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DEPARTMENT OF DEFENSE HANDBOOK

ACQUISITION LOGISTICS

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Section 4: Systems Engineering and the Acquisition Process

4.1 INTRODUCTION

Acquisition logistics is a multi-functional technical management discipline associated with the design, development, test, production, fielding, sustainment, and improvement modifications of cost effective systems that achieve the user's peacetime and wartime readiness requirements. The principal objectives of acquisition logistics are to ensure that support considerations are an integral part of the system's design requirements, that the system can be cost effectively supported through its life-cycle, and that the infrastructure elements necessary to the initial fielding and operational support of the system are identified and developed and acquired. The majority of a system's life-cycle costs can be attributed directly to operations and support costs once the system is fielded. Because these costs are largely determined early in the system development period, it is vitally important that system developers evaluate the potential operation and support costs of alternate designs and factor these into early design decisions.

Acquisition logistics activities are most effective when they are integral to both the contractor's and Government's system engineering technical and management processes. When this is the case, system designers, acquisition logisticians, and program managers are best able to identify, consider, and trade-off support considerations with other system cost, schedule and performance elements to arrive at an optimum balance of system requirements that meet the user's operational and readiness requirements.

4.2 DEFENSE SYSTEMS ACQUISITION PROCESS

The acquisition of a defense system is conducted within a management framework described in Department of Defense Directive 5000.1, *Defense Acquisition*. This directive establishes a flexible management approach for acquiring systems within recognized constraints. It mandates an integrated, total systems approach to the definition of needs and opportunities, the formulation of alternatives, the acquisition of total systems, and their operational sustainment. In short, it mandates a systems engineering approach for the total life cycle of a system.

The procedures to be used are contained in Department of Defense Regulation, 5000.2-R, *Mandatory Procedures for Major Defense Acquisition Programs (MDAPS) and Major Automated Information System (MAIS) Acquisition Programs*. The procedures described are mandatory for MDAPS and MAIS acquisition programs as they are defined in the instruction. However, the process they describe is to be generally applied to any acquisition program.

The acquisition process addresses the life cycle of a system. Its cyclic nature is best understood by looking at the succession of systems which have been used over time to provide a similar capability (e.g., tanks, fighter aircraft, air defense systems, etc.). The evolutionary relationship of their designs is clear. Most acquisitions are initiated to replace or upgrade existing systems. The systems may no longer meet operational needs, or can be substantially improved in capability, or are no longer affordable to operate. Experience developed during a retiring system's operational life provides important insight for the initial definition of support requirements for its replacement. This information, and the current operational needs, form the basis for establishing supportability requirements and constraints for a new acquisition. And the operational history of that new acquisition will form the basis for its successor when it is no longer serviceable. In reality, then, the trigger which initiates the defense systems acquisition process—the determination and definition of an operational need requiring a materiel solution—occurs during the operational phase of an existing item.

The acquisition process is intentionally flexible to accommodate the wide variety of potential system solutions to a recognized need, opportunity, or deficiency. Supportability analyses are conducted for one of two basic objectives:

- To ensure that supportability is included as a system performance requirement.
- To ensure optimal support system design and infrastructure.

The supportability analyses to be accomplished vary from program to program and from phase to phase. What supportability analyses need to be conducted is largely determined by two key factors—the acquisition phase and the type of acquisition.

The acquisition process is controlled by the acquisition management process. This process divides a program into a series of logical phases. Each phase targets specific issues and objectives which generally correlate to one of the engineering states of a design. The issues and objectives reflect those which should typically be addressed before proceeding to the next phase and state of design.

Acquisition phases are separated by decision points at which total system designs are reviewed and evaluated against phase issues and objectives. These decision points are Milestones 0, I, II, and III. Passing a milestone review represents the decision approval to proceed to the next program phase. The acquisition management process phases are shown in Figure 4-1. However, the specific number of phases and the content of each are aligned with the particular needs of a program.

