(e) Prepare the Test and Evaluation Master Plan (TEMP).
(f) Prepare the System Engineering Management Plan (SEMP).
(g) Plan, coordinate, and conduct the conceptual design review.

2. *Preliminary system design phase:*
   (a) Accomplish functional analysis and the allocation of requirements.
   (b) Accomplish system analysis, synthesis, and trade-off studies.
   (c) Accomplish system integration; that is, the integration of design disciplines, supplier activities, and data.
   (d) Plan, coordinate, and conduct system design reviews.
3. *Detail design and development phase:*
   (a) Accomplish system analysis, synthesis, and trade-off studies.
   (b) Accomplish system integration; that is, the integration of design disciplines, supplier activities, and data.
   (c) Monitor and review system test and evaluation activities.
   (d) Plan, coordinate, implement, and control design changes.
   (e) Plan, coordinate, and conduct equipment/software design reviews and the critical design review.
   (f) Initiate and maintain production and/or construction liaison and customer service activities.
4. *Production and/or construction phase:*
   (a) Monitor and review system test and evaluation activities.
   (b) Plan, coordinate, implement, and control design changes.
   (c) Maintain production and/or construction liaison and conduct customer service activities (i.e., field service).
5. *System utilization and life-cycle support:*
   (a) Monitor and review system test and evaluation activities.
   (b) Plan, coordinate, implement, and control design changes.
   (c) Conduct customer service activities (i.e., field service).
   (d) Collect, analyze, and process field data. Prepare reports on system operations in the user environment.
6. *System retirement and material disposal:*
   (a) Prepare plan for system retirement.
   (b) Monitor material disposal and recycling activities.
   (c) Prepare reports on environmental impact(s).

As noted in Section 6.2.2, these tasks reflect what is envisioned as being critical to the successful implementation of the system engineering process. This does not mean to imply a tremendous level of effort. The tasks must be tailored to the particular applications, and the accomplishment of many of these requires a significant input from other organizations. A major objective is to provide a mechanism for *integration,* and the interfaces and relationships between system engineering and other organizations are extensive. For example, the conductance of a life-cycle cost analysis as part of the overall system analysis task involves a data exchange with all project-related engineering organizations, finance and accounting, logistic support, produc-

tion, the customer, and so on. The goal of the system engineering organization is to provide the necessary technical management and guidance to ensure that these activities are completed in a timely manner.

To further illustrate the many interfaces that exist, the combined project-functional organization structure in Figure 7.11 has been extended to include a sampling of the required communication channels that must be established between the system engineering function and other organizational elements. These communication links are shown in Figure 7.13, and an abbreviated description covering the nature of the necessary communications is presented in Figure 7.14. The system engineering function, as an integrating agency, must not only provide the technical leadership throughout the system development activity, but must initially establish and subsequently maintain open and free-flowing communications across the board.

Ultimate success in meeting these system engineering objectives is, of course, highly dependent on managerial support from the top down. The president (or general manager), the vice president of engineering, the project "Y" manager, and other high-level managers must each *understand* and *believe in* the concepts and objectives of system engineering. If the system engineering manager is to be successful, these higher-level managers must be directly supportive all the time. There will be many occasions on which individual design engineers and/or middle managers will go off on their own, making decisions that will conflict with system engineering objectives. When this occurs, the system engineering manager must have the necessary support to ensure that actions are taken to "get things back on track."

7.5 SUPPLIER ORGANIZATION AND FUNCTIONS

As defined in Section 6.3, the term *supplier* refers to a broad category of organizations that provide various materials and/or services to the producer (i.e., prime contractor). These items may range from the design and development of a major subsystem to the delivery of a small off-the-shelf part from an existing inventory or the performance of some service. The process for identifying outsourcing requirements, identifying potential sources of supply and the selection of a qualified supplier, and the follow-on contracting activity is described in Chapter 6. The discussion is extended here with a consideration of the supplier organization.

For relatively large projects (involving design and development, manufacturing and production, etc.), the system engineering function may be established at different levels. As shown in Figure 7.1, the customer may establish a system engineering group and a similar function may be included in the producer's organization (i.e., the contractor). Where the outsourcing requirements are significant and suppliers are selected to accomplish the design, development, and manufacture of subsystems and/or major components, the system engineering capability must be extended and included as an identifiable function within the supplier's organization as well. For the purposes of further discussion, assume that the organizational structure for a major supplier will take the form illustrated in Figure 7.15 (an extension of Figure 7.1). It is impor-

