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Project Management and Systems Engineering Guide

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PART A: CHRONOLOGICAL GUIDE

I. INTRODUCTION

THE PATTERN OF SUCCESS

The role of the project manager is to acquire equipments which will perform the required functions at an affordable price and by the time they are needed. In these days of constrained budgets, “affordable” may be defined as the least total cost to the government only with the proviso that the functions to be performed are worth that expenditure. Literally hundreds of studies have looked at defense acquisitions over the past 50 years. Reading the conclusions and recommendations from a 1949 report is like reading the results of a 1974 report. Project after project fails to achieve these goals. Each report is clear; projects fail to meet performance objectives, overrun costs by 150%, and slip schedules 25-50% or more. In the vast majority of cases, the project goals were not achieved for the following reasons:

- misspecification (usually gross over-specification creating artificial technical problems)
- failure to manage risks
- obscuring of the project goals through extraneous paperwork requirements
- failure to adequately define what is required
- underestimating the required project resources (sometimes intentionally, in order to “buy in” and get a project started)

These reasons are, however, only the symptoms of underlying problems in the acquisition community. The TELCAM project looked at successes and failures in industry as well as government; the successful project has the same traits whether in industry or in government. An acquisition project also shares many traits with a small business, so TELCAM also solicited information from the Small Business Administration. Again, success is a pattern, whereas failure is a deviation from that pattern. The major difference between failures in industry and failures in government is that a failing project in industry is usually rapidly terminated; the government failure usually plods on to an elegant wreck.

What is the elusive pattern of success? The projects cited as successes will have two main features:

- A strong, knowledgeable project manager who acts as the ultimate authority for all project matters — tasking, budgeting, technical decisions.
- A small, dedicated team executing project tasks.

The key words above are: strong, knowledgeable, ultimate authority, small, dedicated, and team. Excellent studies of the nuclear power program[1], the Polaris system,[2] and NTDS[3] are available which show these forces at work. "Strong" appears to be a peculiar necessity in the government projects, as each success seems to attain that status in spite of "the system." An ultimate goal of acquisition R&D must be to change "the system" to allow average individuals to be successful project managers. Until that goal is reached, there is still enough of a task to create knowledgeable managers. Some spectacular failures have been managed by strong, unknowledgeable individuals. A project needs a strong champion in order to "steal" sufficient authority to become a purposeful autonomous entity, but authority unwisely wielded is disaster. The government project manager is not held accountable for his actions; accountability is the "quality assurance" incentive used to check authority in industry.

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[1]Nuclear Navy (1946-1962), RG Hewlett and F. Duncan, Chicago, 1974
[2]The Polaris System Development, Sapolsky, Harvard, 1972
[3]The NTDS Development, RW Graf, United Research, Inc., 29 Jan 1964

In addition, most successful project teams were found to be goal-oriented and opportunistic. Individual team members were confident of success, in spite of great technical difficulties, and really wanted the project to succeed. In contrast, team members of unsuccessful and stagnant projects focused on problems and mired down into details. The attitudes of the team members reflected the attitudes of the project leadership.

The first procurement of muskets by the Army in 1798 seemed straightforward. Eli Whitney promised to produce and deliver muskets built by assembly line techniques, and using interchangeable parts, within 8 months; actual delivery was made 10 years late. Our military procurement problems actually predate the nation itself; one verse of "Yankee Doodle" went

> "And there we saw a thousand men
> As rich as Squire David,
> And what they wasted every day
> I wish it could be saved"

referring to one of General Washington's encampments.

On 27 March 1794, Congress appropriated $768,000 for the construction and manning of six frigates. Each frigate was to cost $100,000. When the UNITED STATES, CONSTITUTION, and CONSTELLATION were finally launched in 1797, each cost close to $300,000. The national budget in 1797 was about $5.7 million.

The innumerable instances of procurement problems which have occurred repeatedly over the years have only worsened with time. The evolving acquisition system operated in ignorance in the 1790s, and this basic ignorance exists today throughout the acquisition community. Less than 30% of the project managers interviewed by TELCAM knew the operational objective of their project; only 5% could relate technical features of the project to operational considerations. Only 2% of the project managers were aware of any actions being taken on their project to reduce risks of any kind; only half knew what progress was being made or what difficulties were being encountered on major tasks! Under these circumstances, it is a wonder even greater failures do not occur than those already found. One of the major factors aggravating this situation is the lack of project manager accountability for the end item in the field. A project manager may only influence 4 years of project life, whereas the end item may be in use for 20-50 years. The project manager determinations affect all but a few percent of the total life costs of a project.

Figure I-1 shows the percentage of total ownership costs committed during conceptual planning, design, development, acquisition, and operations for past major programs. In the past, decisions made during the concept and planning phases committed 70% of the total life-cycle cost funds of a program, and design, development, acquisition, and operations accounted for only 30% of that total cost. Notice that only about 1% of the life-cycle costs are expended during this conceptual phase. The effects of applying system engineering principles, including life-cycle cost analysis through the planning and RDT&E phases of a program and the "design to cost" concept are expected to change this distribution considerably by affecting a larger portion of that early 70% commitment.

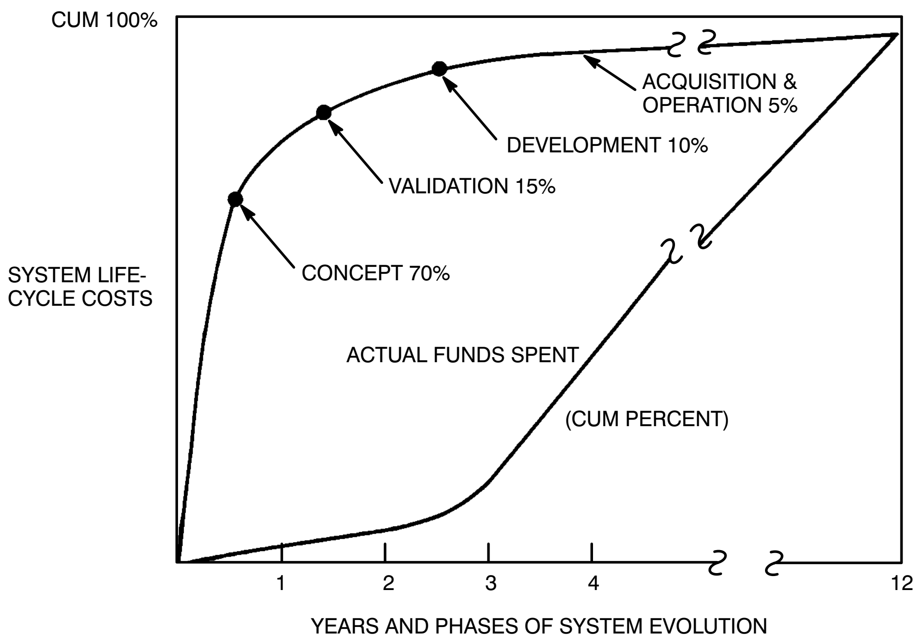


Figure 1-1. Systems funds committed by initial planning decisions.

Notice that 90% (or more) of the total project cost is fixed after only 10% of the funds have been expended. Unless the project manager assumes responsibility for the total, it is impossible to attain the lowest possible project cost. Considering that support costs may be altered by as much as two orders of magnitude by decisions in the conceptual phase, it can be seen that a naive approach to project management can have a devastating effect on operating budgets; likewise, sound management can lead to a highly efficient use of funds.

The acquisition manager should try to obtain equipments which are fully capable of doing the required job and which have the following characteristics:

Reliable
Maintainable
Supportable
Procurable
Producible

The remainder of the Guide discusses the many facets of these factors.

THE PROJECT MANAGER

A manager and a project are established for a single purpose. It makes no difference that the project is designated a major program and its manager a program manager or that the project is called a tasking with a project engineer in charge. Program manager, acquisition manager, project manager are, for the purposes of this guide, synonymous, being different in scope but like in character. Project management is the planning, executing, directing, and controlling of a relatively short-term project or systems-oriented organization established for the completion of specific goals. In this guide, those specific goals will be an acquisition and implementation of military equipments and the subgoals associated with each phase of the cradle-to-grave of those equipments; however, the principles presented are basic and universal and adaptable to many other project circumstances.

The project manager ideally will plan, organize, monitor, and direct the project to its goals as effectively as possible. Efficiency is a secondary consideration, since maximum efficiency often compromises effectiveness. It is generally agreed that, in the competitive atmosphere of military affairs, ineffectiveness is catastrophic. Organizations which manage for efficiency are called functional organizations. In executing his tasks, the project manager will draw on expert assistance from many functional areas and will establish lines of organization control which will allow him to manage efficiently. In general, he has two cardinal rules to follow:

- Do not do it yourself — accomplish through the project organization.
- Organize your resources to fit the project — be prompt and precise in defining the organization.

The project organization exists within an organization (which will normally be functionally organized). In order to reach its goals, it must live within the chain of command of its parent organization, and it must establish a chain of command within itself. A chain of command is an organization of three elements: responsibility, authority, and accountability. Usually a project's charter will define the project goals without mention of these three elements. Organization instructions may define project manager responsibilities in a general way with only implications of assigning authority and no actual accountability. In practice, the project manager should assume that he is fully responsible for meeting his project goals and he should assume all the authority that he is allowed by law and by his supervision to meet his responsibilities. Within the project organization, he will clearly reassign responsibilities, delegate appropriate authority, and hold accountable each responsible individual. The key to his success will often be his authority and his ability to exercise and delegate it. Outside the project, the manager should elicit the cooperation of those who have authority above him, to ensure that he is backed up, by keeping his chain of command informed truthfully, concisely, and specifically. Authority is the power to make decisions. It is important to remember that small decisions must be made. A "no decision" is worse than a "wrong decision" because with the wrong decision the manager knows what he did and can correct it; with no decision, the situation will inevitably grow worse, perhaps without any indication of the appropriate corrective action. Admiral Nimitz was reputed to have said, "the time for taking all means for a ship's safety is while you are still able to do so." Decisions are required to solve problems; solutions usually result from perspiration — not inspiration. When a manager has a problem, he has basically three methods available to solve it; the important thing is that the decision be made.