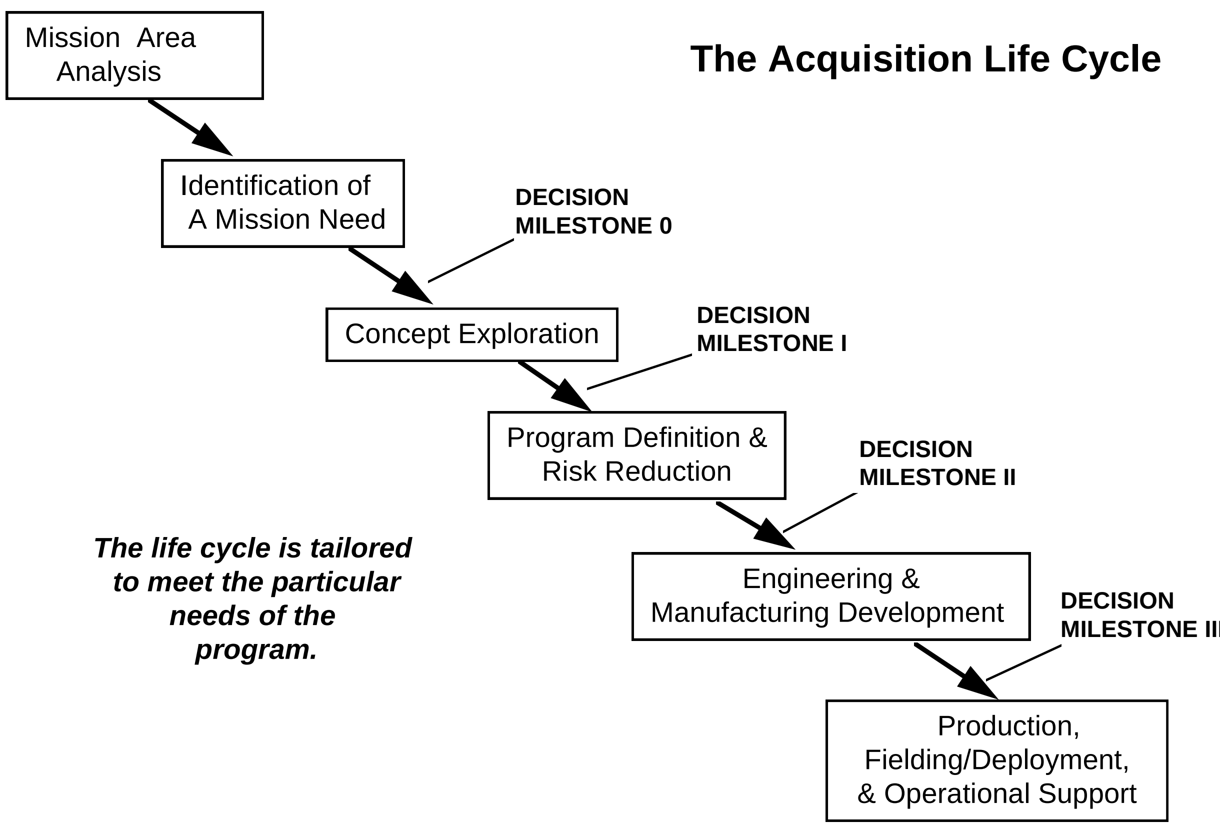


Figure 4-1. Acquisition Life Cycle

4.2.1 Type of Acquisition

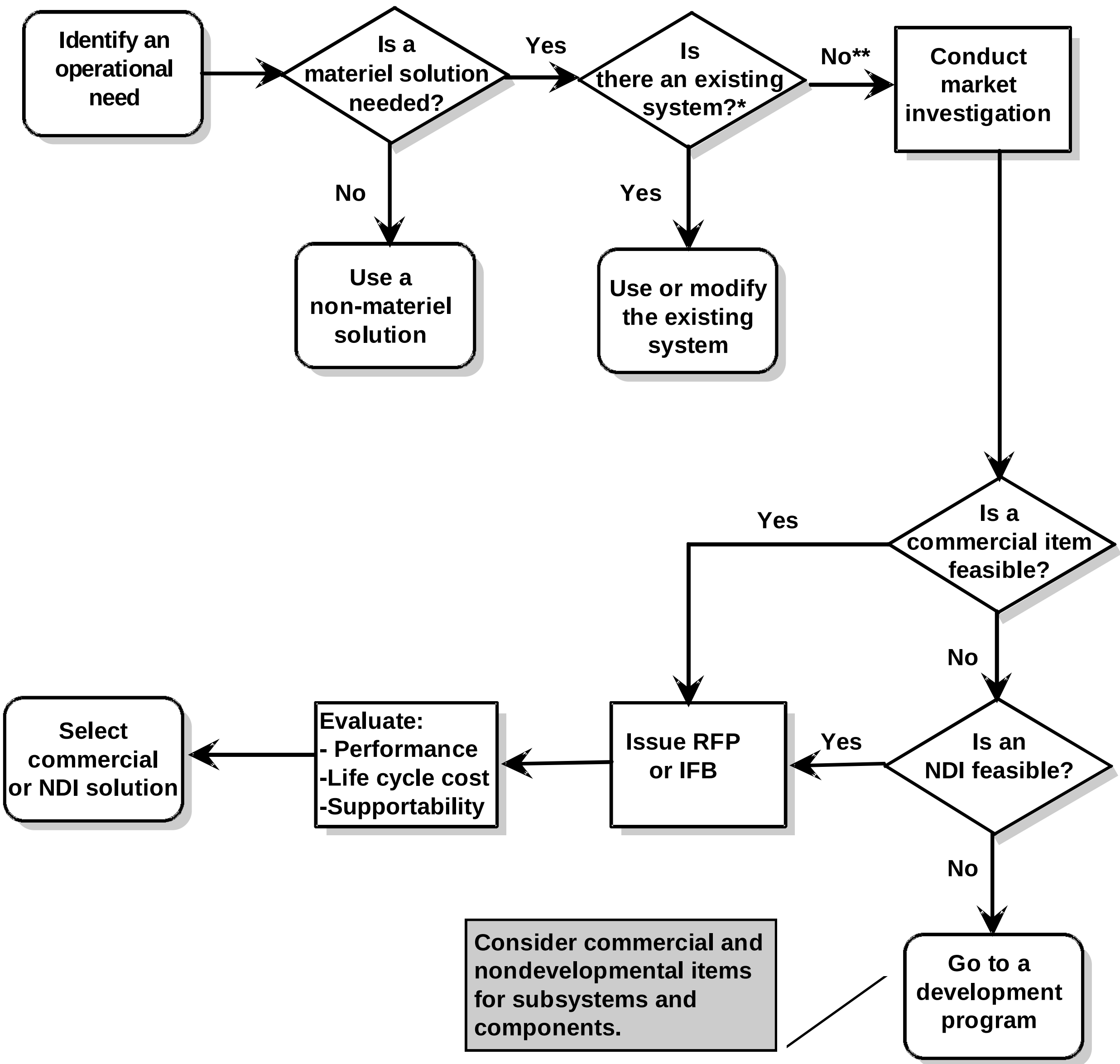
"Type of acquisition" generally relates to the amount of design activity required to complete a total system. There are four basic types of acquisitions. The types of acquisition are, in order of preference: (1) modification of an existing system; (2) commercial item, (3) nondevelopmental item (NDI), and; (4) development. There are sub-categories within each type; for example, a product improvement program may be for upgrade of an existing DoD item or for an item developed by a foreign military organization. Figure 4-2 shows the steps in making a type of acquisition decision.