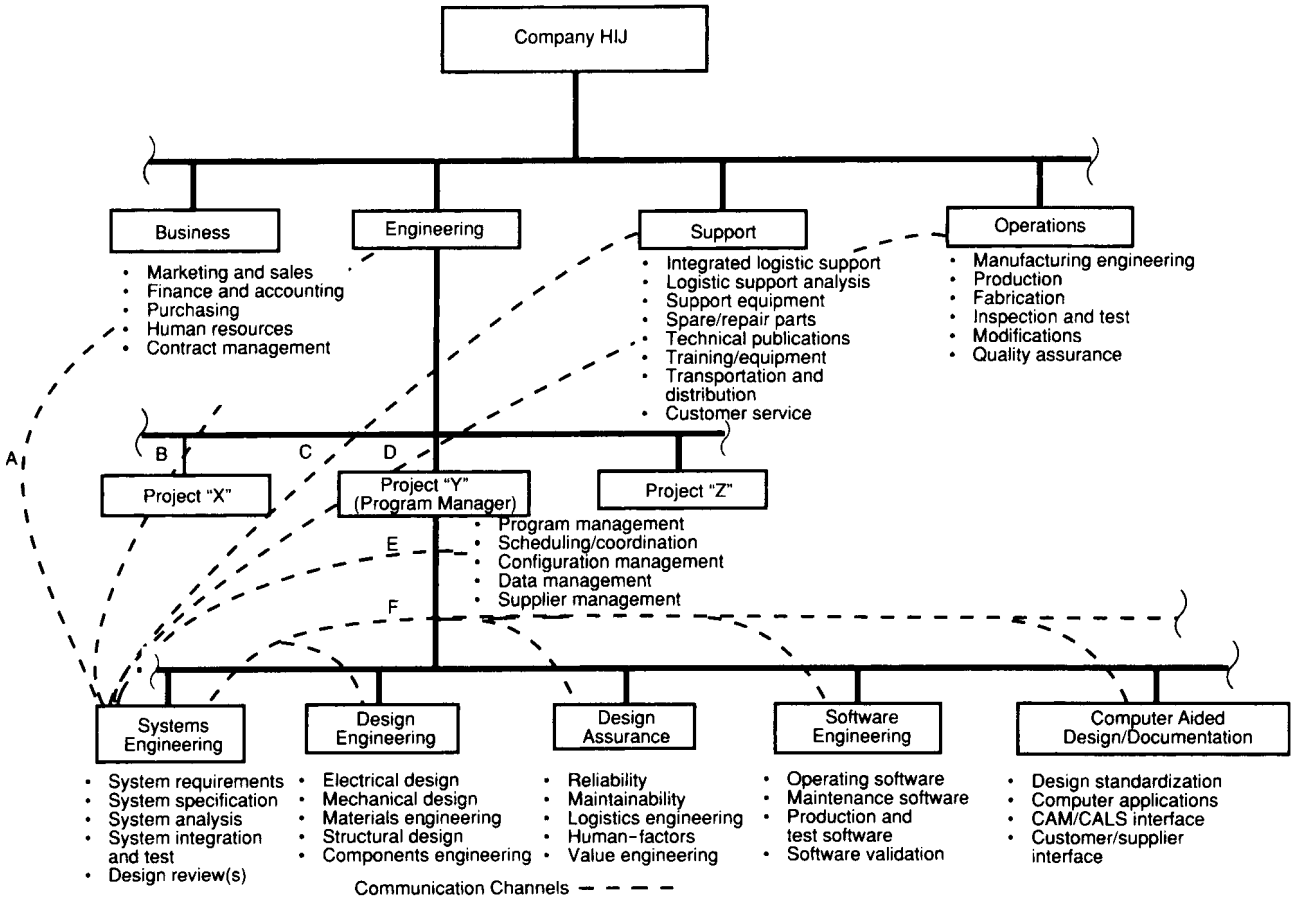

Figure 7.13 Major system engineering communication links (producer organization).

Communication Channel (Figure 7.13)	Supporting Organization (Interface Requirements)
A	1. *Marketing and sales* – to acquire and sustain the necessary communications with the customer. Supplemental information pertaining to customer requirements, system operational and maintenance support requirements, changes in requirements, outside competition, etc., is needed. This is above and beyond the formal "contractual" channel of communications. 2. *Accounting* – to acquire both budgetary and cost data in support of economic analysis efforts (e.g., life-cycle cost analysis). 3. *Purchasing* – to assist in the identification, evaluation, and selection of component suppliers with regard to technical, quality, and life-cycle cost implications. 4. *Human resources* – to solicit assistance in the initial recruiting and hiring of qualified project personnel for system engineering, and in the subsequent training and maintenance of personnel skills; to conduct training programs for all project personnel across the board relative to system engineering concepts, objectives, and the implementation of program requirements. 5. *Contract management* – to keep abreast of contract requirements (of a technical nature) between the customer and the contractor; to ensure that the appropriate relationships are established and maintained with suppliers as they pertain to meeting the *technical* needs for system design and development.
B	To establish and maintain ongoing liaison and close communications with other projects with the objective of transferring knowledge that can be applied for the benefit of Project "Y"; to solicit assistance from other companywide functionally oriented engineering laboratories and departments relative to the application of new technologies in support of system design and development.
C	To provide an input relative to project requirements for system support, and to solicit assistance in terms of the functional aspects associated with the design, development, test and evaluation, production, and sustaining maintenance of a support capability through the planned system life cycle.
D	To provide an input relative to project requirements for production (i.e., manufacturing, fabrication, assembly, inspection and test, and quality assurance), and to solicit assistance relative to the design for producibility and the implementation of quality engineering requirements in support of system design and development.
E	To establish and maintain close relationships and the necessary on going communications with such project activities as scheduling (the monitoring of critical program activities through a network scheduling approach); configuration management (the definition of various configuration baselines and the monitoring and control of changes/modifications); data management (the monitoring, review, and evaluation of various data packages to ensure compatibility and the elimination of unnecessary redundancies); and supplier management (to monitor progress and ensure the appropriate integration of supplier activities).
F	To provide an input relative to *system-level* design requirements, and to monitor, review, evaluate, and ensure the appropriate integration of system design activities. This includes providing a *technical* lead in the definition of system requirements, the accomplishment of functional analysis, the conductance of system-level trade-off studies, and the other project tasks presented in Figure 6.6.

Figure 7.14 Description of major project interface requirements.