PROBLEM SOLVING

Classical Method		Scientific Method		Shotgun Method	
1	What is the problem?	1	Define the problem	1	Make decision
2	What are the alternatives?	2	State objectives	2	Analyze research
3	What is the best alternative?	3	Formulate a hypothesis	3	Correct
		4	Collect data	4	Implement
		5	Classify, analyze, and interpret data against the hypothesis	5	Repeat 2–4 as required
		6	Draw conclusions, generalize, restate, or develop new hypotheses		

The solution should be kept in perspective by asking, "Is it adequate?" and "Is it too elaborate?" These questions are asked in the context of the ultimate project goals.

In order to make decisions, the manager must be informed. The manager uses the project organization and procedures to keep informed of project activities, usually utilizing some form of convenient management information system. Again, the solution is tailored to the needs. On small projects, the project manager will keep directly informed about all the specifics of his project. On large projects, the project manager will rely mainly on reports and plans and will focus on exceptions to the overall plan.

THE SYSTEMS ENGINEER

Systems engineering is both an engineering management discipline and a technical engineering process. It is a branch of engineering devoted to the design, development, and application of complete systems, taking into consideration all elements in a system or process and their integration. A system is an integrated assemblage of elements operating together to accomplish a prescribed end purpose.

As an engineering manager, the systems engineer is responsible for planning, organizing, and tracking the system design elements: technical performance, internal and external interfaces, production and support cost elements, documentation (and data management), configuration management, and test issues.

As a deputy (or assistant) project manager, the systems engineer is responsible for risk management and for structuring the technical effort to match the project resources and the acquisition strategy.

As a technical task manager, the systems engineer is responsible for the system design. System design decisions account for 70% of life-cycle costs; total life-cycle costs may be affected by as much as two orders of magnitude.

System design translates operational requirements into technical specifications. The specifications describe a product design which is compatible with the user requirements, the usage environments, the project resources, the production requirements, and the support environment. System engineering provides the DISCIPLINE to assure that the product is consistent with the requirements and with the other system design elements.

The system design parameters include:

- schedule
- risks
- supportability
- maintainability
- accessibility
- quality
- security
- storage and handling
- transportability
- project cost/life-cycle costs
- producibility
- reliability/dependability
- availability
- tools/test equipment
- safety
- testability
- packaging and packing
- EMC/EMI/EMP/EME/HERO/TEMPEST

- usage, storage, and transportation environments
- project engineering environment (CIE tools)
- human factors for operation and maintenance
- platform interface and installation requirements
- available technologies (for build, buy, modify decisions)
- future modification requirements
- contractual resources and relationships

ALSO — DOES IT MEET THE USER'S REQUIREMENTS?

In order to obtain up-the-line cooperation to get higher order decisions, the project manager and systems engineer should know their own project and also related projects. In knowing their own project, the management can confidently relate accurate information to their superiors. This confidence and frankness can play a role in generating trust which will be valuable if problems requiring outside assistance arise. Also, the knowledge of other projects will assist the manager in recognizing the parent organization's perspective and in establishing a priority to obtain the needed decision. Avoiding "tunnel mindedness" can be very helpful when competing for a share of limited organization resources — especially funding. Avoid "buttering up" reports to show only good news; major problems cannot be covered up and will torpedo this facade. The project must satisfy the parent organization's goals.

KEY CONCEPTS

PLAN! The process of planning the project is important in uncovering the risks and developing an acquisition strategy. But don't forget, a PLAN IS ONLY AS GOOD AS ITS EXECUTION.

Don't confuse information and data. You need good information; data is only the means of obtaining information.

LEAD! Be a team leader. Set the highest professional and ethical standards for yourself and for your team. Communicate.

DELEGATE! Choose the knowledgeable experts you need and give them the responsibility and authority they need — then hold them accountable. Support your team. Reward your winners.

SUMMARY

The system acquisition process is a bureaucratic methodology for transforming operational requirements into a technical implementation. It is governed by procedures, instructions and directives, regulations, laws, and the congressional budget process. The project manager must navigate this bureaucratic sea while maintaining control of the project. The system engineering discipline assists the project manager by providing an effective system design most efficiently within the constraints imposed by the acquisition system and the "real" world.

This guide is offered in recognition of the fact that most project managers are good technical people who may be inexperienced managers. It is also an attempt to offer practical methods to implement the recommendations of the various government studies on reducing costs (see appendix B), many of which are not addressed by directives and instructions. It is hoped that the Guide will serve as a useful navigational tool for the manager as he or she weaves the project's course through instructions, budgets, specifications, and the like to a successful implementation in the Fleet.

II. REQUIREMENTS DEFINITION

The most basic step in any successful endeavor is to thoroughly establish a goal. This chapter cites the elements necessary to define the goal for an acquisition project. These elements determine how an item will be used and supported and how much it will cost through its life cycle. All the steps which follow must point toward the project goal.

A project which is not confined to basic research has objectives which must ultimately be application oriented. The identified application is defined in terms of user requirements. Usually, these requirements will be documented by an Operational Requirement (OR) (OPNAV INST 5000.42). A project not having an OR will normally be part of or closely related to a project which is so documented; alternately, a project whose purpose is to replace existing equipment may assume the same user requirements as the extant equipment. In any case, certain user-oriented parameters must be known before valid technical requirements can be generated. The following requirements elements should be identified before progressing into a conceptual effort.

Operational need — the operational problems and threats to be addressed by the project including the scope and parameters of the expected threat environment, deficiencies in present capabilities, and the consequences of not satisfying the need; i.e., statement of how vital the system will be and the required system availability.

Operational concept — a statement of how the user is to use the new capability to combat the operational need. This includes definitive mission parameters, i.e., mission duration, ship-air-shore platforms involved, intervals between missions, the mission environment, the system utilization rate, etc., and requirements for the system to be compatible with other systems. The number of systems to be implemented and the priorities of implementation are included.

Performance goals — the known performance criteria, operating modes, and other system characteristics stated with minimum acceptable limits and allowable degradation conditions.

Life support goals

Life expectancy

Special logistic and training support considerations and constraints

Nominal goals for mission and operating reliabilities

Level of maintenance capability constraints including the maximum annual maintenance time at the organizational level

Cost objectives

Production design-to-cost goals given the number of systems to be acquired within the postulated time frame

The maximum annual maintenance cost at the organizational level

Initial operational capability (IOC) — the desired Fleet introduction date

Additionally, an OR will state whether there are ongoing/related efforts which should be coordinated with the project.

If any of the above requirements elements are deficient, efforts should be initiated to obtain the needed information prior to, or as soon as possible during, the conceptual phase.

ORIGINATION OF REQUIREMENTS

Requirements can be operationally (user) generated or technology-generated. The acquisition process assumes that all requirements are operationally generated, but most successful projects are, in fact, championed by the technologist. (Over 9 out of every 10 projects were actually technology-generated.) Nevertheless, the successful technologist obtains user support and at least maintains the appearance of operational generation of the requirement. There are perhaps 1000 times more valid needs than there are budgetary resources to support formal requirements to address those needs, so mutual support from OPNAV (representing the user communities) and the systems command (representing the technologies) is needed to establish a formal requirement.

Fleet deficiencies are often identified by the type commanders through the systems commands. This process sometimes loses the initial operational flavor and assumes a technical solution. This process may miss the opportunity to reserve several problems beyond the original statement of deficiency, resulting in a requirements statement which is too narrow in scope.

The technologist often "sells" a technology to the user community as a potential solution to various needs. This may result in an attempt to misapply the technology to do more than it can do effectively. Also, the Fleet may not be able to develop a clear concept of how the technology should be employed or supported. This results in a requirements statement which is poorly defined and probably too broad in scope.

The source of the requirement is important to the system designer because requirements are never adequately defined. Operationally generated requirements probably will not have realistic cost or schedule constraints and may make technical assumptions which attempt to violate laws of physics. Technology-generated requirements probably will not have clearly stated concepts of employment and concepts of support. The behind-the-scenes maneuvering to generate a requirements document which will be supported by the budget process normally leads to the omission of even the valid information which might have been available to the original person recognizing the need. Therefore, the system designer almost always must dedicate some significant effort towards clarifying the requirements. For further information, see chapter IV.

REQUIREMENTS ORIENTATION

Requirements are operationally oriented or technology-oriented. Operationally oriented requirements include:

- Requirements to counter new threats
- Requirements to support new tactics

Technology-oriented requirements include:

- New capabilities of technology to
  - create a new threat potential
  - establish more effective tactics
  - be put to use (GEE WHIZ factor)
- Capabilities to replace obsolete equipments to
  - reduce the cost of ownership
  - increase reliability and maintainability
  - improve operability
  - improve survivability (especially in the face of new threats)
  - provide additional capabilities (faster, more lethal, etc.)

The orientation of the requirement directly affects the statement of requirements and the level of information which is initially available to the system designer. The orientation may also affect the project priorities and may restrict the system engineering options.

Regardless of the initial orientation of the requirements, the system engineer should assess the system design from all orientations in the process of clarifying the requirements. The project manager should be aware of the requirements orientation and the requirements origination in order to properly assess the "politics" behind the requirements statement.

III. PROGRAM PLANNING

This chapter provides some keystones of demonstrated value in the organization, planning, and execution of a project. The manager is exhorted to consider goals, resources, constraining factors, and risks as one coherent entity.

Program planning is an art which attempts to assemble a number of conflicting elements into a coherent, practical plan leading to an acceptable result. These elements are:

Program objectives
Available resources
Constraining factors
Risks

Thus, the program plan must achieve the program objectives with the available resources within the constraints at an acceptable risk.

The program objectives will include, as a minimum, the satisfaction of the operational requirement. If the requirements are not sufficiently well defined, any undertaking to satisfy them will waste valuable resources. Often additional objectives will be manifest, such as "delivery by 1979," "within $30,000," or "maintain compatibility with what we have now." These additional objectives may not be wholly consistent with the "best" solution to the primary problem; nevertheless, they must be addressed. Sometimes it is possible to influence the statement of objectives. If so, try to make the primary objective (satisfying the operational requirement) as clearly defined as possible and minimize other objectives. When sec-ondary objectives are included, determine how much flexibility can be tolerated in meeting them.

