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THESIS

AN INTEGRATED LOGISTIC SUPPORT MODEL FOR
MAJOR WEAPON SYSTEMS OF THE
PAKISTAN NAVY

by

Shahid Latif

June 1987

Thesis Advisor:

Alan W. McMasters

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19 ABSTRACT (Continue on reverse if necessary and identify by block number) Previous acquisitions of major weapon systems by the Pakistan Navy have lacked adequate logistic support planning. During most weapon system acquisitions, emphasis has traditionally been placed on getting the hardware in place with the least possible cost. Other elements affecting operational use, and specifically, sustained readiness, have clearly been secondary. Accordingly, after systems have been introduced into the navy, additional costly expenditures have been necessary to operate and maintain these systems effectively. As a solution to this problem, this thesis offers a simplified version of the Integrated Logistic Support (ILS) used by the United States Navy and other components of the U. S. Department of Defense for the life cycle support management of weapon systems from					
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19. ABSTRACT (continued)

"womb-to-tomb". By following the road map provided in this thesis, the Pakistan Navy should be in a better position to develop a streamlined life cycle support management plan for weapon systems during future acquisitions.

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I. INTRODUCTION

A. GENERAL

How to obtain effective support of a weapon system during its operating cycle has long been a topic of heated debate between operator and logistician. In particular, logistical support of weapon systems in the Pakistan Navy has remained problematic in the past. The need exists to improve the present concepts and methodologies used by the Pakistan Navy for the logistical supportability of major weapon systems of the fleet. Unfortunately, like most Navies of the third world nations, the Pakistan Navy is supported by an anemic national economy. Financial constraints plague all facets of national growth. Per force, the Pakistan Navy has to be cautious in spending the available budget and must adopt cost cutting approaches in the pursuit of operational readiness objectives without making undue compromises. However, it is a fact of life that a significant portion of the defense budget goes to support systems and equipment in operation.

The support requirements for spare parts, maintenance, training, facilities, and the like are determined to a large measure by the design of the equipment. Attention to designing with the objectives of driving support costs down can result in significant long range reduction in the life cycle costs of systems. These early costs associated with deliberately designing for support in future are off-set in subsequent years by reduced lower system/equipment operation and maintenance costs.

B. IMPORTANCE OF LOGISTIC SUPPORT

Rapid advancement during the last two decades in weapon technology has led to increasingly complex and sophisticated hardware systems. With the advance in technology, logistics requirements have increased in general. In addition, maintenance-support requirements have also become more complex. It is no longer possible to meet maintenance and support goals on an "as required" basis with the current state-of-the-art hardware.

During the last decade costs associated with system/product acquisition and logistic support have increased at an alarming rate. At the same time, decreasing government budgets combined with inflationary trends have resulted in less money available for procurement of new systems and for the maintenance and support of

those items already in use. This requirement to increase overall productivity in a resource constrained environment has forced attention to all aspects of system life cycle. Total system cost must be given more attention, particularly those costs associated with system operation and support, since these costs constitute a large portion of the life cycle cost. The severity of the lack of cost visibility problem can be related to the "iceberg effect" illustrated in Figure 1.1 [Ref. 1].

Experience has shown that logistic support is a significant contributor to life cycle cost. Further, the decisions made during early stages of system planning and conceptual design have a serious impact on the projected life cycle cost for a given system. It is therefore essential that logistic support be considered, as part of the decision making process, in the early phases of weapon system planning and design.

The fact that maintenance and support technology had not kept pace with the advancement of hardware development, had long been accepted by the military. Recognizing the increasing need for more effective maintenance and support techniques, the United States Department of Defense, in 1964, directed that the basic elements of Integrated Logistic Support (ILS) be included in planning for the acquisition of defense systems and major items of equipment [Ref. 2]. A more recent definition [Ref. 3] of ILS is given below.

A disciplined, unified, and iterative approach to the management and technical activities necessary to: (a) integrate support considerations into system and equipment design; (b) develop support requirements that are related consistently to readiness objectives, to design, and to each other; (c) acquire the required support; and (d) provide the required support during the operational phase at minimum cost.

C. PURPOSE AND SCOPE

The Pakistan Navy has applied parts of ILS in various forms and uncoordinated pieces during past acquisitions of major weapon systems. This was largely due to the resource constraints faced and partly due to lack of proper guidance concerning ILS and its impact in the long run. A case in point was the acquisition of Atlantic Breguet Long Range Maritime Reconnaissance aircraft, which clearly suffered from inadequate support planning. Due to lack of proper facilities and trained personnel, the aircraft had to be flown to France a number of times for maintenance at exorbitant costs.

This thesis is basically a curtain raiser on the subject and attempts to lift the fog around ILS by highlighting its concept and impact on life cycle support of weapon

systems. It provides an overview of the elements of ILS for the acquisition of a major weapon system and presents suggestions for the development of guidance and major directives by the Pakistan Navy in implementing ILS. The presentation has been kept sufficiently simple from a functional point of view to enable easy comprehension by those who read it and to facilitate any future implementation. In keeping with this aim, all efforts have been made to avoid as far as possible, the Acquisition Strategy and Project Management procedures and principles which are typical to the United States Navy or other components of the United States Department of Defense, but which do not directly apply to the Pakistan Navy.

D. PREVIEW

In Chapter II the author traces the development of the Integrated Logistic Support system as it evolved from a U.S. DoD initiative, and focuses on the application of the ILS concept in the acquisition of weapon systems. Also highlighted in this chapter are the management responsibilities of the different key players involved in ILS planning and implementation.

Chapter III pinpoints the short falls in the life cycle planning concepts presently utilized by the Pakistan Navy. Additionally, it describes the weapons procurement process in Pakistan, and the most common avenues of procurement which are available to countries lacking local production, in meeting military hardware requirements. This chapter also highlights the likely impediments which might be faced by the Pakistan Navy in implementing the ILS philosophy in future procurement or acquisition of weapon systems, and presents ways and means to overcome those problems.

Chapter IV presents a summary of the thesis and also the conclusions and recommendations for implementing ILS during future acquisition of major weapon systems by the Pakistan Navy.

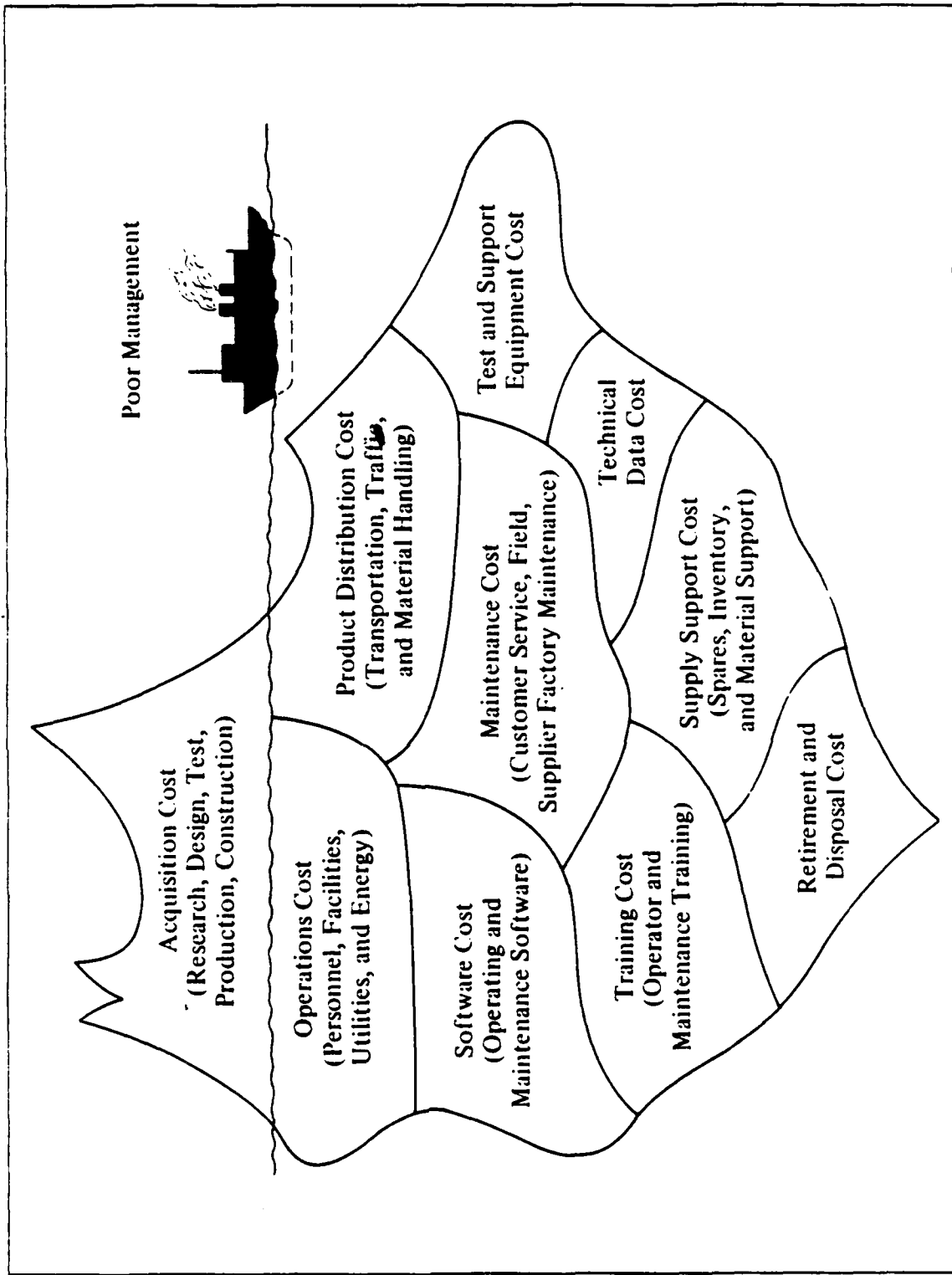


Figure 1.1 Total Cost Visibility.

II. DEVELOPMENT OF ILS SYSTEM IN WEAPONS ACQUISITION

A. NEED

In the early sixties, it was generally realized by the U.S. military and congressional leaders that military readiness, being fundamental to national security, required emphasis on the rapid and responsive support of deployed forces, as well as the careful management of national resources. They also realized that the most economical and cost effective way to maintain weapon systems and equipments at a high state of readiness could best be achieved by "integrating" the logistic support for military systems and equipment. The term Integrated Logistics Support (ILS); was coined by the Department of Defense in DoD Directive 4100.35.