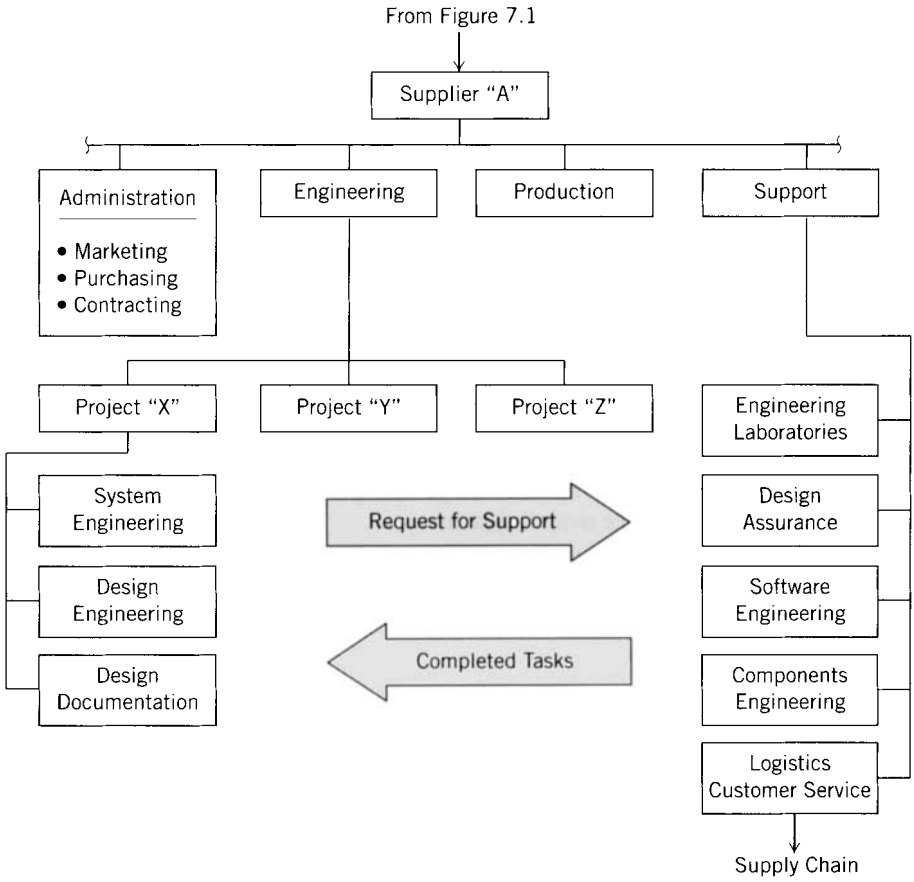

Figure 7.15 Large-scale supplier organization.

tant to keep in mind that system engineering requirements must be traceable from the customer on down to the major supplier.

Referring to Figure 7.15, the system engineering activity need not be large and may include only one or two key individuals. In any event, there must be a "focal point" within the supplier's organization to ensure that the applicable system engineering tasks are performed in a timely and efficient manner. Such tasks may include the following:

1. Conduct feasibility studies and define specific design criteria for the system component(s) being developed. This information is based on system operational requirements, the maintenance concept, functional analysis, and the allocation of requirements as they apply to the supplier-produced item. Supplier requirements in this instance are included in a development specification (Type "B")—see Figures 3.2 and 6.15.

2. Prepare a supplier engineering plan (or equivalent). This plan should constitute an expansion of the SEMP and must reflect those requirements that support system engineering objectives.
3. Accomplish synthesis, analysis, and trade-off studies in support of component design decisions, and as they impact higher-level system requirements.
4. Accomplish design integration activities; that is, ongoing coordination and integration of design disciplines, activities, and data.
5. Prepare and implement a test and evaluation plan covering the system component(s) being developed. Integrate testing activities into system-level test requirements where feasible. Monitor, review, and evaluate component testing activities conducted at the producer's facility.
6. Participate in equipment/software design reviews and critical design reviews as applicable; that is, formal design reviews that cover the system component(s) being developed and its interfaces with other elements of the system.
7. Review and evaluate proposed design changes as they apply to the component(s) and impact the overall system.
8. Initiate and maintain liaison with production/manufacturing activities that support the system component(s).
9. Initiate and maintain liaison with the producer (i.e., prime contractor) throughout all phases of the program when supplier activities are in progress.

Although large projects may require the supplier to complete all of these tasks, the level of activity will obviously be scaled down for smaller projects. It must be emphasized (once again) that the system engineer is not be expected to personally complete all of these activities, but will be required to assume a leadership role to ensure that they are accomplished within the supplier's overall organizational structure.

For suppliers involved in production or manufacturing only, the system engineering focus is directed primarily to total quality management (TQM). It is important to ensure that the characteristics initially designed into system components are maintained through the subsequent production of multiple quantities of these items. As the production process can be highly dynamic and material substitutions often occur, it is necessary to guarantee that each of the components produced does indeed reflect the quality characteristics initially specified through design (refer to Section 3.4.10). Thus, close communications must be established with the supplier's quality control or quality assurance organization.

In dealing with suppliers of standard off-the-shelf components, it is important to prepare a good specification for the initial procurement of these items. Input-output parameters, size and weight, shape, density, and other key performance parameters must be covered in detail, along with allowable tolerances. Uncontrolled variances in component characteristics can have a significant impact on total system effectiveness and quality. Complete electrical, mechanical, physical, and functional interchangeability must be maintained where applicable. Although there are many different components that are currently in the inventory and fall within the category of "commercial off-the-shelf" (COTS), extreme care must be exercised to ensure that like components

(i.e., those with the same part number) are actually manufactured to the *same standards.* Moreover, the allowable variances around key parameters must be minimized.

It must also be kept in mind that there are many different categories of suppliers and that there is often a layering effect, as illustrated in Figure 6.31. In addition, many of these suppliers may be located across the United States, Canada, Mexico, Europe, Africa, Asia, Australia, and South America (see Figure 6.30). It is anticipated that supplier organizational structures will vary from one instance to the next. Thus, an objective is to identify the particular organizational group (or individual) who has been assigned responsibility for the completion of the required system engineering tasks and to establish the necessary communications and working relationships that will produce effective results.

7.6 HUMAN RESOURCE REQUIREMENTS

In considering organizational elements as they pertain to system engineering, it is necessary to address the human resource requirements, the staffing of a system engineering organization, leadership characteristics and motivational factors, and personnel development. Although there will be variations in each situation, there are certain common objectives that should be met from the employer/employee standpoint.

7.6.1 Creating the Organizational Environment

As discussed in Gibson, Donnelly, Ivancevich, and Konopaske, the study of organizations should address *structure, processes,* and *culture.*[7] Accordingly, "structure is the formal pattern of how an organization's people and jobs are grouped." Structure is usually illustrated in the form of an organizational chart, such as those described in Sections 7.4 and 7.5. Further, "processes are activities that give life to the organization chart. Communications, decision making, and organization development are examples of processes in organizations." Such processes have been highlighted and covered throughout the earlier chapters of this text. The third element is *culture,* which deals with an organization's personality, atmosphere, environment, and the like: "The culture of an organization defines appropriate behavior and bonds, it motivates individuals, and governs the way a company processes information, internal relations, and values. It functions at all levels from the subconscious to the visible. . . . Cultures of organizations can be positive or negative. An organization's culture is positive if it helps to improve productivity. A negative culture can hinder behavior, disrupt group effectiveness, and hamper the impact of a well-designed organization."