Resources include:

- manpower
- talent
- facilities
- time
- funding
- test equipment
- information, and the like

These resources are the raw materials from which the program is built. The primary problem is to determine what types and levels of resources will be needed. Manpower and talent together comprise personnel resources, which are indispensable; they are cited separately to emphasize the fact that people and knowledge do not solve problems—knowledgeable people solve them. Time is a flexible resource which is normally not a problem unless there is not enough (as when a ship schedule must be met). Most of the other resources can be tapped easily enough as long as it is known that they are needed. The most important resources are personnel and funding; most projects succeed or fail on the availability of them. The typical failure has an excess of manpower, a paucity of talent, and a lack of control on the allocation of funds. Less is better. Too many people make a project unmanageable and obscure valuable talents from the tasks to which they should be applied. If one could give the program objective to a single engineer, possessing the knowledge and talent needed, a "best" product would result. However, most projects contain complexities that an individual cannot cope with alone, so a team of specialists is usually assembled. Nevertheless, the tendency is to have too many "cooks" on the project. The Sidewinder missile, Mirage fighter, and the Navy's first nuclear propulsion plant were all designed by teams of fewer than 40 individuals. On the other hand, the C-5A was "designed" by over 1200 engineers and the F-111 by over 600. The personnel resource requirement should be based on the talent necessary to complete the tasks with a minimum amount of manpower. Personnel and funding are inextricably related. The level of funding required must be sufficient to obtain access to the necessary level of other resources; the complexities of funding are discussed separately later in this chapter.

The most obvious program constraints are limits on, or a lack of, resources, particularly funding and time. Constraints are always present since no resource is infinitely available, but the constraints are not crippling unless they limit a resource at a level below sufficiency. If a resource is constrained below the level of necessity, the program should be canceled; however, most constraints simply limit planning options. Two more subtle con-straining factors are policy and politics. Most policies simply provide guidance or standardize procedures and do not pose planning problems as long as they are known. Policies which pose problems which cannot be tolerated can be changed or waivered as long as valid justifi-cation exists. Request the change or waiver from the originator of the policy; if relief is not obtained, a solution to the problem can generally be found with the policymaker's help. Politics can make or break a project. Typically, an otherwise flexible constraint will become cast in concrete through political manipulations, and adverse decisions will be made beyond con-trol of the project. Every situation is different, and little guidance can be offered here except to know the strength of friends and the weaknesses of foes and to try to let project friends do battle, allowing project personnel to remain behind the scenes and seemingly aloof of the wars. In general, it is desirable to influence constraining factors to allow a maximum amount of flexibility; this allows the project manager to place the constraints on tasks rather than outside influences.

Risks are always present in any program, but they can generally be managed and reduced to an acceptable level. Project planning must provide a framework to identify, assess, and act upon risks. The resources necessary for these functions consist of valid information and proper talent. Additionally, the project must be sufficiently flexible to accommodate changes which may be necessary to manage risks. Risk management is a function mandated to the project manager by DoD Directive 5000.1 and SECNAV Instruction 5000.1. Some techniques and methods for managing risks are contained in chapter XXI.

ORGANIZATION

The program plan organizes the program elements in a series of tasks to achieve the program objectives, determine resource requirements, and identify constraining factors and risks. When the tasks are well defined, it is easier to make the estimates required, particularly estimates of funding and schedule. As in any estimating process, there are always latent estimating errors. Assuming reasonable estimating (not chronically optimistic or pes-simistic), estimating errors can be drastically reduced for the collective project by making increasingly more detailed estimates because actual estimating errors will tend to cancel as they are aggregated and errors of omission will tend to be limited by the thoughtful uncovering of obscure detail tasks.

The standard method of organizing this hierarchy of tasks is the Work Breakdown Structure (WBS). MIL-STD-881 provides guidance in constructing WBSs. Once constructed, the WBS becomes a convenient framework for organizing task assignments, budgeting resources, assessing risks, estimating life-cycle costs, and a host of other management tasks. The complexity of the WBS will directly reflect the complexity of the program. The WBS for simple projects can easily be managed by hand; for complex projects, the aid of a computer is useful. It is advisable to create separate breakdowns using a common WBS for the following program items:

Tasks and resource requirements
Costs
Milestones
Risks
Nonrecurring and recurring life-cycle costs
Production costs, fixed and variable
Technical performance measures

In each structure, it is advisable to recognize the design, fabrication, test, assembly, and documentation tasks associated with each level of complexity; such a breakdown will improve the accuracy of estimates made at the level even though it may not be either practical or desirable to collect accounting data at that level. Refer to chapter XXII for guidance on How to Use a Work Breakdown Structure.

For a complex system, a WBS may contain as many as seven, eight, or nine levels. While the manager must be aware that the detailed levels exist, he must also be careful not to get mired and saturated in details. As a rule of thumb, no individual should attempt to directly manage more than four levels; this figure has been well established by empirical study across both government and industry. A complex project might be organized as illustrated below.

Individual Responsible	Equipment Breakdown Level
Project Manager/System Engineer	1. System 2. Subsystem 3. Sets
Deputies (one per group)	4. Groups 5. Units 6. Assemblies
Lead Engineers	7. Subassemblies 8. Modules 9. Parts

Of course, each project is different, so the project organization must conform to the project peculiarities. Organizational boundaries, equipment complexities, and technology implications may dictate the organizational structure. In any case, the goal is to create a project organization in which each task is assigned to the most capable individual possible giving him the responsibility and authority to execute that task and providing a clear-cut chain of command, integrating him into the organization as his task is integrated into the project. The clear-cut chain of command is essential to the accomplishment of the higher-order tasks at the system/subsystem level and to the maintenance of accountability among those working on the project.

Obviously, many tasks are contingent upon the completion of other tasks. The relationships between tasks are important to two essential management functions: tracking progress and risk management. When estimating the time required to complete a task, it is important to consider the impact on other tasks if schedule must be slipped or cannot be made at all. If this effort is included in the initial planning, realistic alternative plans can be developed and appropriate allowances can be made for schedule slippages. A common error in milestone planning is to assume that each task will be completed in an expected (most likely) time. In practice, each task will be completed early or late with the average of all tasks at the expected time. But early completions of a subtask frequently do not contribute to an early completion of the larger task, whereas a late completion of a subtask may make late completion of the larger task inevitable. Studies of large numbers of projects in the government and industry show an average schedule slippage of 25% beyond the expected end date. Careful milestone planning will compensate for inherent slippages so that the end objective is reached when promised.

MANAGEMENT INFORMATION SYSTEMS

Project management must be cognizant of the progress and problems of the tasks in order to correct problems early and to steer the project to a successful completion. It is impossible to wholly replace personal contact between the manager and the performers; how-ever, very large and complex projects make adequate personal contact difficult to achieve. Literally hundreds of management information systems have been evolved to assist managers in keeping track of their projects. To be useful, a management information system must have the following characteristics:

The manager must be familiar with it.

Reporting personnel must understand it.

It must track all the elements critical to the particular project (and preferably no others) (note: these vary from project to project).

It must be timely and accurate.

It must be easy to implement.

Management information systems may run the gamut from informal memos to highly structured computerized systems. From the characteristics above, it can be inferred that the system is nothing more than a method of communicating essential information. Often the system also provides a formal record of progress among organizations. Many of the systems are expensive to implement because they require extensive changes to the reporting organi-zation's way of doing business. Wherever possible, the manager and the reporting organizations should determine a system by mutual agreement. Also, ask only for information which can be used; the purpose of an information system is defeated by extraneous data which can obscure real problem areas.

It is far better to limit the size of a project so that personal contact can be used for management information than to have to implement a management information system in the first place.

FUNDING

No acquisition program can even begin without funding. No matter how badly the Fleet wants or needs the product of a good idea, the product cannot reach the Fleet unless a sponsor is found for the acquisition program. Within the vast acquisition community bureaucracy, there are a number of pots of discretionary funds. To tap these funds, the project must appeal to the prospective sponsor and must be something for which he can gain support through his normal budget channels. Under these conditions, it is possible to get some funding to get started. However, discretionary funds are only a mechanism to get a small amount of funding (usually less than $100k). The full project funding must be obtained through the budget cycle; the discretionary funds should normally be applied toward project planning activities leading to budgetary estimates. The cycle of activities which lead to the formation of the DoD budget and (it is hoped) to the approval of project funds is a long one fraught with pitfalls; the project manager should be aware of these activities and plan his tasks to deliver the right information to the right people at the right time. The budget cycle is formalized in the Planning, Programming, and Budgeting System (PPBS). Virtually all planning in the bureaucratic structure above the project manager is oriented toward the budget. Programming is deciding which budget plans will be put into the budget submission. Budgeting is the dispensing of approved funds and reprogramming those funds as necessary to cover budget overruns. Each level in the chain of command has some authority in the review and reprogramming of funds; project funding is susceptible to alterations at each level. The higher review levels receive only abbreviated information about the budget elements, so changes at high levels are frequently more arbitrary and not within the influence of the pro-ject manager. On the other hand, the levels near the sponsor can be influenced. The project manager can greatly enhance the project funding prospects by:

- developing strong project justifications
- marshaling user support
- selecting a strong sponsor

A project may come under review for potential cuts as often as every 3 weeks, so a committed sponsor is critical. Equally important is the timing of proposals and justifications; figure III-1 shows the PPBS cycle with the points where action may be indicated. For a more detailed explanation of the PPBS, see DoD Instruction 7045.7, SECNAV Instruction 5000.16E, and the Navy Programming Manual.

When making funding estimates, characterize the estimates in accordance with OPNAV Instruction 7040.5; for convenience the appropriate categories are listed in table III-1.