In those times, it was generally felt that weapon reliability had not increased parallel with the technological sophistication of the modern weapon systems. In fact, some of the newer weapon systems were found to be less reliable than older, simpler weapon systems. This phenomenon caused many senior military personnel to say they would be willing to sacrifice some of the performance of the new and sophisticated weapon system for the reliability and maintainability features of the old. Admiral H. P. Smith USN, when Commander-in-Chief of the US Atlantic Fleet, vividly summed up the challenge facing the Department of Defense [Ref. 4] when he wrote:

My ships are burdened with so called sophisticated equipment which have wonderful press clippings concerning their performance. Unfortunately, they won't work when we need them. Those complex systems are generally unreliable and very difficult to maintain. When they work their performance is usually quite good. However, I would gladly sacrifice some performance for the sake of reliability and maintainability. My ships need systems that work when they are needed to work. They don't need any more junk installed in them.

In 1968, Thomas D. Morris, Assistant Secretary of Defense for Installations and Logistics, while emphasizing on the need for fundings for logistic support, stated [Ref. 5]:

Integrated Logistic Support is one of the most complex, and possibly least understood, fields in the management of the acquisition of systems and equipments of the Department of Defense I have heard a major complaint that money for logistic support is the first to be deferred, reduced, or cut and the last to be funded. This obviously is penny wise and pound foolish. I will go so far

as to say that the military service or company that defers that portion of the funding required to support a logistic support program, has inadequately funded the program. We should seriously reconsider such programs.

B. BACKGROUND OF ILS POLICY & GUIDANCE

The Department of Defense issued the first DoD Directive, designated as DoDD 4100.35, Development of ILS for Systems and Equipments, in 1964. It was a major milestone in the evolution of DoD systems management because it formally set forth logistics support as a design consideration that needed to be managed from the conception of a program. DoD also published a ILS Planning Guide [Ref. 6], to help Program Managers establish logistic support objectives in their plans for fielding a new system. The Guide provided a road map of typical logistic actions to be accomplished during the life of a system of equipment. The individual military services then issued local directives to ensure and streamline implementation of Integrated Logistic Support in their peculiar styles and setting.

The original directive on ILS has been revised and reissued a number of times. Other specifications and directive documents have also been developed to enhance the concept of logistic support as a part of system or equipment design. Organizational changes have also been affected to bring the logistician closer to the design process of a new system, hopefully to impact on design decisions that affect supportability. However, the primary objective of the ILS program remains the same; that is, achieving a system readiness objective within an affordable life-cycle cost.

C. LIFE CYCLE PHASES

Implementation of the ILS concept necessitates weaving the threads of the principal ILS elements into the fabric that is the acquisition and support life cycle. There are four distinct phases in the acquisition of a new system. Normally these are concept exploration, demonstration and validation, full-scale development, and production and deployment [Ref. 7]. These phases are separated by decision milestones as shown in Figure 2.1 which is a reproduction from [Ref. 8]. The planning of logistic support requirements begin at the conceptual phase of the acquisition life cycle. The logistic support program is to be formalized by the beginning of the full-scale development phase with appropriate performance milestones delineated throughout development, production and deployment.

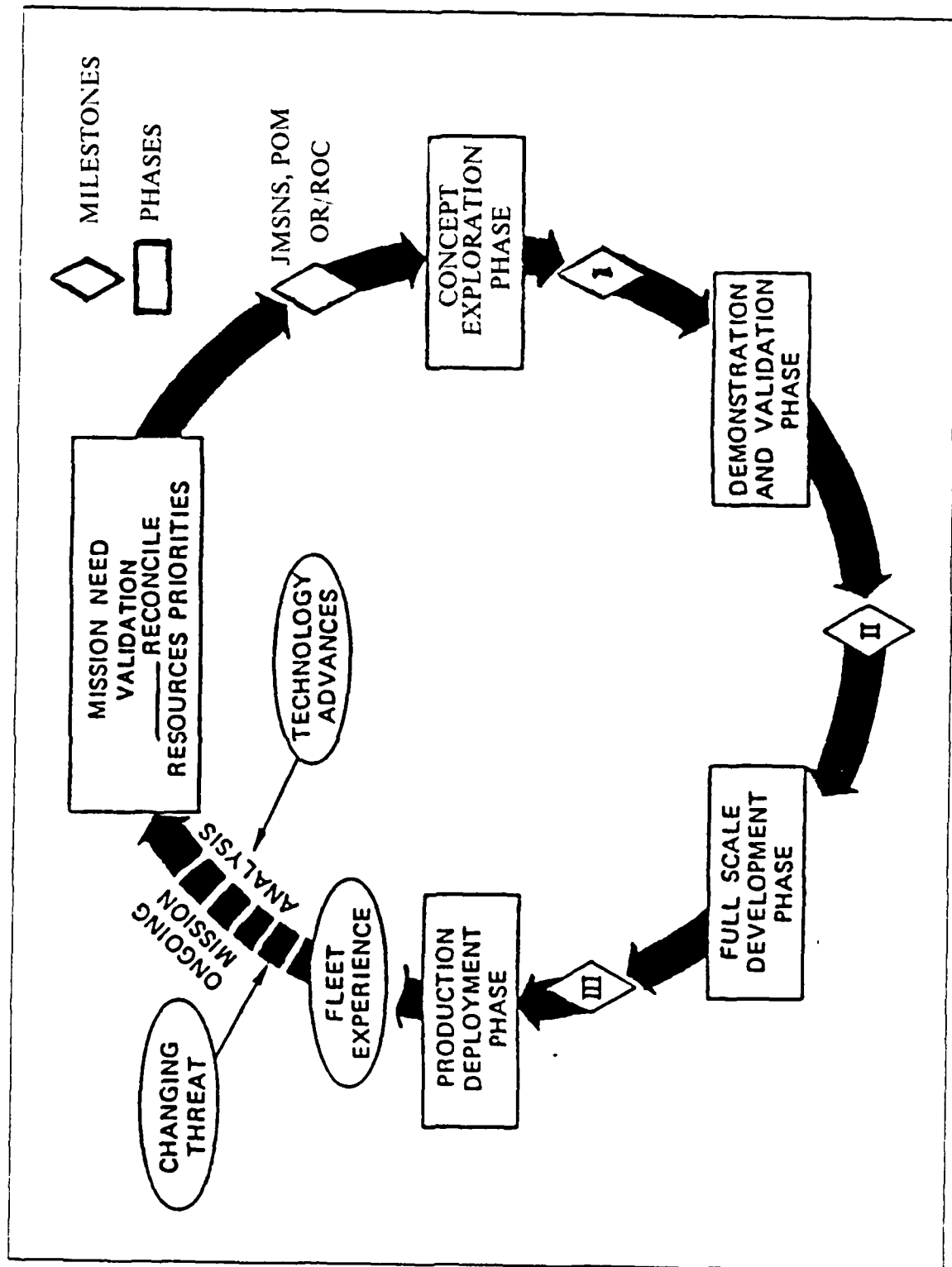


Figure 2.1 Acquisition Phases.

1. Concept Exploration

This is the first phase in the acquisition life cycle. During this phase the technical, military and economic needs for an acquisition program are established through comprehensive system studies and experimental hardware development and evaluation. It is a highly iterative phase, with stages overlapping rather than occurring sequentially. Generally, the following stages occur in this phase.

- Identification and definition of conceptual systems.
- Analysis of threat, mission, feasibility, risk and costs involved in development.
- Evaluation of alternative concepts on the basis of estimated life cycle cost, development schedule and performance.
- Recommendation of one or more concepts for further development.

A broad ILS plan is needed at this phase, and special logistics problems are noted.

Defining some pertinent terms used during the acquisition process is considered appropriate at this stage. These are:

a. Life-Cycle Cost (LCC)

LCC involves all costs associated with the system life cycle, to include the following [Ref. 1]:

- Research and development (R&D) cost - the cost of feasibility studies; system analyses; detail design and development, fabrication, assembly, and test of engineering models; initial system test and evaluation; and associated documentation.
- Production and construction cost - the cost of fabrication, assembly, and test of operational systems (production models); operation and maintenance of the production capability; and associated initial logistic support requirements (e.g., test and support equipment development, spare/repair parts provisioning, technical data development, training, entry of items into the inventory, facility construction, etc.)
- Operation and maintenance cost - the cost of sustaining operation, personnel and maintenance support, spare/repair parts and inventory, test and support equipment maintenance, transportation and handling, facilities, modification and technical data changes, and so on.
- System retirement and phaseout cost - the cost of phasing the system out of the inventory due to obsolescence or wearout, and subsequent equipment item recycling and reclamation as appropriate.

Figure 2.2 illustrates a typical life cycle cost profile of a weapon system. Figures 2.3 and 2.4, both reproduced from [Ref. 1], represent system cost profile

showing yearly separate cost factors and separate cost profiles for individual cost factors respectively.

Life cycle cost must be considered on an equal footing with performance, time and logistic supportability goals. Experience has shown that a major portion of the actual life cycle costs for a given system stems from the consequences of decisions made during the early phases of program planning and system conceptual design. Historically, decisions made during the concept exploration phase (especially which concept and what thresholds are selected) have fixed approximately 70% of the life cycle cost of the system. Roughly 85% of the LCC have been frozen before the full-scale development phase begins, when only a small percentage of the total system cost has been expended. This fact is graphically illustrated in Figure 2.5. Thus, a life cycle approach, if incorporated in concept exploration, can be more economical in the long run. [Ref. 8].

b. System Engineering

It is easy to put a system together but difficult to put the "best" system together. System engineering is the discipline that ties together all aspects of a program to assure that the individual parts, assemblies, subsystems, support equipment and associated operational equipment will effectively function as intended in the operational environment.

A useful definition is given in [Ref. 9].