At this point, it is important to address the issue of "culture" through the design and development of an organization and establishing its human resource requirements, leadership characteristics, staffing, motivation factors and the development of its personnel, and so on. With regard to system engineering, the successful accom-

[7]J. L. Gibson, J. H. Donnelly, J. M. Ivancevich, and R. Konopaske, *Organizations: Behavior, Structure, Processes,* 11th ed., (New York: McGraw-Hill Irwin, 2003).

plishment of the objectives and specific tasks described throughout this text is highly dependent on the overall capabilities and environment that have been created within an organization. There are numerous instances in which organizations have been established and designated as the "System Engineering Department" or the "System Engineering Group," in which the requirements are not being met. On the other hand, there are other instances in which such organizations have been very successful. The key is to establish a structure and its processes and to create an environment that is "positive." This requires promoting communications throughout a given project structure, acquiring the necessary respect in terms of technical capability and assuming a leadership role for the project, and being able to influence the system design and development process on a continuing basis. This may be particularly challenging because the system engineering organization must accomplish much without having control of all of the resources required to complete the job.

The nature of system engineering activities requires consideration of the following characteristics in developing an organizational structure:

1. The personnel selected for the system engineering group must, in general, be highly professional senior-level individuals with varied backgrounds and a wide breadth of knowledge—for example, an understanding of research, design, manufacturing, and system support applications. The emphasis is on overall system-level design and technology applications, with knowledge of user operations and sustaining life-cycle maintenance and support in mind.

2. The system engineering group must have "vision" and be creative in the selection of technologies for design, manufacturing, and support applications. Group personnel must constantly search for new opportunities and must be innovative, and applied research is often required in order to solve specific technical problems.

3. A teamwork approach must be initiated within the system engineering group. The personnel assigned must be committed to the objectives of the organization; a certain degree of interdependence is required, and there must be mutual trust and respect.

4. A high degree of communication must prevail, both within the system engineering group and with the many other related functions associated with a given project (refer to Figure 7.13). Communication is a two-way process and may be accomplished via written, verbal, and/or nonverbal means. Good communications must first exist within the system engineering organization. With that established, it is then necessary to develop two-way communications externally, using both vertical and horizontal channels as required.

Given the objectives described throughout this text, and with these considerations in mind, the appropriate "environment" must be created to allow for the accomplishment of system engineering tasks in an effective manner. *Environment* in this instance refers to both (1) the working environment external to the system engineering function but within the contractor's organizational structure and (2) the working environment within the system engineering group itself.

The creation of a favorable environment within the contractor's organization, or within any other organizational structure being addressed, must start from the *top.*

The president, or general manager, must initially believe in and subsequently support the concepts and objectives of system engineering. On numerous occasions, power struggles will occur, conflicting organization goals and objectives will develop, and there will be a lack of communication between the key organizational entities. This, in turn, usually leads to redundancies, the hiring of unqualified personnel, and the expenditure of unnecessary resources, resulting in waste. A mechanism must be established for quick conflict resolution, and all project personnel must know that the system engineering philosophy *will* prevail, in spite of individual interests. Top management must create this understanding from the beginning.

In addition, the appropriate level of responsibility and authority must be delegated from the top, through the vice president of engineering and the program manager, to the system engineering department manager (refer to Figure 7.11). Responsibilities must be defined, and the commensurate level of authority to control and direct the means by which the activity is to be accomplished must be delegated accordingly. Quite often, a manager is willing to delegate responsibility for a particular activity to a subordinate, but will retain the authority for controlling the resources necessary for task completion. In this situation, the individual assigned the responsibility is powerless when it comes to the full utilization of available resources and, when things go wrong, is unable to respond relative to initiating the appropriate corrective action. He or she becomes discouraged, loses motivation, and the level of productivity ultimately falls off. In essence, the system engineering manager must be given the *responsibility,* the *authority,* and the *resources* to do the job assigned.

It is also important that the proper relationships be established between the vice president of engineering, the program manager, and the system engineering manager, as identified in Figure 7.11. Such relationships are, of course, heavily dependent on the managerial styles of the individuals in these positions. Although there are many variations, the two managerial styles most often discussed are the "autocratic" approach and the "democratic" approach.

The autocratic approach is basically dictatorial in nature and is restrictive in that decisions are generally unilateral; that is, decisions are made from the top down without input from those who are required to carry out these decisions. Managers control, direct, coerce, and even threaten employees to force them to work toward specific organizational goals. On the other hand, the democratic concept is participative and nonthreatening, and organizational interests are group-centered. The general theme is that individuals in the group have some voice in matters that directly affect them.[8]

Although both styles of management are prevalent for certain situations, the democratic style has been accepted as being more effective from a motivational standpoint. In general, people work harder, are more cooperative, and are more willing to accept changes if they feel that they have some influence on the results. Democratic leadership implies an organizational environment in which employees have a chance to

[8]These concepts are related to the managerial views described as "Theory X" and "Theory Y" by Douglas McGregor in his classic book, *The Human Side of Enterprise* (New York: McGraw-Hill, 1960). This is recommended reading for a more in-depth understanding of the human relations movement developed in the 1940s.

grow and develop their skills, where formal supervision is considerate and the application of dictates is not arbitrary, and where individual opinions are solicited and respected. With the democratic approach, as compared with the autocratic approach, management is committed to the recognition of employees as high-level professionals and not merely as factors in the production scheme.[9]

In regard to system engineering, an environment must be created that will allow for individual initiative, creativity, flexibility, personnel growth, and so on. A democratic and participative approach seems appropriate in meeting the objectives stated. Although the manager must maintain authority and provide the necessary direction and control to effectively accomplish the organization's goals and objectives, he or she can introduce some practices that directly support the democratic style. The selected style, it is hoped, will help to create a favorable environment for the accomplishment of system engineering tasks. This is influenced not only by the managerial style employed within the system engineering group itself, but the approach employed by higher-level management that has an impact on the group. Creating such an environment is critical to the objectives stated throughout this text. There are examples in which two (or more) similar organizations have the same basic objectives, the same structure, the same position titles, and so on—but one is productive and the other is not. High-level productivity is a function of the working environment.