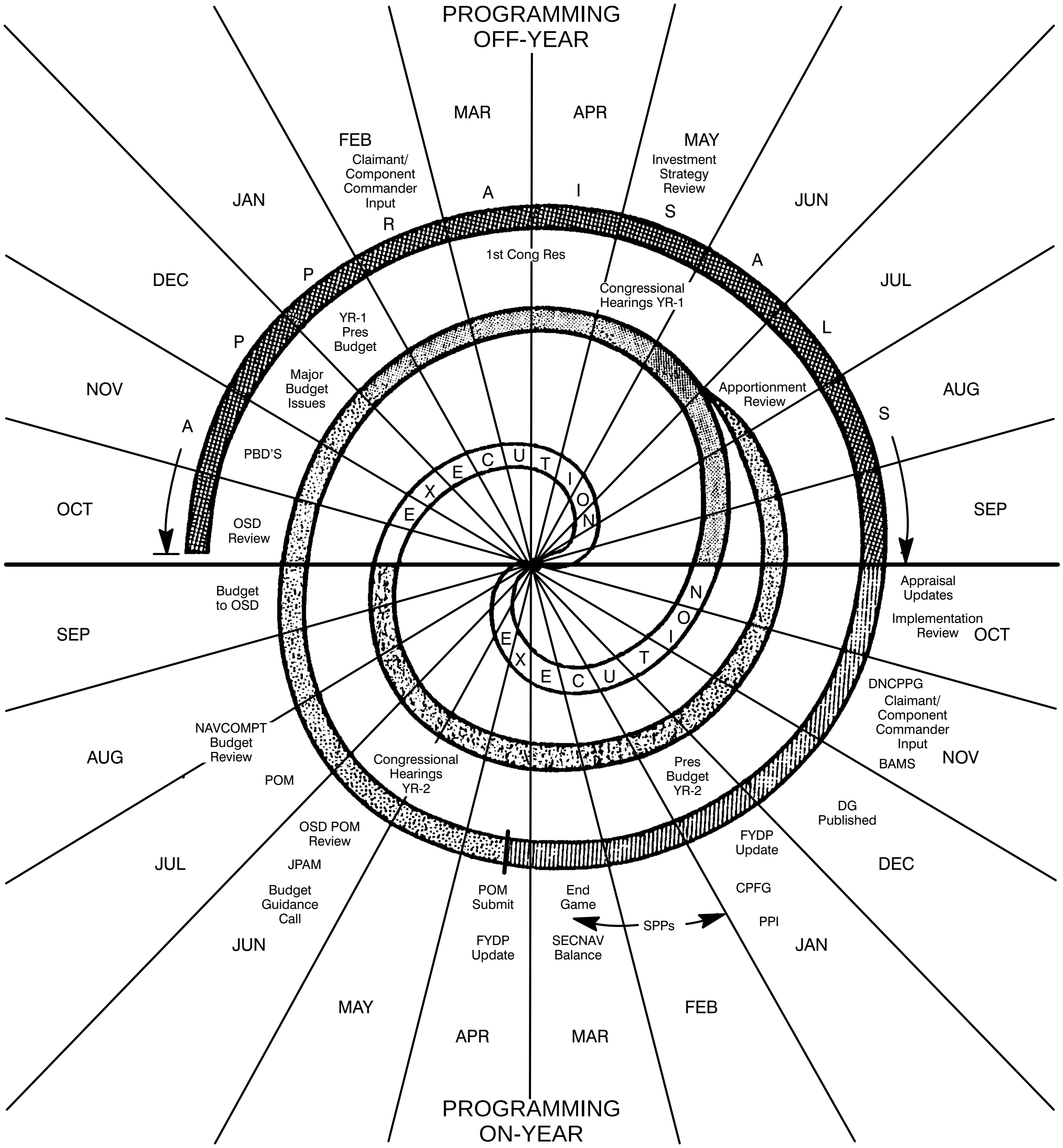


Figure III-1. Planning, programming, and budgeting system (PPBS) cycle.

Table III-1. Cost estimate categories.

Category	Description
A	Contract for item(s) under consideration in existence. Cost estimate based on, included in, or modifying existing contract. In operating accounts, estimate based on firm pay rates or firm operating program costs with requirements defined in detail.
B	Request for proposal (RFP) for item(s) under consideration in hand. Cost data based on Navy's evaluation of the RFP. In operating accounts, estimate based on approved budgeted pay rates or operating program costs with average requirement accurately defined.
C	Lowest budget quality estimate. Based on engineering analyses of detailed characteristics of the item(s) under consideration. In operating accounts, estimate based on proposed budget pay rates or operating program costs with requirements defined in total.
D	Estimate based on technical feasibility studies and/or extrapolation from higher quality estimates for similar item(s). In operating accounts, pay rates or operating program costs should be at least category C but operating requirements are defined only to + or − 10% order of magnitude.
F	Ballpark estimate. Proposal required further definition or further study to refine costs where a higher category, save for one or two requirements thereof, would be justified; this should be spelled out.

When formulating justification, emphasize the project features which are most relevant to the interests of the reviewers and describe them in terms appropriate for the budget category of the funds being made available to the project. The budget categories are described in table III-2.

Table III-2. Navy budget categories.

Research, Development, Test and Evaluation, Navy (RDT&EN)

6.1 Basic Research
6.2 Exploratory Development/Applied Research
6.3 Advanced Development
6.3a Technology originated
6.3b Operational Requirement originated
6.4 Engineering Development
6.5 Systems Engineering Support/Operations Analysis
6.6 Operational System Development and Unallocated RDT&E (to cover emergent requirements)

Military Personnel, Navy (MPN)
Operation and Maintenance, Navy (OMN)
Procurement of Aircraft and Missiles, Navy (PAMN)
Shipbuilding and Conversion, Navy (SCN)
Other Procurement, Navy (OPN)
Military Construction, Navy (MCN)
"Other" Navy (Naval Reserve and Marine Corps)

Important. The budget cycle is at least 2-3 years long, especially when large dollar amounts for procurements are involved; therefore, thorough and accurate advanced planning is essential to ensure that funding is available to support project activities.

PROJECT DOCUMENTATION

The number and variety of documents required simply because a project exists are enough to stagger the imagination. Unless the project manager is prepared, the documentation requirements will be overwhelming. Many of the documents are necessary to obtain funding or to gain various forms of approval. The documentation which may be required in the course of the project in conjunction with the tasks is discussed in the Documentation section of this guide (see chapter XX). Despite all these diverse papers, there are still documents which will be required in one form or another during the project. The sponsor may author some of these documents or may task the project to generate them. Table III-3 sum-marizes the documents, their purpose, and the guidance to their preparation where available.

Usually, there is some flexibility in the preparation of the documents. Often it is possible to survey the various required documents and to write a few paragraphs which, with some cutting and pasting, can satisfy all the requirements. At the same time, there is no point in writing a series of paragraphs filled with pap. Try to make the documents meaning-ful, concise, and accurate; then the few times someone actually uses them, they will work for the project.

Important. Most program documents are reviewed, approved, and used by people who are busy with “fire drills.” Therefore, the documents should be organized to be read and understood in 5 minutes or so. Key issues and proposed resolutions should stand out from supporting information. Documentation should be information rich and not obscured by excessive data or verbage.

Table III-3. Project documents.

Category/Department	Purpose	Reference
Requirements		
Operational Requirement (OR)	Project objectives	OPNAVINST 5000.42
Development Proposal (DP)	Project approach	OPNAVINST 5000.42
Navy Decision Coordinating Paper (NDCP)	Development concept	SECNAVINST 5000.1
Science & Technology (S&T) Objectives	General technical goals	OPNAVINST 5000.42
Program Planning		
Program Management Plan (PMP)	Identifies project objectives, resources, constraints, risks, and management approach	See chapter XXII

Table III-3. Project documents (continued).

Category/Department	Purpose	Reference
Program Planning		
Test and Evaluation Master Plan (TEMP)	Identifies T&E issues, objectives, and resources	OPNAVINST 3960.10
Integrated Logistic Support Plan (ILSP)	Documents support concepts, objectives, and constraints; includes plans and shows relationships between reliability, maintainability, human engineering, safety, personnel & training, provisioning, transportability, tasks, etc.	SECNAVINST 5000.39A OPNAVINST 5000.49A
Configuration Management Plan (CMP)	Management approach to maintain configuration control	SECNAVINST 4130.2
Data Management Plan	Procedures for processing and distributing project data	NAVMATINST 4000.15A (NAVSUP)
Security Plan	Project security procedures	See chapter XXII
Proposed Military Improvement (PMI) Proposed Technical Improvement (PTI)	Initiates installation planning	OPNAVINST 4720.2
Procurement Plans		
Acquisition Plan	Major procurements planning and request for authority	Acquisition Planning Guide (ASN SdL)
Miscellaneous		
Research & Technology Work Unit Summary (DD 1498)	Establishes a record of the existence of the project	SECNAVINST 3900.29B and local instructions
Quality Assurance Plan	Establishes project procedures for quality review, verification, and certification/acceptance	NAVMAT 4855.1 (SPAWAR), MIL-Q-9858A, or MIL-I-45208

Table III-3. Project documents (continued).

Category/Department	Purpose	Reference
Miscellaneous (continued)		
Standardization Plan	Determines the levels of standardization to be implemented and parts selection of criteria	See chapter XXII

PROGRAM TAILORING

If one could give the program objective to a single engineer, possessing the knowledge and talent needed, a "best" product would result. This statement is worth repeating in order to emphasize the necessity of keeping a project manageable. On the other hand, most projects vastly exceed any single engineer's knowledge, talent, or capability to execute the needed tasks within a specified time, so the project team approach becomes the practical solution.

The concept of doing just enough to do a thorough and adequate job is called tailoring. Most of this guide is dedicated to tailoring concepts. For instance, chapter XX includes procedures for tailoring documentation requirements. The "cover your anatomy" approach to equipment acquisition is extremely expensive and wasteful of resources, and often leads to project failure by emphasizing nonproductive tasks. The techniques of tailoring constitute a balancing act between insufficiency and overkill. The essence of all the advice in the chapters which follow is, "Require exactly that which is needed."

The problem of program tailoring is that an almost infinite amount of knowledge is required in order to absolutely define what is needed. Gathering this knowledge expends project resources. Eventually a point of diminishing returns results wherein the new knowledge gained requires more resource expenditure than what can be saved in the acquisition of equipment. At some point prior to the point of diminishing returns, there will be sufficient confidence in the information at hand that decisions can be made with an acceptably low risk.