The acquisition type names generally relate to the state of design of the primary mission element of the system being acquired, be it hardware or software. Thus a modification program to an existing combat system may include a full development effort for new operational software and only minor change in hardware and support. Conversely, a full development effort for a training system's hardware may require little or no software or support development if commercial software and support designs are used.

It is DoD policy to acquire total systems which meet operational needs at the most affordable life cycle cost. The options are many. But the goal is always to get the best balance between total system design opportunities, operational needs, and program constraints. To achieve this goal, each aspect of a total system must be considered, the alternatives identified and evaluated, and the tradeoff decisions made and implemented.

Deciding the type of acquisition program to be implemented is the first major step in determining what systems engineering activities to include in a program's acquisition strategy. The supportability analysis portion of the systems engineering process begins with the identification of an operational need. The initial operational requirements and concepts are evaluated to identify support implications and alternatives. Here are two examples: 1) A requirement for a small quantity of a new highly reliable system suggests greater affordability under a commercial repair support concept than under an organic concept. This opportunity should be investigated further. 2) An interoperability requirement suggests a standardization opportunity that might reduce the support burden of the system. The standardization candidate should be evaluated for its performance and design suitability, and the support risks and benefits of the candidate should be explored.

Modification programs are most often conceived of as such from the outset, perhaps because of the significant investment represented by materiel assets to be modified or the limited scope of the modification. In these instances the support evaluations are usually bounded by the scope of the needed change and are conducted in the context of the existing support concept. Where possible, however, opportunities to introduce more responsive and/or affordable support alternatives should be developed.



*** Existing system must meet the user's need, or can be modified to meet the user's need.**

**** In preparation for the market investigation establish objectives and thresholds for cost, schedule, and performance based on the user's operational and readiness requirements.**

Figure 4-2. Acquisition Decision Process

When modification of an existing system is not the clear program direction, early identification of support issues and alternatives provides key input to system requirements development and tradeoff analysis activities. They are combined with other systems engineering estimates and projections also based upon the operational requirements. The result is a set of performance requirements for the total system.

The total system requirements provide a basis for market investigation of commercial and/or nondevelopmental item solutions that have potential to meet performance needs and other program objectives (e.g., cost, schedule). Flexibility is important in evaluating potential candidate designs. It may be possible to adjust specific needs within acceptable levels or to accept minor modifications to avoid eliminating an otherwise suitable design solution. Ensuring development of performance requirements that address and balance all elements of a total system design helps to avoid the selection of “fixed” design solutions that have not been evaluated against the needs of the total system.