7.6.2 Leadership Characteristics

The system engineering organization is composed of a group of individuals with varying abilities, different roles and expectations, diverse personal goals, and distinct behavioral patterns. Although individuals within the organization are highly dependent on one another, they often push in different directions because of some of these factors. The challenge for the system engineering manager is to integrate these various characteristics into a cohesive force, leading to the accomplishment of organizational objectives. The manager must not only ensure that the job is completed in a satisfactory manner, but it is hoped that he or she will inspire and motivate his or her subordinates to *excel* in the fulfillment of organizational objectives. It is apparent that the manager must create a climate that presents challenges (not threats) for the individuals involved.

In facilitating this objective, the manager should initiate certain practices that are responsive to both the organization and the individual needs of people within the organization. As a start, the democratic style of leadership, discussed in Section 7.6.1, tends to promote the necessary environment for the organization. Within this framework, the manager should encourage the participation of individuals in goal setting and in decision making, and should promote communications. By doing so, he or she will not only tend to improve motivation from within, but will also acquire a better

[9]A review of the literature on human motivation is recommended at this point. Three good references are (1) A. H. Maslow, "A Theory of Human Motivation," *Psychological Review* (July 1943); (2) F. Herzberg, B. Mausner, and B. Snyderman, *The Motivation to Work,* (New York: John Wiley & Sons, Inc., 1959); (3) M. S. Myers, "Who Are Your Motivated Workers," *Harvard Business Review* (1970).

understanding of the individuals in the organization. This understanding can be enhanced by taking the following steps:

1. Recognize the personal characteristics of each individual in the organization in order to better match the individual with the job requirements. A person may excell in one situation, but do only a mediocre job in another situation, even though the ability to do both and the overall organization climate remain relatively constant. In essence, the manager must assign employees to the type of work they do most effectively. A high-quality output is essential if the system engineering organization is to gain respect and retain a leadership role on a project.
2. Inspire each individual to excell in his or her job by creating an atmosphere of personal interest. An employee tends to perform better if he or she knows that the supervisor is personally interested. Personal interest is developed through involvement at the employee level.
3. Be sensitive to employee problems related to their work such so that each can be addressed on personal terms. The solution to a problem should, if at all possible, consider the effects on the individual employee.
4. Evaluate employees on a personal basis and initiate rewards promptly when warranted. Promotions and merit raises should not be given to the organizational hierarchy alone, but should be directed to the best performers.

Good communications and good rapport with employees must be established from the beginning. Obtaining the desired organization environment not only depends on the intent of the manager in initially establishing such practices, but is highly dependent on the manager's personal leadership ability in directing the activities of the organization over time. The best planning in the world will have little benefit unless the actions that follow in the implementation phase are directly supportive. As a goal, the manager should strive to exhibit the characteristics listed in Figure 7.16.

7.6.3 The Needs of the Individual

With the discussion thus far primarily covering the organization environment and the desired characteristics of leadership, it is now important that some attention be given to the needs of the individual employee. If the manager is to inspire, motivate, and deal successfully with subordinates, then a good understanding of these needs is necessary.

As a starting point, the reader should first review A. H. Maslow's theory dealing with the hierarchy of needs. The theory was developed to identify relatively separate and distinct drives that motivate individuals in general. The following five basic needs are identified:[10]

1. The physiological needs, such as thirst, hunger, sex, sleep, and activity. These constitute the needs of the body, and unless these needs are basically satisfied, they remain the prime influencing factors in the behavior of an individual.

[10]A. H. Maslow, "A Theory of Human Motivation." *Psychological Review* (July 1943).

Leadership Characteristics
1. Acceptance: Earns respect and has the confidence of others.
2. Accomplishment: Effectively uses time in meeting goals and objectives.
3. Acuteness: Mentally alert and readily comprehends instructions, explanations, and unusual circumstances.
4. Administration: Organizes his or her own work and that of his or her subordinates; delegates responsibility and authority; measures, evaluates, and controls position activities.
5. Analysis and judgment: Performs critical evaluation of potential and current problem areas; breaks problem into components; weighs alternatives; relates, and arrives at sound conclusions.
6. Attitude: Enthusiastic; optimistic; and loyal to firm/agency, superior, position, and associates.
7. Communication: Promotes communication within and between organization elements.
8. Creativeness: Has inquiring mind; develops original ideas; and initiates new approaches to problems.
9. Decisiveness: Makes prompt decisions when necessary.
10. Dependability: Meets schedules and deadlines in consistent manner and adheres to firm/agency policies and procedures.
11. Developing others: Develops competent successors and replacements.
12. Flexibility: Adaptable; quickly adjusts to changing conditions; and copes with the unexpected.
13. Human relations: Is sensitive to and understands personnel interactions; has "feel" for individuals and recognizes their problems; considerate of others; ability to motivate and get people to work together.
14. Initiative: Self-starting; prompt to take hold; seeks and acts on new opportunities; exhibits high degree of energy in work; not easily discouraged; and possesses basic urge to get things done.
15. Knowledge: Possesses knowledge (breadth and depth) of functional skills needed to fulfill position requirements; uses information and concepts from other related fields of knowledge; and generally understands the "big picture."
16. Objectivity: Has an open mind and makes decisions without the influence of personal or emotional interests.
17. Planning: Looking ahead; developing new programs; preparing plans; and scheduling requirements.
18. Quality: Accuracy and thoroughness of work; maintains high standards consistently.
19. Self-confidence: Self-assurance; inner security; self-reliance; takes new developments in stride.
20. Self-control: Calm and poised under pressure.
21. Self-motivation: Has well-planned goals; willingly assumes greater responsibilities; realistically ambitious; and generally eager for self-improvement.
22. Sociability: Makes friends easily; works well with others; and has sincere interest in people.
23. Verbal ability: Articulate; communicative; and is generally understood by persons at all organizational levels.
24. Vision: Possesses foresight; sees new trends and opportunities; anticipates future events; and is not bound by tradition or custom.