System engineering is the application of scientific and engineering efforts to (a) transform an operational need into a description of system performance parameters and a system configuration through the use of an iterative process of definition, synthesis, analysis, design, test and evaluation; (b) integrate related technical parameters and assure compatibility of all physical, functional and program interfaces in a manner which optimizes the total system definition and design; (c) integrate reliability, maintainability, safety, survivability, human and other factors into the total engineering effort.

c. Maintenance Concept

The maintenance concept defines what will be repaired and at what maintenance levels (i.e., organizational, intermediate, and depot), the major functions to be accomplished at each level of maintenance, basic support policies and primary logistic support requirements. A support policy specifies the anticipated extent to which repair of an equipment will be accomplished (if at all). It may dictate that an item should be designed to be nonrepairable, partially repairable, or fully repairable. It

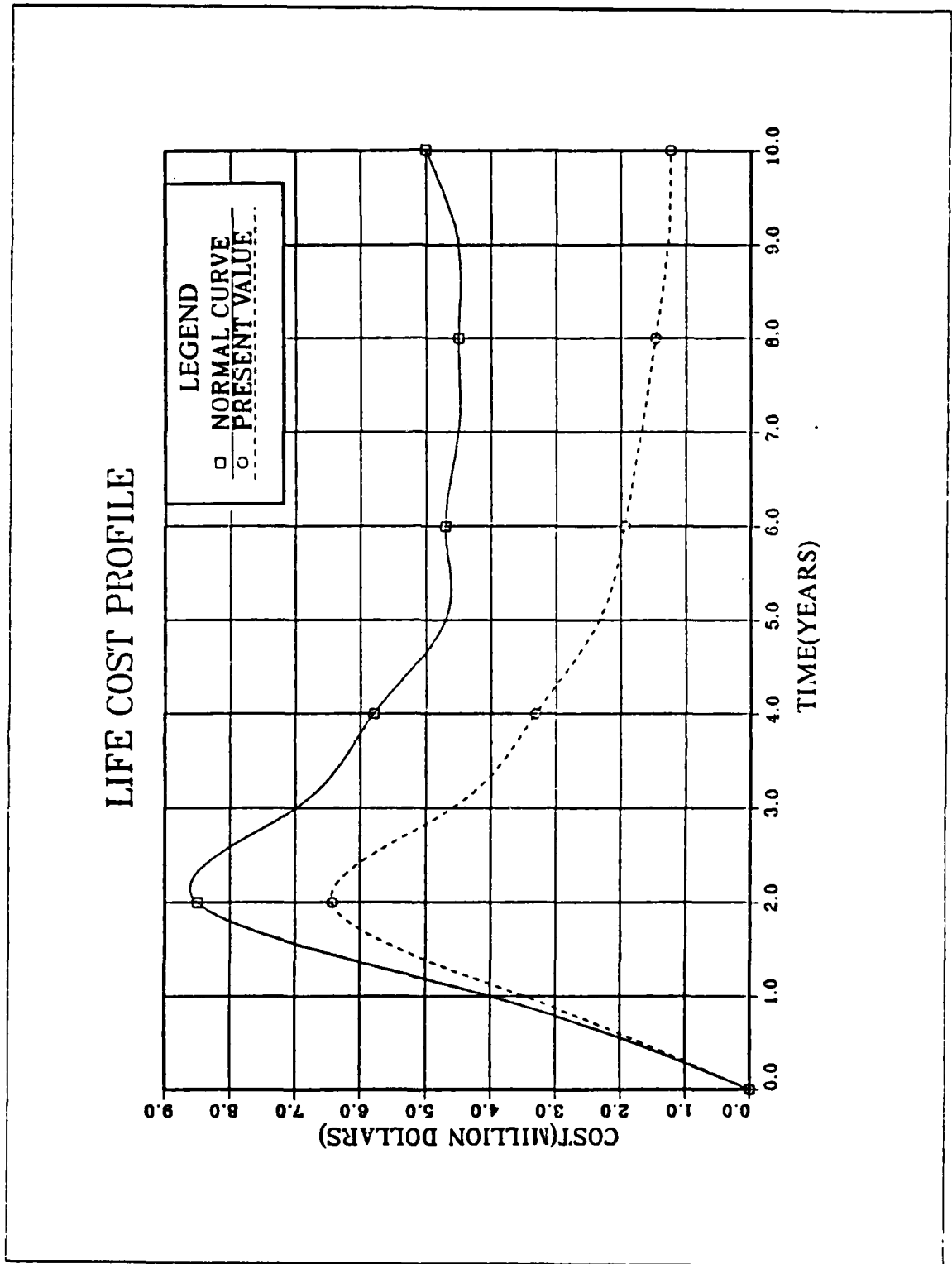


Figure 2.2 A Typical System Life Cycle Cost Profile.

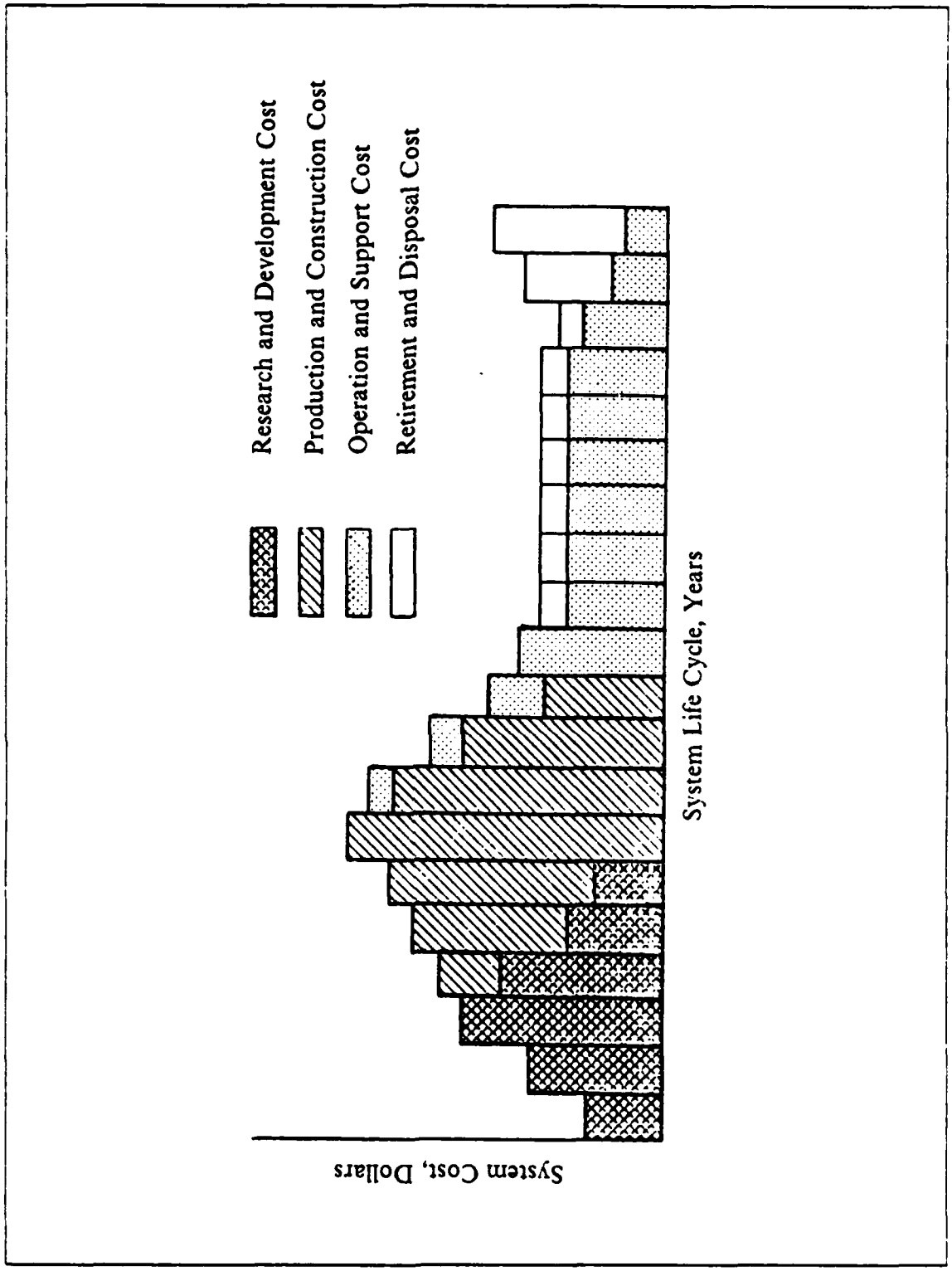


Figure 2.3 System Cost Profile-showing separate cost factors.