The perception of "acceptable risk" is affected by technical difficulty, resources ($) at risk, and the level of review interest. Larger projects incur higher level reviews, but even small projects can receive high-level review interest because of the potential military benefits. The higher levels of review and greater resources at risk demand a lower technical risk to compensate for the higher political risks. A very small project can tolerate higher risks because a complete project failure constitutes a small loss. A very large project demands low-risk decisions because even a partial failure constitutes a very large loss.

The information level needed for very small efforts (the one- or two-man efforts on the order of $500k or less) can be satisfied by educated guesses in most cases. The individ-ual(s) executing the tasks should be thoroughly experienced in the critical tasks to be performed, such as design or installation planning or testing. On less critical tasks, appropriate expert advice should be located on a free- or part-time basis. The task leader should be responsible for researching noncritical issues to his satisfaction. The success of the project will hinge on the selection of task personnel and on the proper determination of critical issues.

At the extreme of the very large project (major program as defined in DoD Directive 5000.1), supporting research and test projects should be utilized to validate information as well as gather it. Full-time expert assistance will be utilized for a large range of issues. The size of the program will limit the number of issues which can be treated as noncritical.

To illustrate program tailoring, consider the issue of reliability as it might be treated by projects of various sizes. In a very small project, reliability can probably be ignored as an independent issue; good design practices can be depended on to yield sufficient reliability. The small project might require a reliability prediction for support planning purposes, but a cursory prediction using MIL-HDBK-217 can suffice. An intermediate project would require a more detailed prediction and would probably require a failure modes and effects analysis (FMEA); a reliability specialist would be employed to assist in these tasks. Also, intermediate projects may use reliability testing as a portion of qualification tests. Large and very large projects may employ a full-time reliability specialist to directly influence the equipment design and to perform other reliability tasks; reliability testing should play a significant role in the reliability program as a formal reliability growth technique may be utilized. These brief descriptions show how a given issue gains importance with project size and management response grows accordingly. In each case, it is assumed that reliability is not a critical issue in the operational requirement; if it were, a more intensive effort would be made for each project size.

Table III-4 describes the levels of information which give various degrees of confidence to the decision-making process. Refer to chapter XIX for information regarding the test and evaluation procedures which are essential to high-confidence decisions. Figures III-2 and III-3 are provided to help conceptualize the relationship between project size and the acceptable levels of information for project decisions.

Require what is needed, reject the unnecessary. Obtain expert advice during early program planning to assist in the tailoring process.

Table III-4. Levels of information for decision making.

0.	Noneducated guess	guesses
1.	Educated guess by a nonexpert	
2.	Educated guess by an expert	
3.	Expert advice	information developed from experience
4.	Research and analysis	
5.	Analysis and simulation	validated information
6.	Diagnosis of prior experience	
7.	Partial testing in use (such as a Fleet Research Investigation or Development Assist)	
8.	Full-scale testing in use (such as an Operational Assist or OPEVAL)	

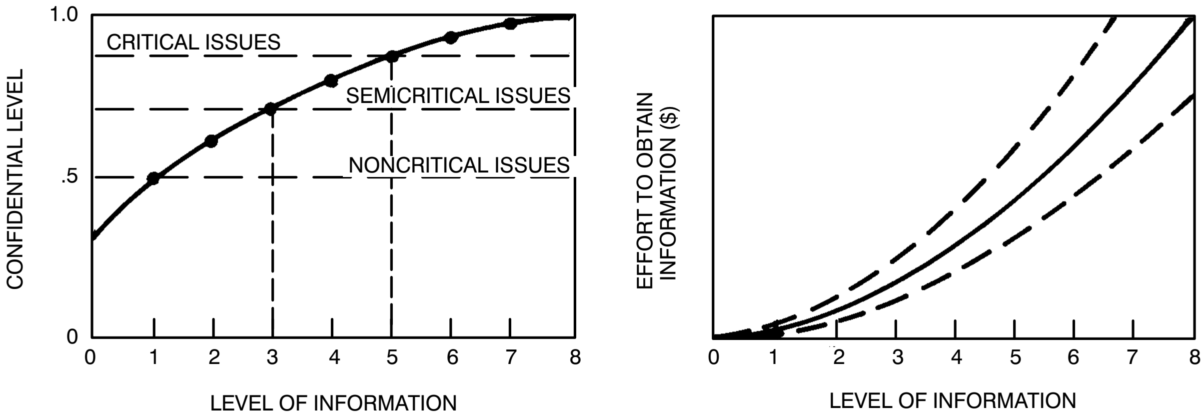
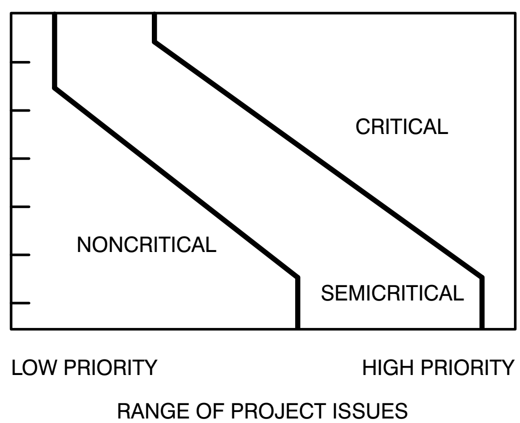


Figure III-2. Level of information (from table III-4) vs confidence and effort to obtain.



ACQUISITION CATEGORY	REVIEW INTEREST	PROJECT SIZE RDT&E $	PRODUCTION $
I	SECDEF	> 500M	> 1B (VERY LARGE)
II	SECNAV	> 100M	> 500M (LARGE)
III	OPNAV	< 100M	< 500M
IV A	SYSCOM	< 20M	< 100M (INTERMEDIATE)
IV B	SYSCOM	< 5M	< 20M
IV C	SYSCOM	< 2M	< 5M (SMALL)
IV D	SYSCOM	< 500k	< 2M (VERY SMALL)

Figure III-3. Project size vs range of project issues.

CHAIN OF COMMAND

The project manager and systems engineer must respond to two chains of command—their own administrative chain of command (NRaD branch head, division head, depart-ment head, engineering director, etc.) and the project chain of command (acquisition manager, OPNAV sponsor, SECNAV, DoD). The acquisition system is governed by law, rules, regulations, directives, and instructions; these regulatory constraints, policies, and procedures are implemented through the administrative chains of command of each organization participating in the project.

The separate organizations each have their own set of implementing instructions, which may cause conflicts between organizations participating in a project and conflicts with specific project goals. Often an organization will have implementing instructions which define a standard operating procedure and which require approval for deviations from the standard. It is important for the project manager to become familiar with the key instructions of each organization in the project chain of command as well as those in the administrative chain of command. When potential conflicts exist, the project manager should initiate a preferred resolution in writing and obtain approval from each chain of command. Table III-5 provides a listing of the instruction standard subject classification numbers which should be investigated for applicability to a project. When key documents are obtained, check their references to determine if additional documents are required.

Table III-5. Key instruction standard subject classification numbers for projects.

SECNAVINST 5210.11C Standard Subject Identification Codes

1500	Training
2000	Telecommunications
2200-2299	COMSEC
2240	TEMPEST
2400-2499	EM Spectrum, esp 2400, 2410, 2420
2450	EMC
3000	Operations and Readiness
3080-3099	Reliability and Maintainability
3560	(Embedded Software)
3900-3999	RDT&E
3900	General
3910	Plans
3960	T&E
3961	TEMPs
4000	Logistics (General)
4105	ILS
4120	Standardization (Specifications, parts selection)
4130	Configuration Management
4140	Life-cycle Cost Model Records
4200-4399	Contracting
4200	General
4210	Policies
4275	Contract Clauses Administration
4330	(Warranty provisions)
4400-4499	Supply Material
4408	Spare Parts
4423	Provisioning and Documentation
4490	Advanced Planning
4700-4799	Maintenance, Construction, Conversion
4700	General
4720	Alterations and Improvements
4750	Upkeep (PMS)
4790	Maintenance Engineering/Level of Repair
4800-4899	Production Preparedness
4855	Quality Assurance/Control
4858	System Effectiveness/Value Engineering
5000	General Standard Operating Procedures
5100	System Safety
5200-5299	Management Programs and Techniques
5200,5234	Software Standards
5370	Standards of Conduct, Ethics
5500-5599	Security
5510	Information Security
7000	Financial Management (Cost Estimating)
8000	Ordnance Material
9000	Ship Design
13000	Aeronautical Material
13050	Avionics Configuration Management
13070	Avionics Reliability
13630	Aeronautical ATE

IV. CONCEPTUAL PHASE

Decisions made during the conceptual phase dedicate a significant portion (typically 70%) of a system's total life-cycle costs; sometimes costs can be affected by as much as two orders of magnitude. In order to achieve the most overall performance at the lowest cost, the conceptual phase must consider the total user requirements while completing the normal tasks of the project phase. This chapter discusses the tasks to be performed and ways to integrate the total requirement into them. The management of technical risk is included as a primary task.

INTRODUCTION

The conceptual phase of any program or project is critical to its ultimate success or failure. In general, this phase is placed in jeopardy by the lack of resources made available to resolve the very large uncertainties bearing upon the feasibility of applying technologies to perform the tasks needed to satisfy the stated requirement. The problem thus posed is further exacerbated by the ability to defer unresolved questions into later program phases. On the other hand, it would require an inordinate amount of time and expenditure of resources to completely resolve all pertinent issues. Some amount of risk must be assumed in order to satisfy the stated requirements expeditiously. Therefore, the tasks of the conceptual phase are twofold:

To formulate feasible approaches to the problem solution

To assess and manage the risks associated with each

These tasks are normally performed in two closely associated steps known as concept formulation and technical approach development. The first step delineates one or more promising concepts; the second integrates into the overall program plan, assesses risks, and provides proof of feasibility (or infeasibility) for each concept (see figures IV-1 and IV-2).