Figure 7.16 Checklist of leadership characteristics.

2. The safety and security needs, which include protection against danger, threat, and deprivation. Having satisfied the bodily needs, the safety and security needs become a dominant goal.
3. The need for love and esteem by others, or social needs. This includes belonging to groups, giving and receiving friendship, and the like.
4. The need for self-esteem or self-respect, and for the respect of others (i.e., ego need). An individual wishes to consider him- or herself strong, able, competent, and basically worthy by his or her own standards.

5. The need for self-fulfillment or the achieving of one's full potential through self-development, creativity, and self-expression. This relates to the human desire to grow, develop to the point of full potential, and ultimately attain the highest level possible.

The needs are related to each other, and are ordered in a manner that will stimulate consciousness and activity. As a need becomes satisfied, activity emphasis shifts to the next need category. In other words, a satisfied need is no longer a motivator, and the next need becomes a driving factor.

Whereas Maslow addressed the overall hierarchy of needs from a general standpoint, Herzberg's research resulted in his "motivation-hygiene" theory, which identifies factors commonly known as "satisfiers" and "dissatisfiers." The theory was developed from research pertaining to the job attitudes of 200 engineers and accountants, and was based on two questions: (1) "Can you describe, in detail, when you felt exceptionally *good* about your job?" and (2) "Can you describe, in detail, when you felt exceptionally *bad* about your job?" The results were classified in two categories as follows:[11]

1. *Satisfiers:*
   (a) Achievement—personal satisfaction in job completion and problem solving.
   (b) Recognition—acknowledgment of an accomplishment (e.g., a job well done)
   (c) Work itself—actual content of the job and its positive/negative effect on the employee
   (d) Responsibility—both responsibility and authority in relation to the job
   (e) Advancement—promotion on the job
   (f) Growth—learning new skills offering greater possibility for advancement
2. *Dissatisfiers:*
   (a) Company policy and administration—feelings about the adequacy or inadequacy of company organization and management, policies and procedures, and so on.
   (b) Supervision—competency or technical ability of supervision
   (c) Working conditions—physical environment associated with the job
   (d) Interpersonal relations—relations with supervisors, subordinates, and peers
   (e) Salary—pay and fringe benefits
   (f) Status—miscellaneous items such as size of office, having a secretary, and a private parking place
   (g) Job security—tenure, company stability or instability
   (h) Personal life—personal factors that affect the job (e.g., family problems, social problems)

[11]F. Herzberg, "Work and Motivation," *Studies in Personnel Policy Number 316: Behavioral Science, Concepts and Management Application* (New York: National Industrial Conference Board, 1969).

Most of these factors have some bipolar effects. For instance, "advancement" certainly is a *satisfier* when it happens and may be somewhat of a *dissatisfier* when it does not occur. However, this category weighs much more heavily as a satisfier. The item "salary" is definitely a dissatisfier when pay scales and fringe benefits are poor, and is a mild satisfier when the compensation is good. In this case, the predominant classification for salary is that of a dissatisfier. In any event, all of the factors listed represent needs of the individual and should be considered by management.

Myers conducted research involving 282 subjects (including engineers, scientists, and technicians) interviewed at Texas Instruments commencing in 1961. The categories used were "motivators" and "dissatisfiers," and the results as they pertain to engineers are noted in the following list. The items listed and identified with an "M" are clearly motivators, and those with a "D" are definitely dissatisfiers. For instance, the item "pay" is clearly a dissatisfier if considered as being inadequate, and "advancement" is definitely a motivator when it occurs. Once again, there are bipolar effects; however, the categorization does indicate where the greatest impact occurs.[12]

1. Work itself (M)
2. Responsibility (D)
3. Company policy and administration (D)
4. Pay (D)
5. Advancement (M)
6. Recognition (D)
7. Achievement (M)
8. Competence of supervision (D)
9. Friendliness of supervision (D)

In summary, the needs of the individual employee will vary somewhat, depending on his or her situation. If one need is satisfied, then another need becomes predominant, and so on. In addition, these needs are often related to the business position of the company in which the person is employed (or the success of the organization overall). If the firm is in a growth posture, the individual's perceived needs may be somewhat different than if the firm is experiencing a business decline and the prospect of laying off employees is apparent. Finally, the manager's job is twofold. He or she must (1) be aware of the individual needs in the organization and create the necessary conditions for employee motivation and (2) satisfy those needs on a continuing basis to the extent possible. Human motivation is a key to organizational success, and an understanding of the concepts in this section should help in meeting this objective.[13]

[12]M. S. Myers, "Who Are Your Motivated Workers," *Harvard Business Review* (1970). This study employs factors comparable to those used by Herzberg.

[13]A comparison of four "content theories of motivation" is presented in J. L. Gibson, J. H. Donnelly, J. M. Ivancevich, and R. Konopaske, *Organizations: Behavior, Structure, Processes,* 11th ed., (New York: McGraw-Hill Irwin, 2003), Chapter 5, pp. 126–139. This includes a discussion of Maslow's Need Hierarchy, Alderfer's ERG Theory (existence, relatedness, and growth), Herzberg's Two-Factor Theory, and McClelland's Learned Needs Theory (achievement, power, and affiliation). Only two of these are covered in this chapter.

7.6.4 Staffing the Organization

The requirements for staffing an organization initially stem from the results of the system engineering planning activity described in Chapter 6. Tasks are identified from both short- and long-range projections (refer to Figure 6.25), combined into work packages and the work breakdown structure (WBS), and the work packages are grouped and related to specific position requirements. The positions are, in turn, arranged within the organizational structure considered to be most appropriate for the need (refer to Figures 7.2 through 7.15).