If a commercial or non-development design solution is determined to be acceptable, the supportability analyses’ focus becomes the detailed design of the support. If a commercial support concept was included in the alternative selection decision, supportability analyses should be limited to those aspects of the support system design required to interface the commercial support with the existing support system. Demonstrated supportability characteristics of the total system design are usually sufficient to project and assess commercial support design and performance. If organic support was the preferred alternative for the commercial/non-developmental system design, the design information will be used to conduct the essential analyses for support planning and logistics data product development.

If market investigations do not identify acceptable design solutions, this approach is discontinued, and program activities focus on a development solution for the primary mission element of the system. Even in a full development program, consideration should be given to meeting other system element design requirements (e.g., mission software, support system) with commercial or nondevelopmental solutions. Additionally, lower-level performance functions of the development item should be analyzed for opportunities to include the use of commercial or nondevelopmental subsystems or components.

4.2.2 Acquisition Strategy

An acquisition strategy details the requirements, approaches, and objectives of a program. The strategy development is initiated with the results of the acquisition decision process. This decision is supported by early studies and analyses of operations and support requirements and by market investigation results. The strategy is developed in line with the acquisition decision and the associated systems engineering and other program activity requirements associated with the type of acquisition decision. These requirements are further tailored based upon specific program needs and constraints.

Traditional DoD acquisition environments, based primarily upon proprietary products and isolated data processing systems have resulted in a costly, poorly integrated, and *closed* (rather than *open*) infrastructure in most organizations. The *open systems* approach mandated by current DoD policy (reference DoD 5000.2-R, paragraph 4.3.4) encompasses the selection of specifications and standards adopted by industry standards bodies or de facto standards for selected system interfaces, products, practices, and tools. Open systems standards define interfaces which support portability, interoperability, and scaleability (i.e., expansion); and are available to the public. Potential benefits realized from the use of open systems standards include reduced costs, increased competition, and increased interoperability. Note, however, that an open system standard IS NOT SYNONYMOUS with the use of commercial and non-developmental items (C/NDI) . An open systems standard is primarily concerned with interface compatibility to promote interoperability between multiple suppliers' equipment

Ideally, *open systems* represent a transparent environment in which users can intermix hardware, software, and networks of different vintages from different sources to meet differing needs. In reality, systems are not purely open or closed. Because industry standards do not generally meet all military needs, trade-offs must be made between performance, cost, supportability, availability of standards-based products, and the ability to upgrade. The result is that for any given system, the degree of openness may have many interpretations.

As with any integrated effort, supportability analysis activities must be aligned with the related systems engineering disciplines whose activities provide essential support planning information relative to the hardware and software designs.

4.2.3 Design Flexibility

The degree of flexibility in the total system hardware, software, and support system designs is a basic consideration in deciding what supportability analyses can and should be performed.

The objective of most support system design activities is to identify support considerations (e.g., constraints) which may influence selection of system hardware and software design and support alternatives to improve readiness, supportability, and cost. If the hardware design is fixed, as it would largely be in a commercial or NDI acquisition, these early analyses might seem to have little benefit. In the case of product improvement programs, the scope of proposed improvements might limit design flexibility to specific subsystems and may or may not open non-affected areas of the design to redesign opportunities that would address changes to reduce the anticipated support burdens.

Flexibility may exist for the design of the support system but not in the hardware system. Commercial items for which maintenance support plans have not been developed are typical examples of this situation.

Integrating supportability requirements into system and equipment design requires that designers be oriented toward supportability objectives from the outset. Technical information generated during the design process must be disseminated among designers and members of the supportability disciplines to surface interface problems. Technical design information—diagnostic features, electromechanical interfaces, reliability estimates, item functions, adjustment requirements, and connector and pin assignments—that determines supportability should be an integral part of design documentation. When design flexibility exists, the performing activity's plan should describe the generation, control, and approval of this type of design documentation.

4.2.4 Available Resources

Supportability analyses require time and resources. It is pointless to impose supportability requirements that depend upon an analysis whose results may not be available in time to contribute to the design decisions which they are intended to affect. The exception to this rule would be a situation where the potential improvement can be included as part of future pre- planned product improvements such as technology insertion programs.

It is DoD policy to fund readiness and support considerations in the front end of programs. Nevertheless, resources are constrained in practice. If program funds are short, it may be possible to perform some activities, such as the requirements definition activities, with in-house capabilities. If the in-house capability is limited but funds are available, such analyses might also be accomplished by "program support" contractors with the required expertise.

Another approach is to capitalize on the interrelationships between the analyses. For example, an analysis of an existing system feeds the identification of supportability drivers of a new system. These, in turn, feed the selection of targets for supportability improvement in the new system. If, for some reason, only one of these activities could be afforded, then the identification of targets for improvement would be the logical pick of the two. The process of target identification will obviously lose precision since human judgments and estimates will be substituted for hard data. But this approach does result in the decision as to the program's supportability targets of improvement.