A most important element in concept formulation is ensuring that as complete a set of factors as possible is used to identify promising approaches; these factors include, but are not limited to, the following:

- Functions, modes, inputs, and outputs dictated by the requirements
- Mission constraints, such as reaction time, probability of detection, and probability of error, preferably embodied in an effectiveness model
- Support constraints, including minimum acceptable values, for reliability, maintainability, availability; goals for operability and transportability; and safety requirements
- Environmental constraints tailored to the worst-case conditions under which the equipments are expected to operate (not necessarily full MIL-SPEC)
- Cost constraints in both acquisition and support of the equipments, assessed through an LCC model

- Producibility constraints arising from the quantities required in the near term and far term

Ultimately, the system must be capable, supportable, and affordable. The importance of a well-defined operational requirement as a baseline to this effort cannot be overstressed. The methods of defining requirements depend on the type of requirement. In general, operational requirements will fall into one of the following categories:

1. Replacement of an existing capability or group of capabilities

2. Replacement of existing capabilities plus additional features which enhance those capabilities

3. Replacement of existing capabilities plus new capabilities

4. Supplanting of existing capabilities by new capabilities

5. Entirely new capabilities

A capability is an ability to accomplish a sub-mission (i.e., to detect, to communicate, to track); the sum of capabilities constitutes an ability to perform operational missions (i.e., ASW, AAW, gunfire support, convoy escort). Requirements to replace an existing capability (categories 1-3) can usually be stated as deficiencies to be corrected or improved upon while assuming nondeficient characteristics as extant. Category 1 requirements almost always arise from obsolescent equipments which are, or are becoming, difficult to maintain, hard to support, unreliable compared to what can now be attained, and so forth; detailed information on the support characteristics and support parameters (MTBF, MTBCM, MTTR, A_O, MDT) should be obtained on the existing equipments and used to establish minimum acceptable parameters and design goals for the current project. Category 2 requirements generally involve performance deficiencies but may also contain support deficiencies; the required performance characteristics may usually be generated through threat analysis and operations analysis, if they are not explicitly stated in the requirements document. Category 3 requirements usually arise from expanding missions or where it has become desirable to automate previously manual functions; category 3 performance characteristics will tend to be more operationally oriented than those of category 2, but are similar in the steps needed for their derivation. **All requirements based in existing capabilities (categories 1-4) should depend on a detailed knowledge of those capabilities and their deficiencies in performance and supportability to derive the goals for the new equipments**.

Requirements based on new capabilities to some extent (categories 3-5) must have definitive characteristics stated; if not supplied in the requirements document, threat analysis and operations analysis will be necessary in some degree. However, the best method (in terms of the accuracy of information obtained) for determining the required characteristics is a Fleet Investigation (see OPNAVINST 3960.10 series). The Fleet investigation should be instrumented to measure all parameters pertinent to the particular threat scenario, so that effective methods of simulation and accurate test plans may be generated to support the proof of feasibility phase.

As a guiding policy replacement capabilities should be at least as good in performance supportability as replaced capabilities at less total life cost; or should supply improved performance/supportability at the same cost; or both. New capabilities should be incorpo-rated within well defined bounds for acquisition cost, support costs, and logistics requirements.

Ultimately, the operational requirements must be transformed into technical (specification) requirements. The following sections discuss the formulation of the various technical parameters; however, a guiding force in the ensuing tradeoffs must be the criticality of the system or equipments to the operating organization (ship, airwing, etc.) which it services. The following definitions are provided:

Vital	Equipments which are essential to the primary mission(s) of the organization or for damage control or for personnel safety
Semivital	Equipments which are essential to secondary missions or which are supportive to the primary missions, damage control, or personnel safety
Nonvital	All other equipments

Note that a vital system (such as uhf shipboard communications) might be made up of semivital equipments by virtue of the inherent system redundancy. Conversely, an equipment which is common to a number of semivital systems might be considered vital if no sufficient backup is provided. These categories are useful in establishing:

The level of risk which can be acceptably assumed without terminating the program (see table IV-1)

The acceptable limits for support parameters, especially mean downtime and maximum downtime

The priorities and proportional shares of funding and manpower resources which can reasonably be allocated to the equipment in development, procurement, and support

On the last point, it is obvious that the cost-benefit payoffs must be significantly higher for a nonvital or semivital equipment to justify equal consideration with a more vital equipment competing for the same resources. The determination of system criticality is normally stated in the requirements documentation, although sometimes implicitly, and must be considered in the program planning (see chapter III), as well as in the determination of support parameters (see SUPPORT PARAMETERS in this chapter).

The above considerations require a great deal of information in order to make intelligent decisions early in the conceptual phase. In large measure, the manager's ability to control risks and to achieve ultimate project success rests in his knowledge of what uncertainties exist and his utilization of available information to make correct determinations. The next section deals with prospective sources of information.

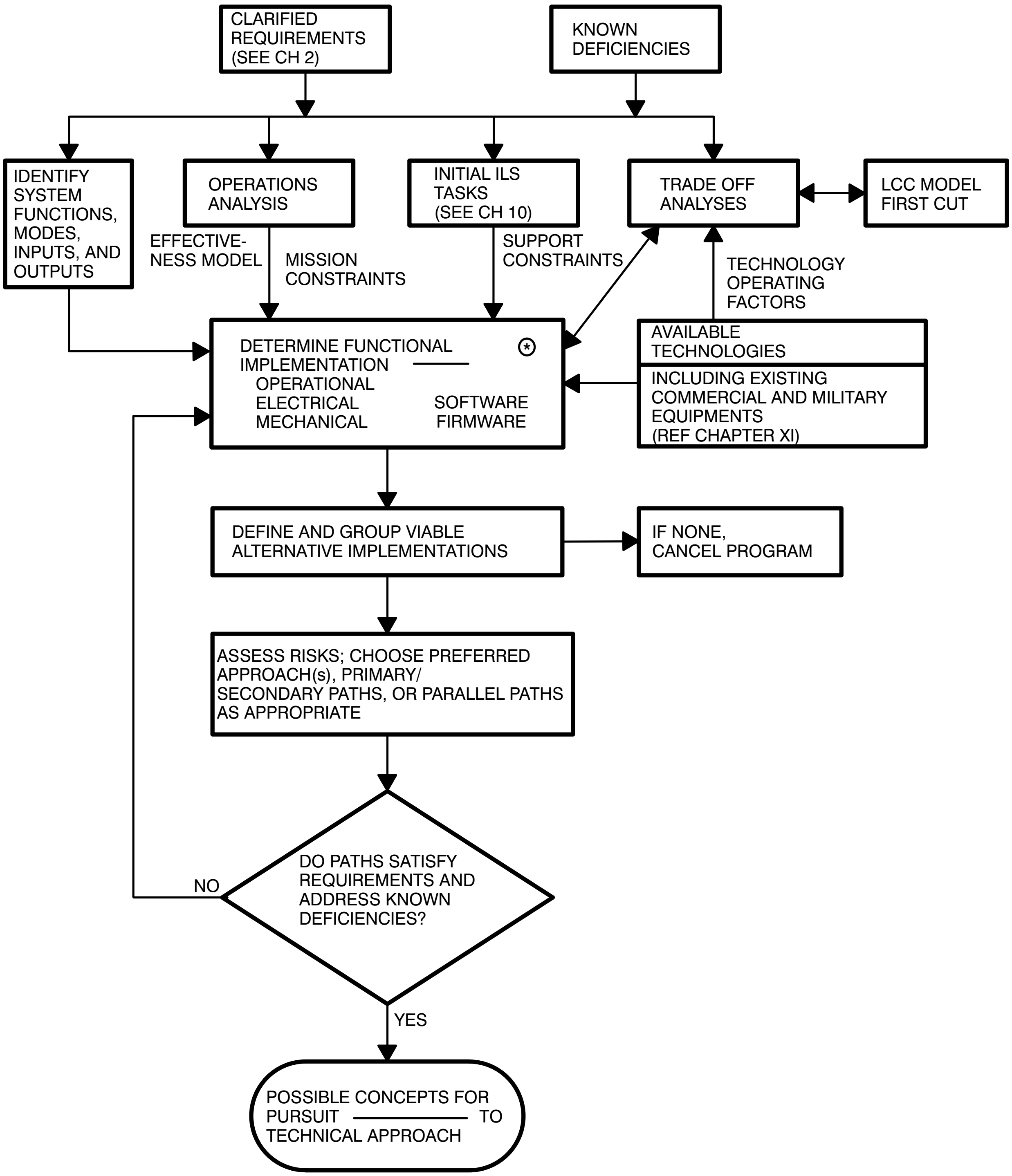


Figure IV-1. Concept formulation.