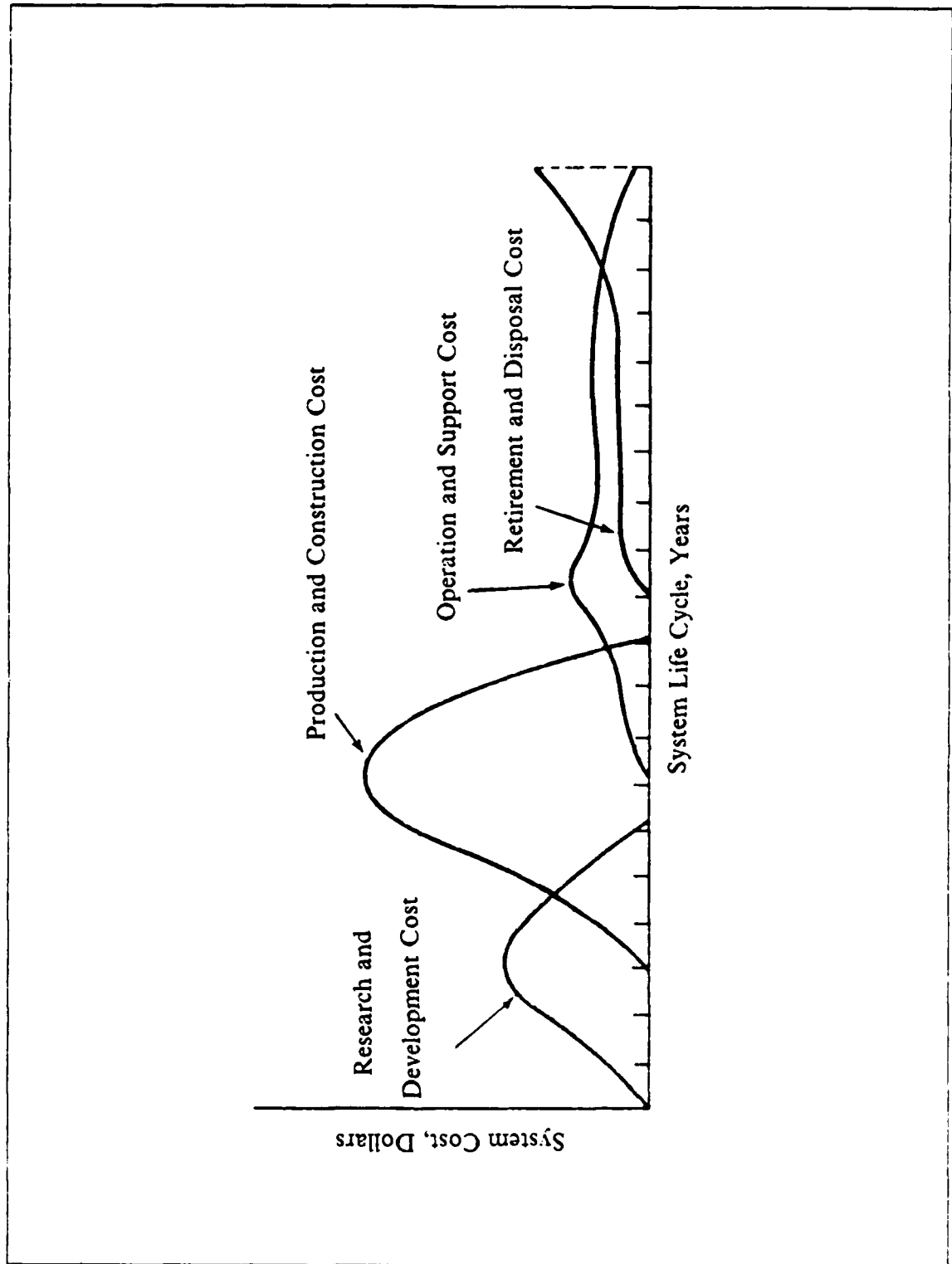


Figure 2.4 Individual Cost Factors in a System Life Cycle.

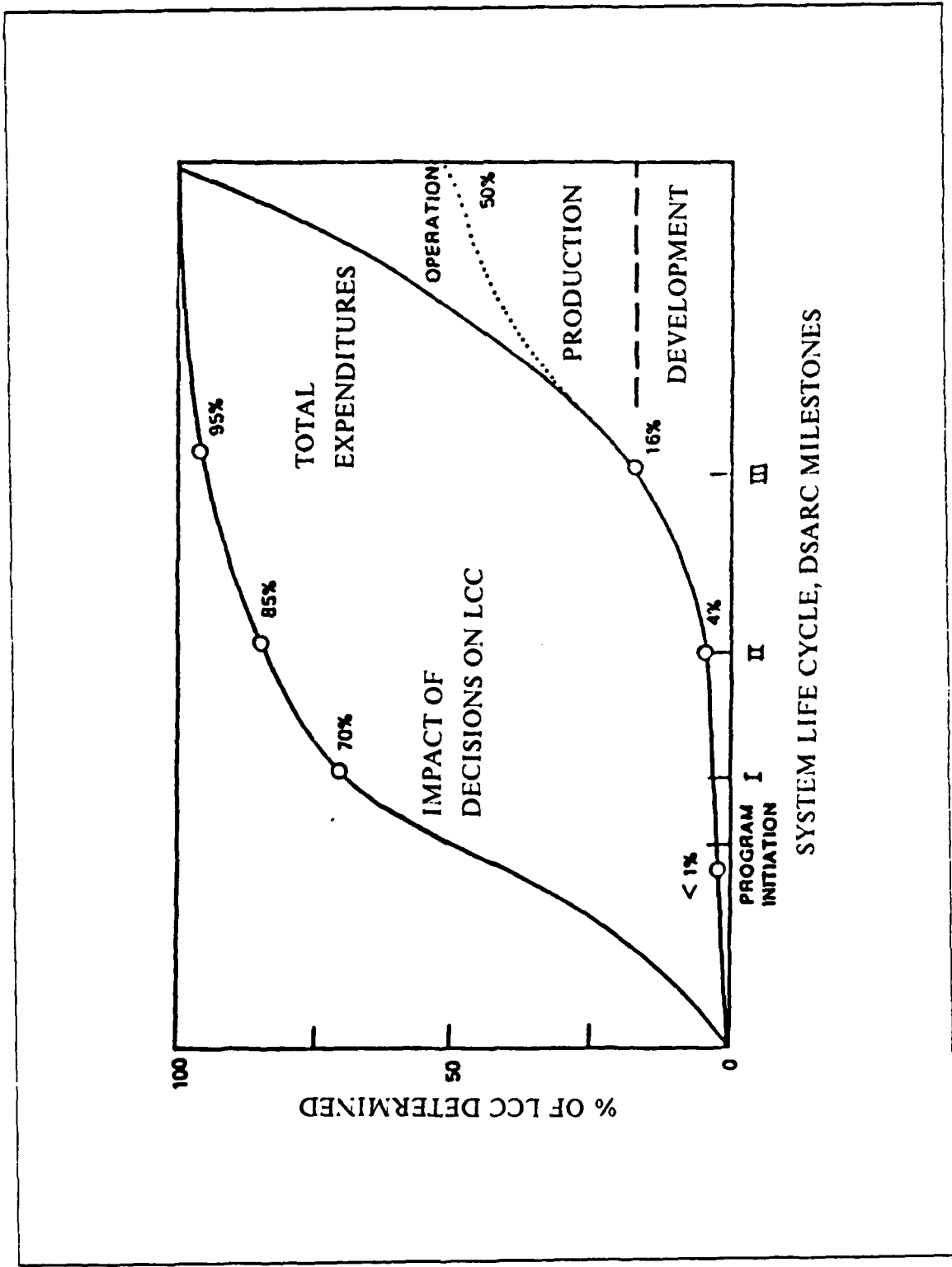


Figure 2.5 Typical Weapon System Life Cycle Cost.

may also specify what test equipment and repair parts are needed. Logistic support requirements relates to the organizational responsibilities for maintenance in accordance with the support policy. For instance, if the support policy dictates that no external test and support equipment is allowed at the operational site, then the prime equipment design must incorporate some provision for built-in self test. The maintenance concept is defined at program inception and is a prerequisite to system design and development.

d. Reliability, Maintainability and Availability (RM&A)

- Reliability - can be defined simply as the probability that a system or a product will perform in a satisfactory manner for a given period of time when used under specified operating conditions. Numerous ways can be found for specifying reliability; however, they all boil down to quantifying the degree of dependability of a given item. Reliability is a design attribute. It either is or is not designed into the equipment and cannot be improved per se either by testing or by actions of logisticians or support personnel.
- Maintainability - is defined as the ability of an item to be retained in or restored to a specific condition when maintenance is performed by personnel having specified skill levels, using prescribed procedures and resources, at each prescribed level of maintenance and repair. Maintainability can be described by many measures, the most common being mean-time-to-repair (MTTR) and mean maintenance man-hours per operating hour.
- Operational Availability - is defined as a probability that a system or component is in an operable state at the start of a mission when called for at an unknown (random) time. Availability is a function of reliability, maintainability, and fleet support and is usually given as a design goal.

2. Demonstration and Validation

The second phase in the acquisition of a new system is called "Demonstration and Validation". During this phase major program characteristics are validated and refined through extensive study and analysis, hardware development or prototype testing. Emphasis is given more to hardware development and evaluation than to paper studies in order to obtain a better definition of program characteristics and greater confidence in risk resolution and ultimate outcome. It include commitments that contractors are willing to make on major program characteristics. The quantity of prototype/hardware validation depends on the nature of the program, the risks and trade-offs involved, and the suitability of the system definition products. The skeleton ILS Plan is completed by the completion of this phase.

3. Full Scale Development

In this phase, the weapon system, including all the items necessary for its support, is designed, fabricated and tested. The intended outputs are hardware models and the technical documentation required for initial provisioning of spare parts and inventory. Test and evaluation are carried by the contractors and the service concerned. Technical and engineering problems which need to be solved are uncovered during this phase. These problems are continually addressed in view of possible trade-off with stated operational requirements, costs and operational readiness dates. Early during this phase, a detailed ILS Plan is prepared which includes appropriate milestones for achievement of all support objectives.

4. Production and Deployment

During this phase, efforts are directed towards providing and maintaining the desired operational capability and inventory. Production of hardware, system deployment and establishment of support operations should commence as per plans. The ILS Plan is implemented as production starts. A systems oriented logistics support organization should be functioning by this time to meet the requirements of the operational mission.

D. MANAGEMENT RESPONSIBILITY FOR ILS PLANNING

In the United States Navy, the Commanders of the Naval Hardware Systems Commands are responsible for establishing specific policy and procedures for the uniform application and execution of ILS planning by their functional and Project Management Organizations [Ref. 10]. Briefly, the specific responsibilities are:

- Designation of a single Headquarters level organization for ILS policy, and assigning it with the responsibility to establish, maintain, and monitor a system that assures timely and adequate ILS planning; implementation of ILS plans; acquisition of required logistic support resources.
- Designation of an acquisition manager for each system and equipment for which the headquarter and field activities are responsible.
- Designation of an ILS manager for each system and equipment for which their headquarter and field activities are responsible.
- Ensure that sufficient funds are budgeted and made available for ILS feasibility studies, trade-offs and planning.
- Ensure that responsible activities initiate timely and appropriate procurement and funding actions.

1. Project Manager

As regards implementation of the ILS policy, the project managers are required to establish a visible and viable ILS organization. They are to utilize the planning documents to adopt an early and effective approach for achieving ILS for their projects. A project manager is also required to produce an ILS plan and identify the logistic element managers for each ILS element. [Ref. 11]. Generally, important actions required of all project managers are:

- Commence ILS planning concurrently with hardware planning.
- Ensure that appropriate planning documents contain ILS requirements appropriate to the phase of the acquisition.
- Develop and maintain an ILS plan.
- Ensure that all required parties, including representatives of various commands and organizations, and others as appropriate, participate in the planning process.
- Ensure that necessary coordination exists between and with each organization which provide a logistic element manager and logistic resources, as regards functions and responsibilities.

2. ILS Manager

He is responsible for developing quantitative and qualitative support system requirements for inclusion in appropriate project management and contractual documents and ensuring that these requirements are addressed as an integral part of the design process. An ILS manager is to:

- Assess the logistic development data for system to be acquired in order to determine the extent of the required logistic support and develop a plan which adequately provides this support.
- Specify the quantitative and qualitative requirements which must be met to achieve the system support capability.
- Organize and chair the ILS management team.
- Act as the agent for the Project manager in all logistic matters.