With regard to determining specific position requirements for a system engineering organization, one should first have a good understanding of the basic functions of the organization. These are discussed throughout the earlier chapters of this text and, more specifically, in Chapter 6. A review of the assigned tasks, the nature and challenges of the organizational structure, and so on, indicate that, in general, an entry-level "system engineer" should have the following:

1. A basic formal education at the undergraduate and graduate levels in some recognized field of engineering; that is, a master's degree in engineering or equivalent.[14]
2. A high level of general technical competence in the engineering fields being pursued by the organization, project, and so on.
3. Relevant design experience in the appropriate areas of activity. For example, if the company is involved in the development of electrical/electronic systems, then it is desirable for the candidate to have had some prior design experience in electrical/electronic systems. A different type of experience would be required for aeronautical systems, civil systems, hydraulic systems, and so on.
4. A basic understanding of the design requirements in areas such as reliability engineering, maintainability engineering, human factors, safety engineering, logistics engineering, software engineering, quality engineering, and value/cost engineering.
5. An understanding of the system engineering process and the methodologies/tools that can be effectively employed in bringing a system into being; for example, the definition of system requirements and functional analysis and allocation.
6. An understanding of the relationships between functions, including marketing, contract management, purchasing, integrated logistic support, configuration management, production (manufacturing), quality control, customer and supplier operations, and so on.

As the specific definition of a "system engineer" often varies from one organization to the next, individual perceptions as to the requisites will differ. Based on experience, it is believed that a good solid technical engineering education is a necessary

[14]Recognized accredited programs in engineering are defined by the Accreditation Board for Engineering and Technology (ABET), United Engineering Center, 345 East 47th Street, New York, NY 10017. Refer to the latest *Annual Report.*

foundation, some design experience is essential, a thorough understanding of the system life cycle and its elements is required, and knowledge of the many design interfaces is appropriate. If an individual is to successfully implement the functions identified in Chapter 6 (Figure 6.6), then some prior experience in these areas is highly recommended.

Given the basic requisites, the system engineering department manager will prepare an individual position description for each open slot in the organization. A sample position description format is illustrated in Figure 7.17. The position title, responsible supervisor, areas of responsibility and job objectives, background requirements, and the date of need should be clearly identified. The system engineering position requirements are completed and forwarded to the human resources department (or equivalent) in order to proceed with the necessary steps for recruiting and employment.

In staffing an organization, possible sources include (1) qualified personnel from within the company and ready for promotion and (2) personnel from outside and available through the open market. It is the responsibility of the system engineering department manager to work closely with the human resources department in establishing the initial requirements for personnel, in developing position descriptions and advertising material, in recruiting and the conducting of interviews, in the selection

Date of need:

Position title:

Senior system engineer

Supervisor:

System Engineering Department Head

Broad Function:

Responsible for the performance of system engineering functions in the design and development of communication products.

Functional Objectives:

1. Perform system feasibility studies and evaluate alternative technology applications.
2. Develop operational requirements and maintenance concepts for new communication systems/equipment.
3. Interpret and translate system-level requirements into functional design requirements.
4. Prepare system and subsystem specifications and plans.
5. Accomplish system integration activities (including supplier functions).
6. Determine requirements and conduct formal design reviews for all system elements.
7. Prepare system test and evaluation requirements, monitor test functions, and evaluate test results to determine system performance and effectiveness. Make recommendations for corrective action and/or improvement as appropriate.
8. Provide assistance to marketing in product sales activities, and fulfill customer service requirements as necessary.

Requirements:

Degree in electrical engineering (master's degree or higher and some training in managment skills and practices), plus at least 10 years of experience in communication systems design.

Figure 7.17 Sample position description.

of qualified candidates, and in the final hiring of individuals for employment within the system engineering organization. In the process of conducting interviews and selecting system engineering personnel, the characteristics identified in Figure 7.16 should be kept in mind.[15]

7.6.5 Personnel Development and Training

Nearly every engineer wants to know how he or she is doing on a day-to-day basis and what the opportunities for growth are. Response to the first part of the question is derived from a combination of the "formal performance review," which is often conducted on a regularly scheduled basis (either semiannually or annually), and the ongoing day-to-day "informal communications process" with the supervisor. The engineer is given responsibility and seeks recognition and approval from the supervisor. As discussed in Section 7.6.2 there must be close communication, and the supervisor must provide some reinforcement that the employee is doing a good job. The employee also needs to know as soon as possible when his or her work is unsatisfactory and improvement is desired. Waiting until the formal performance review is conducted to indicate that the employee's work is not satisfactory is a poor practice. It is also demoralizing, because, by virtue of not having heard any comments to the contrary, the employee assumes that all is well. In a system engineering organization, it is particularly important for the appropriate close level of communication to be established from the beginning.

The second part of the question, pertaining to opportunities for growth, depends on (1) the climate provided within the organization and the actions of the manager that allow for individual development and (2) the initiative on the part of the engineer to take advantage of the opportunities provided. Within a system engineering department, it is *essential* that individual personal growth take place if that department is to function effectively. The climate (or environment) must allow for individual development, and the individual system engineer must seek opportunities accordingly. The system engineering department manager should work with each employee in preparing a tailored *development plan* for that employee. The plan adapted to each person's specific needs should allow for (and promote) personal development by providing a combination of the following:

1. Formal internal training designed to familiarize the engineer with the policies and procedures applicable to the overall company as a whole, as well as the detailed operating procedures of his or her own organization. This type of training should enable the individual to function more successfully within the framework of the total organization through familiarization with the many interfaces that he or she will encounter on the job.

[15]The human resources department in most companies is responsible for establishing job classifications and salary structures, for the recruiting and hiring of personnel, for initiating employee benefit coverage, for providing employee opportunities for education and training, and so on. It is incumbent upon the system engineering department manager to ensure that his or her organizational requirements are initially understood and subsequently met through recruiting, employment, and training activities.