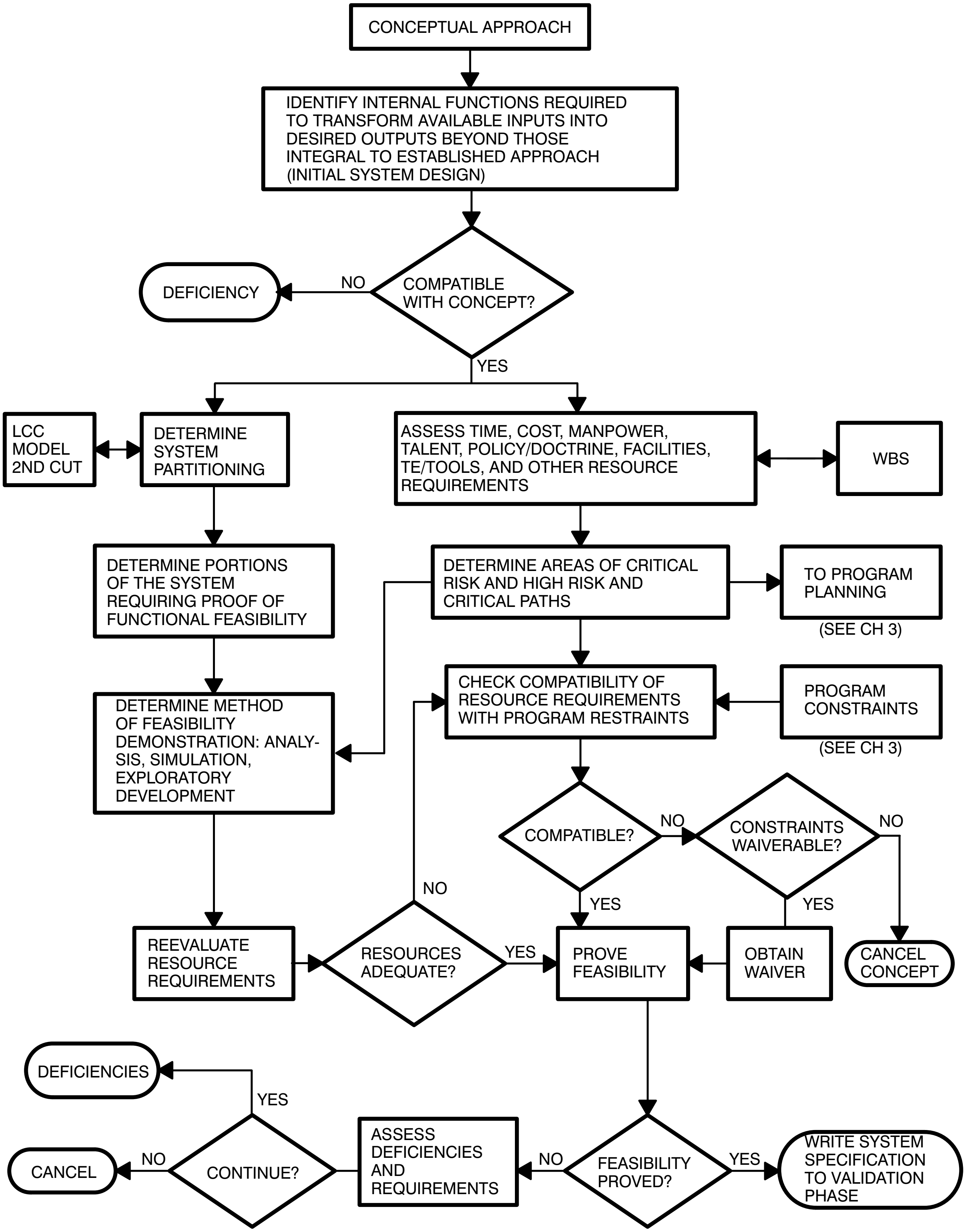


Figure IV-2. Technical approach (for each possible concept).

Table IV-1. Initial risk assessment.

System Character	Risk Assessment	Action
The major items in the system have been previously developed and used together. (Development of noncritical ancillary items is permitted.) (Minor modifications are allowed.)	low	Choose a Preferred Approach which seems most promising to meet project objectives; several approaches may be considered preferred if no clear-cut advantages exist for one over the others.
The major items in the system have been previously developed but have not been used together before.	moderate	Choose a Primary Approach (identical to Preferred Approach under low-risk conditions) and at least one Secondary Approach differing from the Primary Approach in the area of highest risk (most technical uncertainty).
One or more of the major items in the system require development.	high	Choose Parallel Approaches for each item requiring development. At least one of the approaches should be as conservative as possible (i.e., involving minimal uncertainties).

GATHERING INFORMATION

GENERAL

Before putting pencil to drawing board, the engineer will want to obtain as much information as possible about the technology available for application to his design problem. This section is intended to serve as a review of sources of information that the engineer can use to determine ongoing and past technology that applies to his forthcoming system/equipment formulation. The material obtained from this search will allow for valid design decisions as discussed in the next sections, decisions that, it is hoped, will result in an optimal product in terms of cost and effectiveness.

Perhaps the most satisfying and assuring way to determine what is really going on is to have a mouth-to-mouth confrontation with other engineers currently or recently engaged in the type of work of interest. For such a dialog to be of greatest benefit, however, the inquirer should have previously obtained as much background information as possible and some knowledge about the person to whom he is talking and that person's work. For NRaD engineers, the Research Library has practically all the sources of information needed to prepare for meaningful discussion and later design decisions. As a general rule, every information gathering effort should begin with a request for assistance from the Public and Information Services Librarian to save time and avoid trouble.

The remainder of this section covers the information services of research libraries, two outside sources of information, design engineering department services, and the Military Parts Control Advisory Group.

RESEARCH LIBRARY SERVICES

Library services are commonly available to personnel seeking information on available technology and related industry and government organizations and personnel. The following, all available at NRaD, are typical.

Defense Documentation Center (DDC)

Visual Search Microfilm File (VSMF)

Lockheed Information Retrieval Service DIALOG

Systems Development Corporation ORBIT II

Western Research Application Center DATACON

Army ECOM Joint Electronics Type Designations

Miscellaneous Publications

Defense Documentation Center (DDC)

The DDC is the Department of Defense central facility for RDT&E information. One function of the DDC is to acquire, store, announce, retrieve, and provide secondary distribution of scientific and technical documents directly to registered users, including NRaD and its personnel. Quick service is provided by the Defense RDT&E On-Line System of the DDC which connects the Library directly with the DDC RDT&E data banks/Univac 1108 by means of a CRT display keyboard in the library. Information services available from DDC are: Announcement; Technical Report Copy; Bibliography; Selective Dissemination of Information; DD 1498 Work Unit Information; DD 1634 data bank; IR&D data bank; and Referral.

Announcement Services comprise listings of additions to DDC's technical report collection as announced in the Commerce Department's Government Research Announcements and, for classified and limited-distribution documents, DDC's Technical Abstract Bulletin. Both are issued semimonthly and provide descriptive entries and abstracts for reports as well as indexes.

Technical Report Copy Service provides users, upon request, copies of technical reports either in hard copy or on microfiche.

Bibliography Service offers users abstracts of selected documents. In addition to a number of standard bibliographies, DDC will make a computer search to locate those reports most pertinent to a user's research project.

Selective Dissemination of Information (SDI) is an Automatic Document Distribution service which provides regular distribution of microfiche copies of newly acquired documents selected to match a user's specific subject-interest profile.

DD 1498 Work Unit Information Service provides answers concerning the who, what, when, where, how, costs, and other information of DoD-sponsored research and technology in progress. This information includes the name and phone number of the person performing the work. The system is designed to enable the individual user to determine the status of research and technology effort being performed in house or under contract or grant; historical information also may be obtained.

The DD 1634 Data Bank contains R&D program planning information at project and task-area levels.

The IR&D Data Bank contains proprietary information on defense-related in-house work from companies in the DoD-Industry Independent Research and Development (IR&D) program. Because the information is proprietary, its use is limited to those within DoD. The type of information provided is similar to that of the DD 1498 Work Unit Information System. The IR&D data bank can be used through channels other than the on-line terminal, as explained in DSAM 4185.11, the IR&D User's Manual.

DDC's Referral Service provides information about DoD-sponsored specialized sources of scientific and technical knowledge. When information exceeding that contained in DDC is required, this service is used to direct requesters to the National Referral Center for Science and Technology and/or other potential sources of information.

Visual Search Microfilm File (VSMF)

A room is set aside in NRaD's Research Library for use of VSMF equipment — racks holding the 16-mm roll-film cartridges, a microfilm reader-printer, and hard-copy indexes and user's manuals. Two main categories of information are contained on film for retrieval on the reader-printer: "Product Information" and "Specification and Standards." The system is set up for self-use after consultation with the Public and Information Services Librarian.

Product Information Services consists of: Design Engineering Service; Marine Engineering Service; Integrated Circuit Parameter Retrieval Service; and Semiconductor Parameter Retrieval Service.

The Design Engineering Service includes manufacturers' data sheets organized/filmed so that like items appear side by side for rapid comparison. Data are indexed by product description (more than 35,000 descriptions) and manufacturer's name within the following sections:

Electrical
Electronic
Fluid Systems
Instruments
Materials and Fasteners
Power Transmission and Hardware
Production Equipment and Services

The Marine Engineering Service consists of manufacturers' data sheets on marine-unique products and components, and is organized and indexed in the same manner as the Design Engineering Service. (NOTE: Although the Library does not at present provide this service, it is mentioned here because it is available from the VSMF system in the Sustainability Engineering Division, NRaD.)

The Integrated Circuit Parameter Retrieval Service allows IC device selection by defined function, original circuit number, and manufacturer's device number, and the Semiconductor Parameter Retrieval Service allows discrete device selection by electrical and physical parameters.

As for the Specification and Standards Services, information is available on military specifications, MS drawings, military handbooks, and all sections of the American Society for Testing and Materials (ASTM) standards.

The MIL Specification Service contains current military and federal specifications and standards, JANs, and QPLs indexed by document number, title, and product description within the following sections:

Assemblies
Electrical
Instrument
Mechanical
Procedures
General

Two supplements to these data also are provided: “Hot Specs,” which are new, late-release documents; and “Historical,” those documents which have been superseded by documents in the current file.

The MS Drawing Service contains MS, AN, AND, USAF, NASA, and NAS drawings; MIL-D-1000 and associated documents; and Cataloging Handbooks H4-1 and H4-2; with drawings of like items filmed side by side for easy comparison. Indexing is by document number, title, and product description.

The Military Handbooks Service contains all such documents, indexed by document number and title.

The American Society for Testing and Materials Service contains all ASTM standards, indexed by document number and subject, in the following sections:

Metals
Construction
Paint
Petroleum
Plastics
Textiles
Rubber and Electric Insulating Materials
General Test Methods
Miscellaneous

All VSMF Services are updated frequently and regularly to provide current information. In addition, VSMF provides “Extension 99” — telephone data assistance. Subscribers may use a direct telephone link to a staff of data specialists at VSMF headquarters near Denver for assistance in making a search, for information beyond that available, etc.

Lockheed Information Retrieval Service Dialog

Five Lockheed DIALOG files are available at the Research Library which are of particular interest to Center personnel.

NTIS (National Technical Information Service). Contains about 400,000 Government-funded unclassified technical reports.

COMPENDEX (Engineering Index). Has approximately 275,000 citations in all fields of engineering.

INSPEC (Institution of Electrical Engineers). Has 450,000 abstracts in areas of electrical and electronic, computer and control, and physics.

CHEMCON (Chemical Condensates). Has over a million entries in all fields of chemistry.

ERIC (Educational Resources Information Center). All fields of educational research are covered by 185,000 citations.

Systems Development Corporation ORBIT II

Two ORBIT II files may be of value. GEO-REF (American Geological Institute) contains about 4 million items concerning work in geology, mineralogy, oceanography, geophysics, geochemistry, and geomorphology. And SSIE (Smithsonian Science Information Exchange) has about 170,000 entries concerning scientific research projects that are currently funded by federal agencies and state and local governments, universities, colleges, and private foundations.