3. Logistic Element Manager

The logistic element manager is appointed by the respective Naval Hardware Systems Commands, and is basically responsible for ensuring that adequate planning for and availability of his ILS element (e. g., supply support, technical data, facilities, personnel and training) is accomplished in accordance with milestones reflected in the ILS plan. Additionally, he is to maintain close coordination with the ILS manager and all other element managers and provide appropriate quantitative and qualitative inputs to the ILS manager. For example, he provides information on planned and actual:

- Repair turnaround time;
- Mean time to repair;
- Automated versus manual fault isolation;
- Maintenance data display techniques;
- Supply response time;
- Manpower personnel and training projections.
- Facilities construction lead time.

E. SYSTEM FOR PLANNING AND ACQUIRING ILS

The objective of early logistic support planning and analyses is the establishment of end item design and configuration characteristics which provides the needed logistic support resources at least cost. Advance planning must also provide a systematic method to determine these resources. This planning is an iterative process required to convert early goals into specific requirements, which are ultimately translated into demands for available support resources. The result is the Integrated Logistics Support Plan.

1. The Integrated Logistic Support Plan (ILSP)

As program activities evolve during the preliminary design phase, the logistics planning function continues on a formal basis with the development of an integrated logistic support plan (ILSP). This plan, representing a significant expansion of the preliminary logistic support plan, covers all subsequent logistics activities throughout the system life cycle. An ILSP covers all Government and supporting contractor actions, for each weapon system or equipment acquisition. Although variations may occur, the ILSP usually includes a series of individual plans covering the different elements of logistic support. It is the duty of the ILS manager that all concerned parties, including representatives of the service and others as appropriate, participate in the planning process and in the development of the plan.

The ILSP is based on the information contained in the basic planning documents, is initiated at the outset of a program by the ILS manager, and is maintained through the Production/Deployment phase. The function of the ILSP is to identify what integrated logistic support tasks will be accomplished, who will be responsible for their accomplishment, and how and when will they be accomplished. It contains details which form the basis for specific actions by navy activities and for developing the ILS requirements to be included in the contractual documents. One purpose of the plan is to provide a management tool to assure the timely

accomplishment of all assigned tasks by the organizations responsible. It also provides the foundation for coordinated action on the part of the Logistic Element Managers and the contractor, and documents the manner in which each of the applicable elements of logistic support is to be obtained, integrated with other elements, and sustained throughout the life cycle. Included are milestones, delivery points, names and specific responsibilities for persons accountable for each element, basic guidance on the logistic system desired, relationships and inter-dependencies among the personnel, and the monitoring or communications system to pass information among participants.

The ILSP initially begins as an outline at program initiation and must be fully developed by the beginning of the full scale development phase. It is completed during the production/deployment phase after undergoing evolutionary changes to keep it current, and in balance with the rest of the program. It is a dynamic, detailed management document delineating the acquisition manager's plan for ensuring timely, adequate, cost effective logistic support of the weapon system.

While the format and length of the ILSP may vary with the program, following items are normally considered [Ref. 10]:

- Identification of each organization assisting the ILS manager in the overall planning for logistic resources, including names of assigned representatives and their responsibilities. The accomplishment of the planning and acquisition of each element of ILS are specifically assigned along with milestones for accomplishment.
- The methods of communication among the participants in the ILS planning process, to ensure that all parties are kept fully informed of the current status of all other elements. Coordination is crucial to the successful achievement of ILS planning. Identification of the specific documents by which decisions relative to ILS are recorded and communicated, are also included.
- A listing of the logistic support elements along with the scope and planning for each, at the various stages in the evolution of the system or equipment from program initiation through the production/deployment phase.
- A specific approach for performing trade-offs between logistic support elements and between logistic support and design. Examples of such alternatives are repair versus throwaway versus replacement, centralized versus de-centralized maintenance, preventive versus corrective maintenance, and larger repair parts inventory with slow, low cost transportation versus smaller repair parts inventory with rapid higher cost transportation.
- The extent to which Level of Repair Analysis (LORA) will be applied.

- Programming, budgeting, and funding for both the planning for ILS and subsequent acquisition of support resources. Explicit in this requirement is the calculation of the predicted annual and life cycle support costs.
- Motivation, indoctrination and training of personnel participating in the acquisition.
- A specific requirement for and a description of the scope of the logistic support analysis (LSA) to be accomplished. This requirement includes the techniques for conducting design reviews and analyses used to determine the best approach for maintenance and operational support. [Ref. 12].
- The merging of maintainability, reliability and human factors requirements into the ILS planning process.
- Identification of an appropriate management control and appraisal system for evaluation of logistic support milestone.
- Achievement of the pre-planned service support date for the system. The need for contractor support and the service furnished supply support will be considered. Detailed requirements for a smooth transition from contractor support to service support or other logistic support responsibilities are to be included as applicable.
- The scope and timing of the logistic support subsystem program, which includes the planning for incorporation of ILS validation requirements into appropriate places in the test and evaluation program.

F. SUMMARY

This chapter reviewed the development of the ILS concept in weapons acquisition as evolved in the United States of America. The need for integrating support resources for better life-cycle management of equipments led the DoD to issue policy and guidelines for implementation of ILS. The "Integrated Logistic Support Planning Guide", issued in 1968, was the first major publication on the subject. It was tailored to provide a modus operandi for translation of ILS concepts into hardware oriented design goals and management realities. It also described the vital support elements which formed an integral part of the ILS philosophy. An overview of the important considerations in the various ILS elements is provided in Appendix A.

Apart from providing definitions of certain key terms, this chapter also described the management responsibilities in the application of the ILS concept.

In the next chapter the author reviews the present policy adopted by the Pakistan Navy towards weapons acquisition and life cycle support management of major equipments. The distinct advantages of long term support planning which is assured by incorporating an ILS program in weapons acquisition and operation viz-a-viz the

inherent drawbacks of resorting to ad hoc support are also addressed. Lastly, the author describes the existing infrastructure and facilities available with the Pakistan Navy which can support and sustain any ILS effort in future.

III. ILS IMPLEMENTATION BY THE PAKISTAN NAVY

A. INTRODUCTION

Presently Pakistan does not have the capacity to satisfy all her military needs through indigenous production due to a lack of domestic resources. More relevant is the peculiar fact that the Pakistan heavy industry has never launched a prototype development of major weapon system for the defense forces. Consequently, in order to meet her military needs, Pakistan has resorted to procurement of military hardware from friendly countries. In this scenario, the choice is between systems which have already been produced, or are in an advanced stage of development or production.

In selecting a system for procurement from abroad, the major issue is deciding from among the number of systems available for sale by friendly countries. Usually the procurement decision is based upon procurement costs. The Pakistan Navy has, hitherto, acquired ships, submarines and aircrafts from various friendly countries, namely, United States of America, United Kingdom, France, and Peoples Republic of China. Most of these systems, except the submarines and helicopters, are refurbished versions and required varying level of support from the countries of origin. This support mainly consist of a continuous supply of spare parts.

The most important element of support which affects availability of the system after it is introduced in the fleet/field, is the provisioning of spares and repair parts and the subsequent replenishment. These are made available through a procurement pipeline established with the supplier country. It is logical to assume that the country that has incorporated an ILS program in the development and production of the system which is offered for sale is in a far better position to meet the follow-on-support problems of the customer country. Fortunately for the Pakistan Navy, the Government of Pakistan has lately authorized and approved plans for the purchase of three Type 23 Frigates from the United Kingdom. These ships will be built in Britain and present the Pakistan Navy with a unique opportunity of applying the concept of Integrated Logistic Support from the laying of the keel.

B. WEAPONS PROCUREMENT PROCESS

The weapon system procurement process in Pakistan is similar to the acquisition process followed in the United States. Requirement for a better system is put up by the

operational area commanders as an outgrowth of a new need, based upon changed goals or mission, or as a result of deficiency in existing systems' capabilities. The new system is defined in terms of mission, purpose, capability, schedule and cost objectives and not in hardware terms. A paper describing the requirement is routed through the various service headquarters to the Chairman of the Joint Chiefs' of Staff Committee, who forwards it to the Ministry of Defense with his recommendations. Upon approval of the necessity of this requirement by the Ministry of Defense, various systems which meet the required thresholds, and are available from foreign countries, are scrutinized. The manufacturers of the probable systems are requested to submit bids. The list of probable vendors is narrowed down to three and after detailed examination of these proposals, a source is selected by the Ministry of Defense. Funds for the system are requested by the service concerned. The funds normally include, apart from the cost of hardware, the cost of follow-on-support in shape of spare parts, training of personnel, test and support equipment, drawings and manuals etc. Funding approval may then be obtained from the national assembly from the next year's allocation of budget.

C. EXISTING LOGISTICS FACILITIES

The Pakistan Navy has certain facilities already in place which can help support and sustain ILS efforts in future procurement/acquisitions of weapon systems. The Pakistan Naval Stores Depot (NSD) at Karachi is the centralized stocking, accounting and issuing agency for spares and repair parts. All units irrespective of their location submit their demands (requisitions) to the NSD. Similarly, all items being surveyed are sent to the NSD. The NSD is in fact a mini-international procurement organization in addition to other functions. Inventories of parts from five different countries are kept at different groups. These groups are directly responsible for initiating procurement actions from abroad according to requirements and availability of funds.

The Pakistan Navy Dockyard is geared up to carry out long refits and short maintenance overhauls of units on regular basis. All sorts of repairs from hull to boilers, engines, electronics, radio, radar etc., is carried out locally. At suitable times when new systems are being procured, men of the navy dockyard are sent for training on the systems in order to be able to take on maintenance jobs after the new units join the fleet.

The Air Stores Depot is the focal point for procurement, stocking and issue of aviation stores. Presently it caters for the requirements of the Naval Air Station at Karachi. All workshops pertaining to the aviation wing are located at that station.