2. On-the-job training through selective project assignments. Although extensive shifting of personnel from job to job (or project to project) can be detrimental, it is sometimes appropriate to reassign an individual to work where he or she is likely to be more highly motivated. Every employee needs to acquire new skills, and occasional transfers may be beneficial as long as the overall productivity of the organization does not suffer.

3. Formal technical education and training designed to upgrade the engineer relative to the application of new methods and techniques in his or her own field of expertise. This pertains to the necessity for the engineer to maintain currency (and avoid technical obsolescence) through a combination of (a) continuing education short courses, seminars, and workshops, (b) formal off-campus graduate engineering programs provided at the local level (leading to an advanced degree), and (c) long-term training involving opportunities for research and advanced education on a university or college campus. The opportunities for acquiring continuing education while on the job are greater now than ever before, with the availability of the Internet, satellite TV, two-way compressed video (VTEL/PICTEL), videotapes, and computer-based delivery capabilities. If an individual is motivated, he or she can acquire a great deal of support in this area.[16]

4. A technical exchange of expertise with others in the field through participation in technical society activity, industry association activity, symposia and congresses, and the like.

The system engineering manager must recognize the need for the ongoing development of personnel in his or her organization and should encourage each individual to seek a higher level of performance by offering not only challenging job assignments, but opportunities for growth through education and training. The long-term viability of such an organization is highly dependent on personnel development. This, in turn, should enhance individual motivation and result in the fulfillment of system engineering functions to the highest quality standards.

7.7 SUMMARY

It should be noted that the successful implementation of system engineering requirements is not dependent on any one specific organizational structure. Although the various organizational "structures," and their advantages and disadvantages, are identified in Figures 7.2–7.13, a successful system engineering program can be realized through any one of these structures. However the accomplishment of such is dependent on: (1) providing the proper "environment" from the top-down which will allow system engineering principles and concepts to be implemented effectively and

[16]With the current computer technology, one can take courses and acquire a graduate degree (at the master's level) in system engineering, and in other fields, through the Internet without having to travel or leave home. Two of a number of software systems currently in place, and through which course material can be offered, are WebCT and Blackboard (for example).

efficiently; (2) having the proper leadership that understands and believes in system engineering and the benefits that can be realized as a result of its implementation; (3) the establishment of a good communications capability throughout the entire organization, with the customer, and among the suppliers; and (4) incorporating an effective feedback and control capability that will permit periodic evaluation and allow for continuous process improvement.

From experience, there have been numerous occurrences where a designated "system engineering" organization has been established and assigned the responsibility for implementation of system engineering requirements, but where the results turned out to be a failure. In other words, there have been system engineering organizations established, but which have been unsuccessful for one reason or another; e.g., have not had the proper understanding and support from a higher level of management, have not established the appropriate level of communications across the board, have not "educated" others in the project as to the objectives and benefits of system engineering, and so on. On the other hand, there have been situations where a separately identified organizational entity has not been too apparent, but where the requirements have been very successfully implemented, primarily due to upper management support, good communications, a desire for a good quality product, and an appreciation throughout the project/company as to the benefits that can be derived through the implementation of good system engineering practices.

Finally, it should be emphasized that the successful implementation of system engineering requirements is not dependent on any single organizational entity, but is a project-wide (or program-wide) responsibility. Referring to Figure 7.13, while there is an identified "lead" system engineering group, the successful accomplishment of system engineering requirements is highly dependent on the communications and cooperation of all of the other organizational entities as shown. In this instance, the system engineering group will serve in a leadership role, but much of the "doing" takes place in other organizational groups. Again, it's a "team" approach that is essential.

QUESTIONS AND PROBLEMS

1. Describe what is meant by "organization." What are its characteristics and objectives? What factors must be addressed to ensure the successful accomplishment of its objectives?

2. There are various types of organizational structures. Identify at least four different types, briefly describe each, and discuss some of the advantages and disadvantages of each.

3. Refer to Figure 7.1. Where is system engineering accomplished? Who is responsible for the accomplishment of system engineering functions? Identify some of the major concerns associated with the organizational relationships shown in the figure.

4. Based on your own experience, what type of an organizational structure is preferred from a system engineering perspective? Why? Construct an organization chart showing the system engineering group/department/section within the context of a company's (i.e., producer/contractor's) organizational structure. Identify the major organizational interfaces between system engineering and other major activities within the company.
5. Refer to Question 4. For the organizational structure developed, describe the system engineering tasks to be accomplished and identify "input" requirements and expected "output" results for each task.
6. From an organizational perspective, identify and describe some of the conditions that must exist in order to accomplish system engineering objectives in an effective and efficient manner.
7. In regard to organizational "environment," what factors must be considered to ensure the successful implementation of system engineering requirements?
8. Describe some of the major challenges associated with the management of supplier organizations and related activities.
9. Relative to the styles of management, what is meant by "Theory X" and "Theory Y?" Which is preferred for a system engineering organization?
10. What is meant by "organizational culture"? Why is it important?
11. Assume that you, as the vice president of engineering, are planning to hire a new System Engineering Department manager. What leadership characteristics would you identify as being critical (identify in order of importance)?
12. Refer to Figure 7.16. Select and list in order of importance the top 10 characteristics, based on your own experience.
13. What is meant by "IPPD" and "IPT"? Describe the purpose and objectives of each.
14. Refer to the results of Herzberg's research in Section 7.6.3. Based on your own experience, list the "satisfiers" and the "dissatisfiers" in order of importance. List some additional factors as you see fit. A bar chart showing the bipolar relationships is a good way to present your thoughts.
15. From your own perspective, describe the characteristics of a "system engineer" (background, experience, personal characteristics, motivational factors, etc.).
16. As a manager of a System Engineering Department, what steps would you take to ensure that your organization maintains a lead position relative to technical competency?
17. Refer to Figure 7.13. What steps would you take to ensure maximum cooperation with (and support from) Design Engineering? Logistics Support? Software Engineering? Business? Operations?