Performance specifications are streamlining the acquisition process by imposing fewer restrictions and giving more decision flexibility to the developer. Many of these programs include a "fast track" approach in scheduling as well. The schedules of these fast track programs may be making it impossible to accomplish all of the supportability analyses that should be accomplished given the type of acquisition. In this situation select those activities that offer the greatest potential return on the investment.

4.2.5 Prior Work Results

Work previously accomplished can seriously impact the analysis selection. Support drivers and improvement initiatives may already have been identified, developed as inputs in the preparation of program documents. The quality and currency of the available results must be assessed, but if deemed adequate, the work already done may eliminate the need for further iterations or limit the effort to one of updating the available results. However, if the stated requirements or constraints are based upon previously conducted analyses it is essential to test their currency before adopting them as hard limitations. For example, if a supportability requirement such as repair turnaround time for a new system was based upon a preliminary demonstration of a new technology, such as a new composite repair procedure, obtain and evaluate updated repair procedure information before accepting the previously developed requirement.

4.2.6 Available Data and Experience

The availability, accuracy, and relevancy of experience and historical data on similar existing systems is crucial for accomplishment of some supportability analyses. Available data must be examined to determine how much work is needed to provide the necessary focus or relevancy to the new system design. If such data is not available, a special "sample data" effort should be considered to create an analysis baseline, particularly if the needed data is in an area of possible high risk or opportunity.

The objectives and specific supportability analysis activities, including the depth to which they are conducted, also depend upon the acquisition phase of the program. As previously indicated, the acquisition phases are generally defined by the state of design development of a hardware/software element of the total system. Program requirements and objectives should be aligned with the phase of the acquisition process that most closely represents the design activities to be accomplished. Too often acquisition programs attempt to make decisions before sufficient knowledge of the design element is known. The result is always an increase in risk.

4.2.7 Phase Considerations

Each of the acquisition phases is generally characterized by issues and objectives associated with a particular level or state of a design (e.g., conceptual, functional, allocated, physical). These issues and objectives must be satisfied through the milestone review procedures in order for a program to proceed.

When permitted by regulation, the phase definitions should be redefined to fit the particular requirements of the program. Phase activities can be combined between two phases or a phase may be eliminated altogether.

A supportability analysis effort evaluating existing support structure in conjunction with force/fleet analysis, threat analysis, and doctrine development must be conducted prior to entry into any acquisition phase. This effort is critical in developing supportable system requirements. Focus of the effort should be on a macro level and should identify the impacts on sustainment any requirement may have. The results should provide a basis for tradeoffs in system capabilities during the actual acquisition phases (which may or may not follow), as well as ensuring that developed requirements are actually achievable at affordable cost.

Concept exploration phase

The concept exploration phase, Phase 0, is the first phase of a DoD system’s life cycle. If it occurs at all, it typically consists of competitive, parallel short-term concept studies performed to investigate alternative operations and design concepts. The purpose is to identify, define, and evaluate the advantages/disadvantages, risks, costs, etc. of promising operational concepts and system design alternatives. The studies project characteristics and costs of total systems as reflected by their conceptual designs. The results are reviewed at the Milestone I decision point where promising candidates may be selected for further definition and development.

The design characteristics of the selected alternatives generally provide a functional baseline of the system. These baselines define design performance characteristics required to meet operational needs. The functional baseline serves as the basis for establishing initial design thresholds and objectives. The resulting design requirements support preparation of total system design cost estimates and schedule projections and identification of trade-off opportunities. The system objectives are also the foundation for the acquisition strategy and the test and evaluation strategy.

Program definition and risk reduction phase

Phase I is used to further define and refine the operational concept or concepts and those alternative design approaches determined by the Milestone I decision process to be the most promising. The functional baselines are further decomposed into their lower-tiered subsystems. The performance requirements of the system are then allocated down to the lower level functions. This allocated baseline is used in the supportability analyses to project operations and sustainment requirements to be satisfied in the design of the support system. Support alternatives (contractor-supplied, organic 2 level, organic 3 level, etc.) are evaluated against the operations and sustainment requirements. Support alternatives deemed not viable (those not meeting all support requirements and constraints) are discarded. Those remaining become the basis for development of initial support plans and information products (e.g., technical publications, supply support, etc.).

Phase activities often include the development of product prototypes and the conduct of demonstrations and early operational assessments. These activities help to reduce risk at the Milestone II decision. Cost drivers and life cycle cost estimates are kept current with the design to reflect a more detailed understanding of the total system design characteristics.

Engineering and manufacturing development phase

Phase II of the acquisition process is used to complete a stable design for a total system which meets the performance requirements and is producible, supportable, and affordable. Total system capabilities are demonstrated through testing to validate design assumptions, and deployment planning is initiated. Low rate initial production is begun during this phase to provide the minimum quantities required to support operational testing and other design validation activities and to establish an initial production base for the total system.