D. BUDGETARY CONSTRAINTS

Unfortunately, the economic condition of Pakistan, like any other third world nation, is very brittle. Out of the meagre resources allocated for defense purposes, only the most pressing and inescapable requirements or projects survive being deferred or dropped. Accordingly, operational hardware gets the top priority and the bulk of the budget is thus allocated to get the hardware in place. In such a scenario, the funds for logistic support are the first to be reduced, deferred, or cut and the last to be allocated. Most defense acquisition programs in the past were actually inadequately funded for logistic support. This trend is likely to persist in the future also until the economic condition improves.

There exists a significant difference in the budgetary procedures followed in the United States and Pakistan. In Pakistan, presently, the popular five year defense plan practised in many other countries, is not followed. Budget allocations for defense is made on a year-to-year basis. Once a program is funded or allocated a chunk of the pie, it becomes practically impossible to extract additional funds for it without deducting the money from another project. Funds for operations, maintenance and procurement of spares are allocated yearly and are usually based on an incremental budgetary system. In contrast, in the United States of America, projects are mostly funded on a Planning Programming and Budgeting System (PPBS) which is more conducive towards ILS implementation.

E. MAKING ILS FEASIBLE

The incorporation of an ILS concept in any major weapon system or equipment acquisition by the Pakistan Navy appears feasible. However, immediate implementation may not be without the ups and downs which are usually faced by a new concept. The main hurdle in Pakistan may be convincing the Government of the long term advantages of buying the system which has the least life-cycle costs, especially when these costs are spread over a time horizon of 10 to 15 years. In addition computing the Life Cycle Cost (LCC), in a small country like Pakistan, may not be practical because of the difficulties involved in obtaining the necessary cost elements.

Even without being able to determine the LCC, the ILS concept and plan can be developed. The ILS concept has to be introduced at all levels of management as a first step. Plans for more effective support of ships and units which are now operational, may be also developed to the extent allowed by available budget and the structuring of

the ILS elements like, supply support, facilities, etc. Training of personnel in the field of configuration management, information systems and planning for integrating support requirements which is pragmatically possible has to be started as the next step.

Training assistance from the United States of America may be sought, as a sequel to the above, in the practical coaching of personnel for acting as Logistic Element Managers (LEM) and ILS managers, in case ILS applications are needed in future acquisitions of ships or systems.

In the procurement of weapon systems from abroad, due weightage must be given to weapon systems which have an ILS planning in their acquisition, since these systems have far more chances of receiving a better follow-on-support than other systems which lack ILS in their design.

F. ILS RESPONSIBILITY IN OPERATIONAL PHASE

ILS as a system is still evolving. Even in the United States of America, the responsibility of implementing ILS after a ship or unit embarks on operational duty is not clearly defined. ILS is planned and implemented during conceptual stages and birth of a system and until the time the program office is functioning. However, a need exists for tasking an agency which is suitably equipped in terms of control and data information, to ensure continuation of implementation of the ILS concept beyond the program office.

When the Pakistan Navy decides to implement an ILS program in future, a suitable directorate under the Assistant Chief of Naval Staff (Supply Services)--ACNS(S)--should be able to handle and cope up with the job of continuation of the ILS effort after a program office closes down. An ILS cell equipped with current logistics data pertinent to the existing weapon systems, would require setting up. Such a cell can also look after the configuration management control of the systems concerned since it is a closely related function. The proposed ILS cell, while remaining functionally under the ACNS(S) could be put under the administrative control of the Commander Logistics (COMLOG)--the flag officer responsible for maintenance and other logistical requirements of the fleet--and thus be in a good position to provide liaison between the units, dockyard and the naval stores depot.

IV. SUMMARY CONCLUSIONS AND RECOMMENDATIONS

A. SUMMARY

The requirement and necessity of logistic support over the life cycle of a weapon system was defined in Chapter I. It began by stressing the importance of logistic support on the effectiveness of any weapon system and, more importantly, its impact on cost effectiveness lasting the entire life cycle of the system. It was explained that supportability of weapon systems becomes complex and costly with the increase in the complexity of the weapon system itself. The predicament faced by the Pakistan Navy, in having to maintain costly systems without adequate logistic support planning, was then mentioned. The concept of Integrated Logistic Support (ILS) was also defined.

Chapter II focused on the evolution of integrated logistic support from its origin some twenty years ago. Among other directives issued by the DoD, an important step forward in the ILS implementation was the publication of "ILS Planning Guide for DoD Systems and Equipments." [Ref. 6] This planning guide represented a major improvement in the engineering process for new defense systems and equipment - its goal being maintaining a proper balance between operational, economic and logistic factors. Apart from presenting a systematic management approach to the early integration of support criteria into design activities, the guide also identified the inter-related elements of logistic support that required project type management. In short, the planning guide serves the purpose of a "tool kit" for the use of program managers, designers and logisticians; and is intended as an aid to tailoring logistic plans and actions in support of equipment readiness.

In addition to defining important and oft-repeated terms pertinent to ILS, this chapter also dealt the application aspects of integrated logistic support; describing the system for acquiring ILS and the management responsibility for the support planning in an acquisition program.

The peculiar position of Pakistan being a small country with limited production resources, from a standpoint of meeting military hardware requirements for defense purposes, was highlighted in Chapter III. The weapons procurement process in vogue in Pakistan, and existing logistics facilities which are already in place to support an ILS program in future, were described. It was also brought out that budgetary constraint

was the only factor which might obstruct an immediate approval of the Government in allowing the Pakistan Navy to go ahead with an ILS program in weapons acquisition/procurement.

B. CONCLUSIONS

ILS is concerned with management of life cycle support of the complete weapon system from "womb to tomb." Support requirements are considered, planned, and budgeted for in concept development, system design, production, and through the system's operational life. It provides a framework for organizing and managing the resources necessary to support the system, and makes supportability a design requirement as important as cost, schedule, and performance. Alternative support concepts, trade-offs between design criteria and ILS elements are made to achieve optimum support for the system. Integrated logistic support plan reduces uncertainty in support planning and ensures the right resources at the right place at the right time.

Life cycle costs of weapon systems can be reduced by the implementation of integrated logistic support. There are "up front" costs associated with an integrated logistic plan effort. While these costs yield significant long term benefits, they must compete, today, with expenditures which yield near term returns. Discounting the future savings to the present is an effective means to present the cost savings in present dollars.

Planning ILS for the life cycle support of a weapon system is a difficult task, but its long range benefits are both lucrative and rewarding. Incorporation of an Integrated Logistic Support concept in any future major acquisition should relieve the Pakistan Navy of many of the current follow-on support problems. Accordingly, keeping in view the long term advantages, Pakistan Navy must base its choice of procurement of a weapon system on whether ILS is available and has been incorporated as a program in that particular system.

The recent decision of the Government of Pakistan to acquire three Type 23 frigates from the United Kingdom presents a timely opportunity to the Pakistan Navy of reaping the long term benefits of an ILS program.

C. RECOMMENDATIONS

Upon deciding to pursue an ILS philosophy for any acquisition program in the future, the Pakistan Navy should take the following action.

- An ILS manager must be assigned to the program office team.
- Additional funding must be provided to support the ILSP effort.

- ILS must be actively designed into all aspects of the acquisition process.

Importance of utilizing computer resources for managing logistics information cannot be over-emphasized. An efficient management information system is recommended for use by Pakistan Navy in order to track potential problems in cost, schedule and performance, data management, configuration changes and other applications. By assembling data in a standard, systematic, easily retrievable manner, effective trade-off comparisons can be assured, when required.

The development of ILS planning techniques, along with inevitable organizational and procedural changes, is an evolutionary and not a revolutionary process. Relative slow acceptance and implementation in the services or industry may be expected, possibly due to the size of the organizations involved and the natural reluctance of people to make changes. A keen participation and intense interest of the top planning hierarchy of the Pakistan Navy could only ensure a speedy implementation of the ILS concept.

The Pakistan Navy should incorporate an Integrated Logistic Support concept in the acquisition of Type 23 Frigates. ILS planning in the acquisition of these ships should yield considerable benefits throughout the life of the program. ILS should decrease life-cycle costs and improve availability.

APPENDIX A

MAJOR ELEMENTS OF ILS SYSTEM

There are several interrelated elements contained in an Integrated Logistic Support system. DoD Directive 4100.35G 'Integrated Logistic Support Planning Guide', issued in 1968, defined several major elements of ILS which require consideration in the over all support planning.

1. MAINTENANCE PLANNING

The process of developing a maintenance plan is a continuous one that begins early in the conceptual phase of the acquisition life cycle and should be completed as the system enters the production phase. It includes all planning and analysis connected with establishing requirements for the overall support of a system throughout its life cycle. It constitutes a sustaining level of activity commencing with the development of the maintenance concept and continuing through the accomplishment of logistic support analyses during design and development, the procurement and acquisition of support items, and through the deployment phase when an ongoing system capability is required to sustain operations.

Maintenance planning establishes concepts and requirements for each level of equipment maintenance to be performed during its useful life. As such, it defines the corrective actions and supporting requirements necessary to maintain the designed system in its prescribed state of operations. Maintenance functions include checkout, servicing, crew augmentation, status monitoring, inspection, fault isolation, replacement, modification and overhaul. The degree to which these various functions are to be performed by organizational, intermediate, or depot level maintenance must be spelled out. The objective of the maintenance plan is to meet readiness requirements by providing effective support to the system and to do that at the lowest life cycle cost.

Maintenance planning evaluates current and projected maintenance capabilities and translate them into criteria and requirements which can be responded to by the contractor. Initially, the capabilities are stated as concepts and philosophies which later crystalize into specifications as system design progresses. A detailed logistic support analysis (LSA) is carried out to determine the specific maintenance actions to be performed at various levels of maintenance and the resource requirements needed to support those actions.

a. Existing Maintenance Capabilities

Current and projected maintenance capabilities of the operating force must be analyzed for application to the support requirements. Trade-offs are made in recognition of various operations and support restrictions which may be imposed by using these capabilities. As system specifications are defined, operational requirements are analyzed to arrive at the resultant impact on operating forces and supporting maintenance activities. Factors to be considered in maintenance capability estimates include:

- Qualitative and quantitative personnel requirements.
- Support and test equipment.
- Facilities.
- Economic factors.
- Deployment periods and locations.

b. Maintenance Concepts

Various maintenance concepts are analyzed prior to developing support alternatives. Various combinations of performance requirements and maintenance capabilities are traded off to determine the optimum maintenance concept. These analyses are accomplished as part of the maintainability and reliability trade-off studies. Preliminary support requirements are estimated early in the program to allow a comparison of support alternatives for selection of the best. These normally include:

- Projected levels and location of maintenance.
- Fault isolation and system testing approach.
- Equipment overhaul approach.
- Repair of components by maintenance level and location.
- Identifying the most economic level of repair for components and subsystems; that is, organizational, intermediate, and depot.
- Adopting a policy for repairs or replacement of components and parts while emphasizing improved facilities or higher inventory levels respectively.

c. Maintenance Plan Requirements

Maintenance plan requirements are developed which determine the criteria for the development of the maintenance plan during contract definition. These criteria must identify service and contractor responsibilities for planning and supporting actions. In support of a maintenance concept, these requirements may include:

- Maintenance practices to be followed.
- Guidelines and specifications for maintenance.

