so, since the study process conducted during this phase should identify projects that have high risk and are technically, environmentally, or economically infeasible or impractical.

### 2. *The Definition Phase*

The fundamental purpose of the definition phase is to determine, as soon as possible and as accurately as possible, cost, schedule, performance, and resource requirements and whether all elements, projects, and subsystems will fit together economically and technically.

The definition phase simply tells in more detail what it is we want to do, when we want to do it, how we will accomplish it, and what it will cost. The definition phase allows the organization to fully conceive and define the system

before it starts to physically put the system into its environment. Simply stated, the definition phase dictates that one stop and takes time to look around to see if this is what one really wants before the resources are committed to putting the system into operation and production. If the idea has survived the end of the conceptual phase, a conditional approval for further study and development is given. The definition phase provides the opportunity to review and confirm the decision to continue development, create a prototype system, and make a production or installation decision.

Decisions that are made during and at the end of the definition phase might very well be decisions to cancel further work on the system and redirect organizational resources elsewhere. The elements of this phase are described in Table 3.

### 3. *Production or Acquisition Phase*

The purpose of the production or acquisition phase is to acquire and test the system elements and the total system itself using the standards developed during the preceding phases. The acquisition process involves such things as the actual setting up of the system, the fabrication of hardware, the allocation of authority and responsibility, the construction of facilities, and the finalization of supporting documentation. Table 4 details this phase.

### 4. *Operational Phase*

The fundamental role of the manager of a system during the operational phase is to provide the resource support required to accomplish system objectives. This phase indicates the system has been proven economical, feasible, and practical and will be used to accomplish the desired ends of the system. In this phase, the manager's functions change somewhat. He is less concerned with planning and organizing and more concerned with controlling the system's operation along the predetermined lines of performance. His responsibilities for planning and organization are not entirely neglected – there are always elements of these functions remaining – but he places more emphasis on motivating the human element of the system and controlling the utilization of resources of the total system. It is during this phase that the system may lose its identity per se and be assimilated into the “institutional” framework of the organization.

If the system in question is a product to be marketed, the operational stage begins the sales life cycle portion of the overall life cycle, for it is in this phase that marketing of the product is conducted. Table 5 shows the important elements of this phase.

### 5. *The Divestment Phase*

The divestment phase is the one in which the organization “gets out

of the business” which it began with the conceptual phase. Every system – be it a product system, a weapons system, a management system, or whatever – has a finite lifetime. Too often this goes unrecognized, with the result that outdated and unprofitable products are retained, inefficient management systems are used, or inadequate equipment and facilities are “put up with”. Only by the specific and continuous consideration of the divestment possibilities can the organization realistically hope to avoid these contingencies. Table 6 relates to the divestment phase.

Taken together Tables 2 through 6 provide a detailed outline of the overall systems development life cycle. Of course, the terminology used in these tables is not applicable to every system which might be under development, since the terminology generally applied to the development of consumer product systems is often different from that applied to weapons systems. Both in turn are different from that used in the development of a financial system for a business firm. However, whatever the terminology used, the concepts are applicable to all such systems.