The allocated baseline of a total system is transitioned into a full product baseline during this phase. In other words, functional or allocated designs are updated to physical or product baselines representing the actual product hardware. Support system designs are updated as well to keep current with the latest design. The updated support information provides input to tradeoff and other program decisions that may be required. The updated information is also used to update or prepare logistic data products like spares lists, training packages, and technical publications required to implement the support system design.

Production, fielding/deployment, and operational support phase

Phase III includes all design activities needed to:

- Correct deficiencies identified during Phase II test and evaluation activities and low-rate initial production.
- Produce and deploy a total system.

Support activities respond to changes resulting from correction of noted deficiencies and other product baseline changes made to enhance producibility or otherwise improve the product. Additionally, they prepare for transition of the system to operations.

Phase III is used to achieve and sustain an operational capability that satisfies mission needs. The footprint, size, and weight of the system and its logistic support are major considerations for contingency planners. Deploying the total system is very important and needs to be emphasized. The lift requirements and the logistics tail must be kept to a minimum. Operational needs will change over time due to product hardware modifications and aging, the emergence of new threats, changes in the support system capabilities, the introduction of new technologies, and changing economic conditions. Plans are established to monitor the rate and consequence of change on the total system supportability.

4.3 SYSTEMS ENGINEERING

Systems engineering is an interdisciplinary approach to evolve and verify an integrated and life-cycle balanced set of product and processes solutions that satisfy stated customer needs. A total system design would include product hardware, software, and planned logistics resources. This structured, or process, approach integrates the essential elements and design decisions of three interrelated design efforts. The result is a balanced, total system solution to the operational need and other program objectives.

The systems engineering process is used within the Department of Defense to translate operational users' needs into requirements and requirements into designs which meet program performance, cost, and schedule requirements. Figure 4-3 provides an overview of the process.

The systems engineering process follows a logical top-down progression of design refinement. It employs an iterative process in which operational requirements are translated into performance requirements for the functional elements of a system. Design alternatives for each of the system's functional elements are identified and analyzed. The results are used to select the best combination of element designs to achieve the system objective. Performance requirements are refined based upon the selected alternatives, and the updated requirements are further decomposed to the next level of performance function. Once again alternatives are identified and analyzed, and the process is repeated.

The functional decomposition of requirements continues to the lowest logical breakdown of a performance function. At this point the top-down design becomes a bottom-up build. Synthesis of the physical design begins when hardware items are selected to provide identified functions and are arranged in a physical relationship with one another. During this stage of the design's development, analysis is used to verify adherence to each successively higher level of requirement. Estimates and projections are refined and verified through demonstrations and tests.

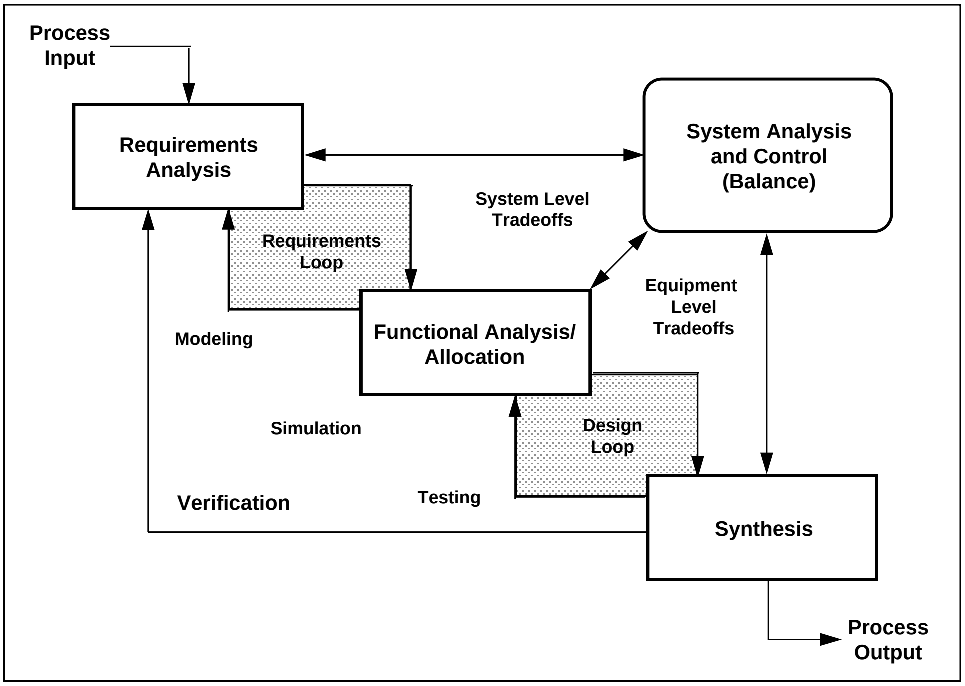


Figure 4-3. Systems Engineering Process Flow

System analysis and control activities in a program serve as a basis for evaluating alternatives, selecting the best solution, measuring progress, and documenting design decisions. These activities include:

- Trade-off studies among requirements, design alternatives, and other cost, schedule and performance related issues.
- Risk management that, throughout the design process, identifies and evaluates potential sources of technical risks based on the technology being used, the design, manufacturing, test and support processes being used, and risk mitigation efforts.
- Configuration management to control the system products, processes and related documentation. The configuration management effort includes identifying, documenting, and verifying the functional and physical characteristics of an item; recording the configuration of an item; and controlling changes to an item and its documentation. It provides a complete audit trail of decisions and design modifications.

- Data management to capture and control the technical baseline (configuration documentation, technical data, and technical manuals), provide data correlation and traceability, and serve as a ready reference for the systems engineering effort.
- The establishment of performance metrics to provide measures of how well the technical development and design are evolving relative to what was planned and relative to meeting system requirements in terms of performance, risk mitigation, producibility, cost, and schedule.
- The establishment of interface controls to ensure all internal and external interface requirement changes are properly recorded and communicated to all affected configuration items.
- Structured program review to demonstrate and confirm completion of required accomplishments and their exit criteria as defined in program planning.

Determining the best set of planned logistic resources for a system is the function of the acquisition logistics discipline of systems engineering. It is accomplished through analysis of those design characteristics which generate a need for, or are associated with, providing operational support to the total system. These design characteristics are developed by many different disciplines pursuing a wide range of systems engineering activities. Individually they may be viewed as either hardware, software, or support system design characteristics. Collectively they represent the "supportability" of a total system.

4.3.1 Supportability

Supportability is the degree to which system design characteristics and planned logistics resources meet system peacetime and wartime requirements. Supportability is the capability of a total system design to support operations and readiness needs throughout the system's service life at an affordable cost. It provides a means of assessing the suitability of a total system design for a set of operational needs within the intended operations and support environment (including cost constraints). Supportability characteristics include many performance measures of the individual elements of a total system. For example: Repair Cycle Time is a support system performance characteristic independent of the hardware system. Mean Time Between Failure and Mean Time to Repair are reliability and maintainability characteristics, respectively, of the system hardware, but their ability to impact operational support of the total system makes them also supportability characteristics.

Supportability characteristics of the total system interrelate the characteristics of the individual designs to provide a top-level assessment of the balance in a total system's design. Operational availability (A_o) and life cycle cost are generally accepted as measures of total system supportability. Other terms used to express similar assessments are equipment readiness and affordability.

Discussions regarding *open system* supportability approaches, methodologies, and recommendations address the unique aspects of an open system interface standard acquisition. When using open system interface standards, a best value approach should be pursued to balance cost, performance, schedule, operational readiness, and supportability. The use of open system interface standards promotes an environment in which interface conformant products from multiple original equipment manufacturers (OEMs) can be integrated to form functional systems. Supportability issues must be part of the criteria evaluated during the selection of the system architecture.

When a total system demonstrates its operational suitability and affordability, the total system element designs are generally considered complete, but most characteristics of a total system are subject to change over time. The rapid turnover in design and software technologies not only creates obsolescence through increased performance capabilities, but also reduces available sources of supply and invalidates repair concepts. So the systems engineering process is used to monitor and assess changes in total system requirements that may lead to new requirements or opportunities for improvement.

The systems engineering approach to design of total systems and their major elements (hardware, software, and support) allows good supportability to be effectively "designed-in." While poor supportability of a system element can be mitigated through the design of the remaining elements, it can only be improved by a change in design.

4.3.2 Major Supportability Criteria

Every acquisition program is different, and specific criteria and emphasis will vary from one program to another. However, three issues— cost, equipment readiness, and manpower and personnel constraints—should always be considered as part of the total system design process because of their ability to affect system supportability.

Cost

Cost constraints are an inescapable economic reality. Obtaining high quality, capable, and affordable systems which meet user needs is the goal of all defense acquisition programs. Evaluating the affordability of a product requires consideration of support investment and operations and support (O&S) costs, as well as other acquisition costs. Life cycle cost estimates compare the investment and recurring ownership costs for different system alternatives. The cost analysis methodology used should consider the support resources necessary to achieve specified levels of readiness (A_o) for a range of assumptions regarding system reliability and maintainability characteristics, usage rates, and operating scenarios. Because of the uncertainty in estimating resource costs like manpower and energy, sensitivity analyses should be performed. Sensitivity analyses help to identify and weight the various factors which drive life cycle costs. This knowledge is key to understanding and managing program risk.