- Plan for system use which outlines details such as environment and deployment, maintenance responsibilities by level and location, frequency and duration of operational use, and operational life cycle of the system.

d. Logistic Support Analysis

As drawings of components and subsystems become available, a logistic support analysis is conducted to determine specific maintenance support actions by frequency, time, and location. It further identifies requirements such as personnel skills, provisioning of spares, supply support, servicing, test and support equipment, technical data and associated facilities.

e. Maintenance Plan

The development of a maintenance plan is a continuous process, since not all desired maintenance characteristics can be initially stated as design parameters. Some are suggested by the system and its intended use. Others are adopted from recognized advances in engineering and manufacturing. Still more will state requirements that alleviate a particular problem associated with earlier, similar systems. For instance, a desirable characteristic for a system could be a minimum number of maintenance platforms. This can be stated as a requirement that all replaceable units be accessible to a mechanic standing on the deck or ground. The components beyond reach of an average sized man should be of proven high reliability. Few of the normally accessible units are to require more than one man for replacement or removal. Finally, most units should be so located that removal of a failed component or part does not necessitate the removal of other components. These are decided advantages from a mobility standpoint since they reduce the number of platforms and special lifting devices that must accompany a deployed unit or system.

The maintenance plan must be ready for implementation when the system becomes operational. Failure to meet the planned objectives at the appropriate time in any of the logistic support elements will materially limit its effectiveness. Trained personnel, in sufficient numbers and at the right time provided with adequate tools, equipment, spares and technical data are vital to optimum support of the system in an operational environment.

2. SUPPORT AND TEST EQUIPMENT

The purpose of the support and test equipment program is to assure that the required support and test equipment is available to the operating forces and supporting maintenance activities in a timely manner. The ability to perform the required

unscheduled and scheduled maintenance depends on the adequacy of the support and test equipment identified and developed concurrently with the prime system and equipment. These equipment include tools, performance monitoring and fault isolation equipment, test and calibration equipment, and handling devices. Their adequacy is the result of both the system and the equipment design. Their availability is the result of careful planning and scheduling to ensure that equipment needed to support the system is delivered with the system.

a. Projected and Existing Capabilities

Based on the required operational capability, an analysis is made of the projected maintenance capabilities of the operating forces and the maintenance activities. An integral part of this analysis is the assessment of support and test equipment used to maintain similar systems at various maintenance levels. This action is based on available operations readiness performance data, system configuration, and the maintenance and maintainability assessments of support needs for projected operations and support modes. The resultant estimates should quantify both existing support equipment that may be utilized and those additionally required.

b. Support Equipment Concept

Support and test equipment concepts are selected on the basis of maintainability and reliability trade-offs and in accordance with the maintenance concept. Support and test equipment trade-off studies are conducted to satisfy the alternative support concepts. Moreover, currently available support and test equipment, experience of the operating forces and maintenance activities with such equipment, equipment under development, and analysis of technical feasibility and cost are considered for the development of new equipment.

c. Support Equipment Plan Requirement

Support and test equipment requirements are developed as planning criteria for:

- Special or general purpose automated/manual system testing and fault isolation equipment.
- Special and general purpose support and test equipment.
- Special or general purpose maintenance handling equipment.
- Development and acquisition plan for new support and test equipment.

d. Support Equipment Plan

The Support equipment plan is approved for use during the development phase. Together with the maintenance plan, it becomes part of the support plan for inclusion in the development contract. Accordingly, the contractor proceeds with development of the items of support and test equipment in the quantities required for test and demonstration.

A problem facing the program manager is that while the design of the new support and test equipment cannot be firmed up until the primary system design is frozen, the support and test equipment must be delivered to the test sites or operational bases before or with the primary system.

The effectiveness of the maintenance activity is affected by the availability of a particular support and test equipment when it is needed. It is, hence, imperative that delivery of all required support and test equipment to the first commissioned ship or unit is accomplished as per planned schedule. Interface action between contractor, storage locations and operating unit must be complete to assure timely delivery.

3. SUPPLY SUPPORT

Supply support is an essential element of the logistics integration effort and is responsible for timely provisioning, inventory control and distribution of spares, repair parts, consumables and special supplies needed to support prime mission-oriented equipment, software, test and support equipment, transportation and handling equipment, training equipment and facilities. Supply support also covers provisioning documentation, procurement functions, warehousing, and the personnel associated with the acquisition and maintenance of spare and repair parts inventories at all support locations.

a. Provisioning

Provisioning is defined as the method of determining and acquiring the range and quantity of support items which are required to operate and maintain an end item of material for an initial period of service. The goal of provisioning is to assure timely availability of the material needed to sustain the operation of end items until the normal replenishment pipelines are ready to provide this support at the least initial cost.

The supply of items to support a system depends on the design of that system and how that system will be maintained. Reliability of a component must be

determined prior to spares procurement. Trade-offs between additional cost of engineering improvement tests versus cost of more spares at lower reliability should be analyzed. The repair level of each particular component must be known. If a component is designed as a throwaway, no repair parts are required. However, the total quantity required of that component would be higher than a item which was repairable. Similarly, if an item is required to be repaired at the organizational level according to the maintenance concept, more repair parts must be procured and stocked at organizational levels. If the item was a depot level repairable, obviously a lesser number of additional components would be required for stock purposes.

Supply planning for spares and repair parts is to be based upon technical inputs from maintenance planners and engineers (e.g. system utilization rate, operating hours, failure rates, required organizational repair rates, maintenance levels and geographical location where spare/repair parts are distributed and stocked; spares demand rates and inventory levels; the distance between stockage points; procurement lead times; and the methods of material distribution).

b. Supply Support Concepts

An initial analysis is conducted to assess the capability of the existing supply system and the projected supply support work load, and storage and distribution techniques which are required additionally. Thereafter, the basic ground rules under which supply support is to be provided are determined. Factors are developed for estimating spares and repair parts costs for the system life cycle. Proposed plans, techniques and concepts developed during in-house or contractor studies are reviewed and a support concept for spares, repair parts, and equipment provisioning objectives are established.

c. Provisioning Plan

A supply plan requirements package is prepared and provided to the contractor. Provisioning and supply management requirements and evaluation criteria, along with management data requirements are also provided. The contractor should be evaluated on his capability to provide responsive production of spare parts, and meet delivery schedules. The supply support plan which is approved must reflect the "best mix" solution of all support element inputs. It should be the product of the latest and best information, and should be integrated with all other planning efforts.

d. Provisioning Document

Preparation of provisioning documentation for spares, repair parts and special supplies begins concurrently with the start of detailed design and maintenance engineering analysis. Quantitative determinations are made based on engineering analyses, contractors' experience, and design and procurement parameters. Contractors' recommendations for the range of items, locations and quantity are often used.

The provisioning documentation effort, which also considers usage data, current engineering changes and initial lay-in quantities, culminates into a allowance listing which shows item nomenclature, stock number, part number, unit of allowance and quantity, price and other standard codes.

e. Procurement of Spares

Based upon the allowance and distribution plan, quantities of spares/repair parts and special supplies are procured and delivered to item managers for issue to units on a date prior to equipment operations. Normal replenishment of spares/repair parts is carried out by the Program Support Inventory Control Point (PSICP) with the help of Provisioning Technical Documentation (PTD) which is prepared by the contractor for all end items that will be supported by the supply system, and the Program Support Data (PSD) which is provided by the Hardware Systems Command to the ICP. PSD describes the hardware acquisition in detail from procurement through preliminary operational capability date and all follow-on acquisitions so that the PSICP can plan for budgeting and time-phasing of procurements.

4. TRANSPORTATION AND HANDLING

This element includes the characteristics, actions and requirements necessary to ensure the capability to support packaging, preservation, storage, handling and transportation of prime mission equipment, test and support equipment, spares and repair parts, personnel, technical data and mobile facilities. In essence, this category covers the initial distribution of products and transportation of personnel and materials for maintenance purposes.

Design requirements and protection procedures that ensure adequate protection at minimum cost must be identified early in the cycle. An analysis must be made of the existing transportation and storage doctrine and procedures within the navy and, if possible, on a interservices level. The deployment capability is paramount in the design

of most systems, (i.e., a helicopter must be capable of being stowed on a frigate or a destroyer-sized ship.) This obviously provides the ship with added flexibility in carrying out its mission. The amount of assembly and disassembly allowable is dependent on the contingencies to be met by the system under design. Containers for costly complex components are considered. The design of these containers for protection, storage and transportation is to be made early in the program.

Generally, the functional requirements and actions, as far as transportation and handling is concerned, are developed from operations and maintenance analyses, equipment design drawings, specifications and other documentation defining transportability criteria, handling equipment and procedures, and packaging and preservation needs. The requirements to be considered mostly includes:

- Transportability criteria such as time, locations, duration, frequency, volume, security and stock limits.
- Desired locations for transportation equipment and facilities.
- Planned availability of existing system capabilities by quantity, volume and location.
- Additional or special transportation and handling procurement requirements.
- Interfaces with other system design and support management functions.

The transportation and handling capabilities to support projected logistics requirements are, initially, evaluated like any other element. The evaluation includes broad considerations of:

- Rationale for requirements identification.
- Requirements constraints on transportation and handling capabilities.
- Current capabilities to satisfy requirements.
- Data on similar equipment.
- Initial transportability trade-offs of designated and backup modes for movement of equipment.

After in-house or contractor transportation and handling trade-off studies are conducted for selection of optimum modes and procedures, transportation, handling, packaging and preservation concepts and requirements are established in consonance with maintainability and reliability trade-offs, results of feasibility studies and maintenance support concepts.