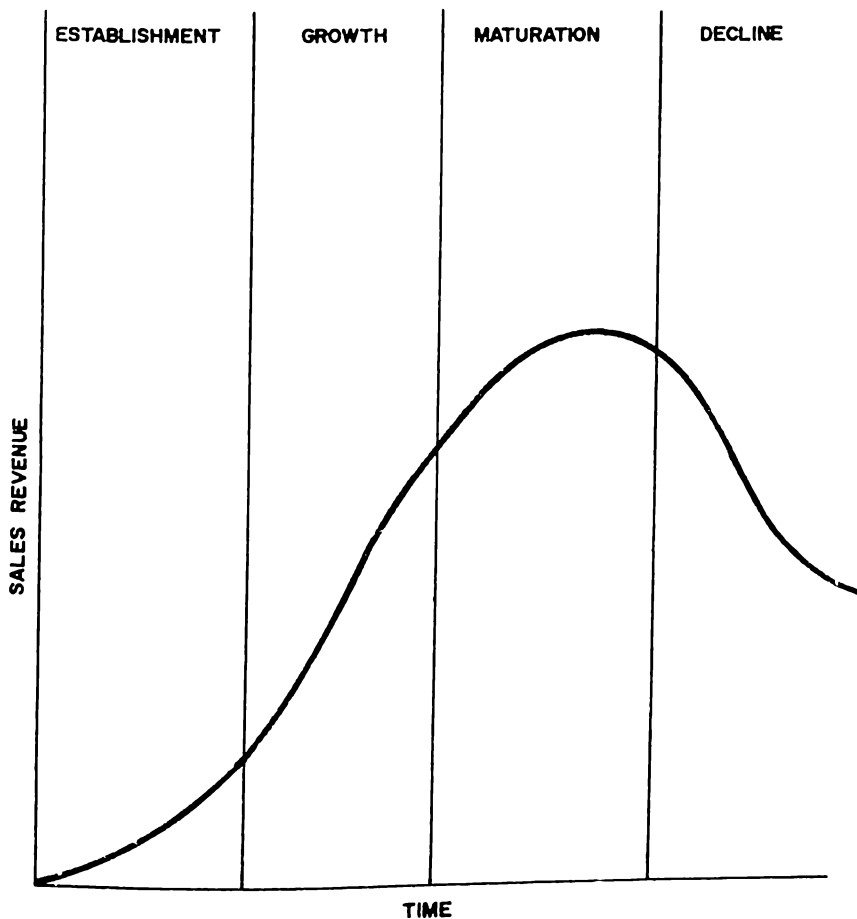


FIGURE 1 PRODUCT SALES LIFE CYCLE

Table I Conceptual Phase

1. Determine existing needs or potential deficiencies of existing systems.
2. Establish system concepts which provide initial strategic guidance to overcome existing or potential deficiencies.
3. Determine initial technical, environmental, and economic feasibility and practicability of the system.
4. Examine alternative ways of accomplishing the system objectives.
5. Provide initial answers to the questions:
  - a. What will the system cost?
  - b. When will the system be available?
  - c. What will the system do?
  - d. How will the system be integrated?
6. Identify the human and nonhuman resources required to support the system.
7. Select initial system designs which will satisfy the system objectives.
8. Determine initial system interfaces.
9. Establish a system organization.

Table 2 Definition Phase

1. Firm identification of the human and nonhuman resources required.
2. Preparation of final system performance requirements.
3. Preparation of detailed plans required to support the system.
4. Determination of realistic cost, schedule, and performance requirements.
5. Identification of those areas of the system where high risk and uncertainty exist, and delineation of plans for further exploration of these areas.
6. Definition of intersystem and intrasystem interfaces.
7. Determination of necessary support subsystems.
8. Identification and initial preparation of the documentation required to support the system, such as policies, procedures, job descriptions, budget and funding papers, letters, memoranda, etc.

Table 3 Production Phase

1. Updating of detailed plans conceived and defined during the preceding phases.
2. Identification and management of the resources required to facilitate the production processes such as inventory, supplies, labor, funds, etc.
3. Verification of system production specifications.



4. Beginning of production, construction, and installation.
5. Final preparation and dissemination of policy and procedural documents.
6. Performance of final testing to determine adequacy of the system to do the things it is intended to do.
7. Development of technical manuals and affiliated documentation describing how the system is intended to operate.
8. Development of plans to support the system during its operational phase.

Table 4 Operational Phase

1. Use of the system results by the intended user or customer.
2. Actual integration of the project's product or service into existing organizational systems.
3. Evaluation of the technical, social, and economic sufficiency of the project to meet actual operating conditions.
4. Provision of feedback to organizational planners concerned with developing new projects and systems.
5. Evaluation of the adequacy of supporting systems.

Table 5 Divestment Phase

1. System phasedown.
2. Development of plans transferring responsibility to supporting organizations.
3. Divestment or transfer of resources to other systems.
4. Development of "lessons learned from the system" for inclusion in qualitative-quantitative data base to include:
  - a. Assessment of image by the customer.
  - b. Major problems encountered and their solution.
  - c. Technological advances.
  - d. Advancements in knowledge relative to department strategic objectives.
  - e. New or improved management techniques.
  - f. Recommendations for future research and development.
  - g. Recommendations for the management of future programs, including interfaces with associate contractors.
  - h. Other major lessons learned during the course of the system.

## Summary

Project management, particularly the management of major R & D projects, is undoubtedly one of the most complex and demanding management concepts in existence. A project in the R & D field has all the elements of an enterprise which has been conceived and built, reaches maturity, completes its mission, and phases out, perhaps all in a period of three to five years. The project manager's task is enormously complicated and diverse; he ties together the efforts of many organizations. He deals with technical and administrative disciplines in pulling together a project team to act as an entity rather than as a fragmented group of functional experts.

The project manager deals with the concepts of management in general. Many of the classical management principles apply; many project techniques may be used to relate these principles. Careful attention must be given to the division of tasks among the project participants. That division of work should be made which offers the fewest technical and contractual interfaces among the participants.

A line organization does not provide the environment essential to project success. In the most flexible of traditional line organizations, it is difficult to maintain a large number of people working in close harmony on creative, abstract work. Creative people do not fit into a precise and orderly line organization where all work is thoroughly organized and all assignments are rigidly controlled; where each individual has a definite area to cover, definite information to work with, and a definite schedule to meet; where bosses must be reported to and subordinates directed. Such an organization may soon have only the few creative ones who lead the others. Innovations are difficult to come by since each one must be introduced and explained in detail at every one of the successive levels of the hierarchical chain.

Project management is an outgrowth of the need to develop and produce large projects in the shortest possible time. It has been developed from a need, but with little theoretical formulation. Project management is necessary for government contracts and subcontracts and is being used more and more for other purposes. An individual placed in the position of a project manager will find little in the literature to clarify his role because it has as yet very few theoretical foundations. Several organizational variations of project management are in vogue, however, which depend on the balance desired between the project and the functional organizations.