All major elements of life cycle cost should be addressed as part of the system analysis and control activities. The objective is to minimize cost within major constraints such as readiness requirements. Ongoing assessments of life cycle costs during a product's acquisition and continuing through its service life provide important insight to effective life cycle management. These assessments are required not only because costs change over time, but also because what constitutes acceptable affordability is also subject to change. What is affordable under one set of economic conditions may be unaffordable under another. Therefore, it is important to investigate opportunities to reduce the cost of ownership throughout all phases of a system's life cycle.

Equipment readiness

Readiness is a measure of an organization's capability to perform assigned mission responsibilities when called upon to do so. A combination of A_o and mission frequencies (e.g., sortie rates), for both surge and sustained operations is a measure of equipment readiness. Equipment readiness predictions are a tool for assessing the operational suitability of a product before its introduction into service. Equipment readiness needs will vary from system to system, and from peacetime to wartime. As was true with manpower and personnel, equipment readiness should be addressed at the earliest stage of a new acquisition.

Manpower and personnel constraints

Reductions in manpower and the increasing complexity of defense systems offer a significant challenge in acquiring affordable defense systems. Early consideration of manpower and personnel requirements is very important. Manpower and personnel constraints (quantities, skills, and skill levels) are major cost drivers of every total system and are as important as any other design consideration. Because of their potential impact on product performance, readiness, and cost, all manpower and personnel requirements for new systems should be identified and evaluated early and alternatives considered. For example, use of commercial support for a low-density, highly complex product could eliminate most of the training costs associated with maintaining a qualified cadre of personnel in an environment with frequent personnel changes.

Estimates of manpower and personnel requirements for new systems are reported at each milestone decision point in the defense systems acquisition process. These requirements provide important input to force structure plans, forecasts, and cost estimates, and help to formulate more cost effective alternatives.

4.3.3 Systems Engineering Application

The level of systems engineering activity needed for a total system depends upon the current stage of design development of its hardware, software, and support. The more design development there is to do, the more systems engineering analysis will have to be performed. As the state of the design evolves, the types and depth of the analyses will also change as program objectives are refined.

The general discussion of systems engineering provided here addresses the full design development cycle. But for most defense systems requirements, there are real opportunities to reduce time, costs, and risk associated with any new design activity. These opportunities lie in making the greatest use of available designs for product hardware, for software, and for logistic support resources and services.

The level of design development required diminishes with the increased use of existing designs in a total system. Certainly the need for many of the supportability-related analyses is reduced in scope and depth, or altogether eliminated once a design alternative is selected. This reduction demonstrates proper tailoring of the systems engineering process based on the changing needs of the program. However, use of the systems engineering process approach is equally crucial for modifications or commercial and nondevelopmental item acquisitions—perhaps even more so. In development programs there is usually time to correct mistakes or deficiencies, but existing design characteristics are relatively fixed (significant change may be costly or impossible). So selecting an existing design alternative for the total system is important. Deficiencies in a selected design have to be compensated for through other design elements of the total system, which diminishes the total system overall. Only an integrated systems engineering approach fosters the essential interactions between the related design activities so that imbalances are identified and addressed.

Determining the optimal approach for a total system's design is a program management decision. All of a program's technical activities, of which the system engineering activities are a part, are intended to support and facilitate sound program management decisions. These decisions determine the next set of activities, which in turn lead to the next set in a constantly evolving set of issues, analysis requirements, and decisions. The acquisition strategy, which is developed in consonance with the policies and procedures of the defense systems acquisition process, serves as a plan for the management and execution of an acquisition program. Figure 4-4 identifies systems engineering principles.

SYSTEMS ENGINEERING PRINCIPLES

- **Know the problem, the customer, and the consumer**. Become the customer/consumer advocate/surrogate throughout development and in fielding the solution; state the problem in independent terms.
- **Use effectiveness criteria based on needs to make decisions.** Select criteria that are measurable (objective and quantifiable).
- **Establish and manage requirements.** Ensure the customer and consumer understand and accept the requirements.
- **Identify and assess alternatives so as to converge on a solution.** Use a systematic architecture/design method.
- **Verify and validate requirements and solution performance.** Quality must be designed in; know the expected results before testing.
- **Maintain the integrity of the system.** Maintain a systems engineering presence throughout the program.
- **Use an articulated and documented process.** Use readily available automated tools wherever appropriate.

Figure 4-4. Systems Engineering Principles

4.4 ADDITIONAL INFORMATION

Department of Defense Regulation, 5000.2-R, *Mandatory Procedures for Major Defense Acquisition Programs (MDAPS) and Major Automated Information System (MAIS) Acquisition Programs*

DoD Directive 5000.1, *Defense Acquisition*

SD-2, *Buying Commercial & Nondevelopmental Items: A Handbook*

SD-5, *Market Analysis for Nondevelopmental Items*