Criteria for evaluating the transportation and handling portions of contract proposals must be developed for inclusion with that of other support elements. Measurement and evaluation methods must be specified to assess adequacy of

contractor proposed programs to identify requirements. The contractor should also be evaluated for the logic of his proposed use of existing capabilities and his justification for additional special support to augment transportation and handling.

5. TECHNICAL DATA

The purpose of the technical data program is to provide for the timely development and distribution of technical data necessary to conduct operations, maintenance, supply, modification, repair and overhaul of the systems and equipment. The best equipment ever designed is useless without adequate support; support is impossible without meaningful publications. The element of technical data is a systematic process for developing, printing and distributing equipment publications pertaining to the system. Technical data provides the link between personnel and equipment. It includes drawings, operating and maintenance instructions, specifications, provisioning information, inspection test and calibration procedures, system installation and checkout procedures, overhaul procedures, modification instructions and special purpose computer programs required to guide people performing operations and support tasks. Such data, apart from covering the prime mission equipment, also covers support and test equipment, transportation and handling equipment, training equipment and facilities.

Many considerations are necessary throughout the life cycle to guarantee complete and timely system publication coverage. A detailed schedule must be developed to ensure availability of appropriate instructions on a timely basis. Manuals must be designed to be understood at the skill level, including intelligence level of the user. The simplest engineering drawings at the contractor's site of a complicated part or process is worthless if the individual who relies on it in the field cannot interpret it correctly. This area is becoming even more critical as system designs are becoming more complex. Review by the user is very important. However, this review must be fully coordinated and planned as the time available is limited. If the reviewer's comments are received after the deadlines, it could well prove to be an unsatisfactory publication support.

Technical data planning is based upon inputs from equipment operations and maintenance planners (e.g., system use, design characteristics, operations and maintenance methods, and frequency and time to repair, etc.). Based on projected support capability requirements, an analysis of the existing data system is carried out to arrive at the existing deficiencies and the areas requiring further study or

augmentation. Technical data considerations based on operational readiness requirements, are identified for application to system feasibility studies, in the pursuit of selecting a technical data concept. This concept defines technical data plans, procedures and requirements, which is converted into a data requirements package for inclusion in the logistics plan requirement. Support management is responsible for the development of ideas and technical data proposals from the contractor into a data plan consistent with the needs of both the operating units and the support units.

The preparation of preliminary technical data commences concurrently with detailed equipment design and maintenance engineering analysis. This data is later expanded and formalized for use in the production and operational phases of the life cycle. Technical data is validated during the subsystem and system demonstration phase to confirm ensuring compatibility of data with equipment configuration. This data should provide sufficient information necessary to conduct operations and maintenance in support of established performance goals. The suitability of the technical data can be verified during tests and demonstrations held by the user.

6. FACILITIES

This element refers to all special facilities needed for system operation and the performance of maintenance functions at each level. Workshops, plants, real estate, housing, intermediate maintenance shops, calibration laboratories, and special depot repair and overhaul facilities must be considered. Capital equipment and utilities (energy, heat and power requirements, etc.) are all included as part of this element.

Early in the acquisition cycle, facilities must be defined as to environment, location, fixed versus mobile, modified versus those already in use, and government versus contractor. Each of these considerations must be weighed in conjunction with the design parameters and maintenance concept. Defining what must be maintained to what level and where, will provide important information to facilities analysis. If new sites are required for testing or storage, early survey for suitability is required. Housing necessary to support test teams and special security requirements for classified systems must be reviewed. Some systems require special power sources, communications, or possible paving or drainage construction. Facilities are costly to build and construction takes considerable time, thus early planning and decisions are essential.

The facilities program is handled like the other elements of ILS. Analysis of facility capabilities required is made. This action is based on available experience data, gross system configuration and maintenance and maintainability assessments of

support needs. Estimates must define existing facilities and those required in addition. Several support alternatives are evaluated and the most favorable facility concepts are selected for further study. A facilities concept is then selected on the basis of maintainability and reliability trade-offs and system feasibility studies. Facilities plan requirements are prepared and evaluated against criteria developed for determining contractor's responsiveness and architect-engineering design specifications.

Facilities specifications and contract documents must be prepared concurrently with the equipment production contracts and construction milestones must be consistent with the schedules of all other elements. Inspection and acceptance of the facility should be progressively accomplished throughout construction and equipment installation, checkout and service test.

7. PERSONNEL AND TRAINING

This element defines the requirements for trained operational and maintenance personnel needed to support the system and equipment through all life cycle phases. A realistic estimate of current manning capabilities, in terms of numbers and skills, has to be made against the probable quantitative and qualitative manning demands of the system or equipment concepts under study. As hardware concepts are developed, design and support decisions must be made with due consideration for their impact on manpower and training requirements. These requirements are translated into specific manning plans in terms of numbers and skill levels for each operation and maintenance function by level and location. Training is designed to upgrade assigned personnel to the skill levels defined for the system. It includes both initial training for system familiarization and replenishment training to cover attrition and replacement personnel. Training data and equipment (e.g., manuals, simulators and mock-ups, test equipment) are developed as required to support personnel training operations.

It is a fact of life that virtually every service experiences problems in the supply of adequate number of skilled personnel for operating and maintaining weapon systems. In the Pakistan Navy, like other navies, manpower costs have increased rapidly in recent years and account for nearly 50% of a ship's annual operating expenses. Accordingly, manpower is considered as an expensive element in the navy inventory and qualifies as a major determinant of the life cycle cost. Since up to 70% of system life cycle costs are determined by decisions made during the concept exploration phase, the program manager and his staff must consider the impact that their decision will have on human resources. This calls for early consideration of this

element; that is, in the design phase. Current United States DoD policy clearly reflects this fact. Manpower, personnel, and training requirements analyses must be made early in the acquisition process, with increasing detail required in successive phases. [Ref. 13] requires that:

New systems shall be designed to minimize manpower (number, grades, specialty, and skill levels) needed. Service studies projecting personnel skill level availability to meet manpower requirements shall be included at program initiation as constraints in system design and shall be integrated with human engineering design criteria to form the basis on initial operating and support concept studies and refined as system development progresses, to form the basis for crew station and maintenance design as well as personnel and training requirements, training devices and simulator design, and other planning related to manpower and personnel. Goals and thresholds for manpower number and skill levels shall be established and evaluated in T&E. Plans for training shall consider trade-offs conducted among job aids, formal training, on-the-job training, unit training, and training simulators. Each program shall develop a cost effective plan for attaining and maintaining the personnel proficiency needed to meet wartime mission objectives. Such planning shall consider provisions for unit conversion to the field system and training of reserve component personnel.

The primary factor driving all manpower costs are the number, complexity, and frequency of operator and maintainer tasks. These factors determine:

- Number of maintenance and operator personnel required.
- Required aptitude level of these personnel.
- Experience level required to perform satisfactorily.
- Amount of general and specialized training required.

Various system design concepts have varying complexity of operator and maintainer tasks. The manpower-and-training cost consequences of these concepts must be traded off against other cost-benefit considerations beginning in the concept exploration phase.

It is important for the system designer to be responsive to overall manning problems and the availability of personnel, and to be aware of the many variables that he does impact in the overall manning equation. These variables include:

- Operator requirements.
- Preventive and corrective maintenance requirements.
- Training requirements.
- Category and skill requirements.
- Administrative and support work load.
- Utility requirements (miscellaneous tasks).

- Facilities maintenance.

On shipborne systems, important secondary savings can result from decreased requirements for onboard service and administrative personnel. These savings can come about either through a reduction of the absolute number of operational and maintenance personnel onboard, or by transferring a greater portion of the support and administrative burden to tender or shore-based facilities.

The development of training aids and other ancillary equipment, such as training manuals and simulator, to support the system, is another important factor. The use of training aids and simulators have become more necessary as the complexities of systems have increased and the cost of expendables such as missiles and projectiles, as well as the cost of ship steaming days or aircraft flight hours, have increased. Where once it was practical and efficient to develop bomb delivery accuracy or gunnery efficiency by practicing with live or dummy ammunition, it is now prohibitively expensive to do so. Yet it is still essential that personnel gain experience in the use of modern equipment and learn to overcome conditions such as electronic countermeasures (ECM) that are encountered in wartime. One means of obtaining realistic training is the use of system simulators and sophisticated training devices that provide feedback on operator effectiveness and performance. Such devices must be as carefully developed as the real system to provide the maximum benefit of training and to ensure that the simulated conditions and operations match the operational environment closely. The development of such trainers must proceed at the same pace as that of the final system.

8. COMPUTER RESOURCES

This facet of support refers to all computer equipment and connected resources, software, program tapes/disks, data bases, etc., necessary in the performance of various maintenance functions at each level. Mostly the information and control systems interfacing with support management include:

- Maintenance engineering and analysis control documentation.
- Engineering test and demonstration records.
- Program schedule and cost controls resulting from PERT and CPM analyses.
- Maintenance management and failure data.
- Miscellaneous requirements forecasts; e.g., personnel, supplies and equipment.
- Configuration management.
- Operational readiness support status.
- Supply management effectiveness reporting systems.

Early in the development phase of the acquisition life cycle, support management selectively identifies the extent to which the above information systems will be required during the item's life cycle, when they will be required and how and by whom the requirements will be met.

It is now almost universally accepted that most of the advanced and sophisticated weapon systems are dependent on their successful operation on embedded computer resources (ECR). Nowadays, ECRs are used to operate systems, to test them, to produce them, to adapt them, and to keep them responsive to changing threats. Program managers utilize ECRs to and monitor system performance failure, cost overrun, schedule slippage, and even loss of program control.

Software development requires the same amount and extent of skill as is required in hardware development. Equal emphasis on software and hardware should apply from the beginning. The ECR must be evaluated for its supportability: common high order language, availability of compilers, transportability of coding, etc. In short, system software should be treated as a vitally important configuration item just as much as any other element.

System software management tools and techniques have matured in recent years. Standards and specifications have been produced. These are now being used in the software development in much the same way that MIL-SPECS have long been used in the hardware development field.

Software management has been recognized as requiring early, intensive, and continuing management. Software standards to be utilized must be identified early in the system conceptual stage. Hardware development that is allowed to proceed in advance of software decisions will generally constrain system design. Program decisions in good designs are made with engineering balance, including hardware and software considerations.

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