Western Research Applications Center DATACON

DATACON accesses all NASA and NASA-sponsored research reports. (The current capabilities of the three preceding data files — DIALOG, ORBIT II, and DATACON — include state-of-the-art reviews on a given subject; single author, subject, or contract inquiries; retrospective bibliographies on a subject or concept; and currently funded project searches.).

Army ECOM Joint Electronic Type Designations

The Research Library has 16-mm film cartridges, prepared and maintained by the Army Electronics Command (ECOM), containing data on the parameters of all nomenclatured equipments in the DoD inventory. The cartridges are usable on the VSMF reader-printer.

Commerce Business Daily

Issues of the Commerce Business Daily are located on the periodical shelves of the Research Library. Clues and leads to ongoing technology of interest, and government and industry participators, may be found in the sections on procurement invitations for services and supplies, contract awards, and the solicitation of research and development sources.

Miscellaneous Publications

The annual US Government Manual and the Navy Technical Facility Register (NAVMAT P3999-1) contain information on Government agencies and personnel, the latter being particularly useful for looking up Navy R&D centers to determine facilities, personnel responsibilities, whom to contact, etc. The Public and Information Services Librarian also can direct the investigator to other documents which may be helpful, such as specialty periodicals, handbooks, and annual buyers' guides; society periodicals and handbooks; and vendors' catalogs.

GOVERNMENT-INDUSTRY DATA EXCHANGE PROGRAM (GIDEP)

The GIDEP is jointly sponsored by the Army, Navy, Air Force, Canadian Military Electronics Standards Agency (CAMESA), NASA, FAA, DSA, SBA, and other federal departments and agencies. GIDEP provides automatic interchange of technical data related to parts, components, and materials utilized in military systems. The data are primarily results from environmental testing conducted by participants who are engaged in design, development, and production of military and aerospace equipment. Service is available without charge to users. Information on GIDEP may be obtained from:

Officer in Charge (Code 862)
Fleet Missile Systems Analysis & Evaluation Group
Corona, California 91720
Phone (714) 736-4677 (Autovon 933-4677)

DoD INFORMATION ANALYSIS CENTERS

The Defense Department supports 18 centers for analysis of scientific and technical information. Each center gathers information in its special area of interest; reviews, analyzes, evaluates, synthesizes, condenses, and summarizes the information; and provides it to individual users. The centers produce critical reviews, state-of-the-art monographs, data compilations, and substantive responses to queries. A charge is made for services to both government and contractor users. Information on the particular center most likely to be able to provide the desired information may be obtained from NRaD's Public and Information Services Librarian.

SUSTAINABILITY ENGINEERING DIVISION SERVICES

The Sustainability Engineering Division at NRaD and similar organizations at other Commands provide a number of services to assist the project manager; these include:

Searches of the Navy's Maintenance Data Collection System (MDCS). MDCS is useful in analyzing current equipment performance and reliability and can help establish design-to-cost parameters.

Assistance in project planning and especially in developing tailored specifications, tailored environmental testing criteria, tailored support methodologies, selection and screening criteria for existing commercial equipments, and life-cycle cost estimates.

Installation planning.

Assistance in parts selection especially using military specifications and the National Stock System.

The Sustainability Engineering Division also performs packaging design, provides drafting services, and coordinates printed circuit layout and fabrication.

At NRaD, the Sustainability Engineering Division also provides the VSMF service.

Military Parts Control Advisory Group (MPCAG)

The MPCAG provides free parts selection advice supported by an extensive staff and computer facilities. Telephone numbers and addresses to obtain assistance are listed in MIL-STD-965.

PERFORMANCE PARAMETERS

There are two aspects to the specification of performance — the degree of functional proficiency to be achieved and the severity of the environment. Traditionally, the specification approach has been to obtain as much performance as possible and to assume the environments called out in military standards and specifications; this approach drives program costs upward and creates unnecessary technical risks. The approach recommended herein is:

1. Specify only those functions, modes, and characteristics completely which are necessary to meet the operational requirements.

2. Specify environments which realistically reflect the actual usage environments.

Military specifications normally reflect a “worst case” environment. This is composed of the most extreme cases of a multitude of environments which are usually grossly in excess of the extremes normally encountered in any one usage environment. Table IV-2 summarizes the environmental parameters which should be considered; appendix A provides more detailed environmental criteria. Test and evaluation planning must be structured with the specified environment as a baseline (see chapter XIX).

Table IV-2. Equipment environmental tests and requirements.

GENERAL REQUIREMENTS

Designator	Environment
1.	Temperature (operating and nonoperating)
2.	Temperature-altitude
3.	Humidity
4.	Thermal shock
5.	Vibration
6.	High-impact shock
7.	Transport shock
8.	Repetitive shock
9.	EMC (interference and susceptibility)
10.	EMP
11.	Electrical transients (voltage and frequency/long term and short term)
12.	Lightning
13.	Magnetic field
14.	Acoustic noise (airborne and structureborne)

Table IV-2. Equipment environmental tests and requirements (continued).

GENERAL REQUIREMENTS

Designator	Environment
15.	Inclination
16.	Radiation
17.	Nuclear air blast
18.	Gun blast
19.	Wind
20.	Icing with wind
21.	Rain and snow, snow loading
22.	Sunshine
23.	Degree of enclosure
24.	Dust
25.	Salt fog, spray, solution
26.	Damaging (corrosive) atmospheres
27.	Explosive atmosphere
28.	Fungus
29.	Maintainability/bench handling
30.	Reliability (burn-in, confidence, indexing, accelerated life, failure-mode analysis)
31.	Combined-environment testing (temperature-humidity-vibration-electrical transients — on/off cycling)
32.	On/off cycling
33.	Acoustic susceptibility (in high-noise environments)
34.	Water impact/hydrostatic pressure
35.	Underwater explosion (for hull-mounted equipments only)
36.	Drop test
37.	Equipment special environments

SPECIAL REQUIREMENT CATEGORIES

Category	Environments	Notes
Vital equipments	10,16,17	16 and 17 for exposed equipments
	6	operating
Semivital equipments	6	nonoperating (normal operating before and after shock)
Nonvital equipments	6	safety criteria
Exposed equipments	12,18,19,20,21,22,23,24	
Sheltered equipments	23	
Standard requirements	1,3,5,6,9,11,14,29,30,31,32,37	

Table IV-2. Equipment environmental tests and requirements (continued).

APPLICATION REQUIREMENTS[1]

Application	Environments	General Equipment Spec	Test Spec	Notes

Shipboard	8,13,15, 25,26,27, 33,34,35	MIL-STD-2036	MIL-STD-2036	for (5) MIL-STD-167
				for (6) MIL-S-901
				Environmental Interfaces MIL-STD-1399
				for (15) per MIL-STD-2036 except 30° (operating) and 60° (without damage or spillage) for submarines
				TELCAM levels use:
				for (5) .5g to 50 Hz
				for (6) MIL-S-901 may be waived

Shore (fixed)	33	MIL-STD-2036	MIL-STD-2036	
Shore (mobile, transportable, vehicular)	2,4,7, 15	MIL-E-4158	MIL-STD-810 MIL-STD-169 MIL-STD-170 MIL-STD-210 MIL-STD-1474 MIL-D-13570	
Airborne	2,4,7,26, 27,28	MIL-E-5400 Prop, Jet, and Helo Aircraft MIL-E-8189 Missiles, Boosters, and Allied Vehicles MIL-E-11991 Guided Missiles	MIL-STD-810 MIL-T-5422 (Navy) Gen Equip Spec	MIL-E-5400 to be replaced by a future revision to MIL-STD-2036
Portable	36 plus applicable general application	Same as general application	Same as general application plus detail spec	
Space	2,4,7,8,16,33	MIL-STD-1540	MIL-STD-1540	for (9) MIL-STD-1541 equipments are all considered vital
Test equipment	7,24,25,27, 28,33	MIL-T-28800	MIL-STD-810	

[1]Environmental requirements should consider standard sheltered or exposed, and vital-semivital-nonvital requirements in addition to those listed.

Table IV-2. Equipment environmental tests and requirements (continued).

APPLICATION REQUIREMENTS[1] (continued)

Application	Environments	General Equipment Spec	Test Spec	Notes
Amphibious				Shipboard and Shore (mobile) combined
Torpedoes	22,24,25,28,34	MIL-T-18404	MIL-T-18404	(37) includes acceleration
Shipboard fire control	2,8,13,15,25, 26,27,33	MIL-F-18870	MIL-T-18870	Same as Shipboard except as by MIL-T-18870. (2) is nonoperating transportation test.

[1]Environmental requirements should consider standard sheltered or exposed, and vital-semivital-nonvital requirements in addition to those listed.

In order to establish those characteristics which can be considered "necessary," the following definitions are useful:

Essential	Those characteristics dictated by the system mission
Less than essential	Characteristics which contribute usefully toward the system mission
Nonessential	Everything else

Necessary characteristics can now be defined as all essential characteristics plus only those less-than-essential characteristics the provision of which will not complicate operation or maintenance and the utility of which outweighs the cost of providing them. When in doubt, leave it out! Some characteristics may be essential to one technical approach and non-essential to another; they are specified only when the technical approach is specified. System specifications generally do not specify a technical approach unless only one approach is clearly acceptable; equipment specifications may direct a particular technical approach, especially when multiple approaches are pursued in parallel.

In determining the specification of a characteristic, quantity must be considered as well as quality. "The receiver must have high sensitivity" — how much is high? Most specified parameters fall into a gray region when a value is not known. Several techniques are available which can be applied to resolve parametric unknowns:

Figure of merit
System effectiveness model
Operations analysis
Value engineering/cost-benefit analysis
Laboratory testing
Exploratory development
Analysis of similar equipment

A system effectiveness model is useful, since it incorporates performance parameters, thus allowing tradeoffs between performance and support. System effectiveness is defined as a product of availability, dependability, capability, and utilization. Availability and dependability are support parameters and are discussed further in the next section. Utilization is an adjustment or degradation factor employed in the event that the system occasionally is used under conditions of stress greater than the design environment; otherwise, it is set to 1. Capability is the probability of a successful mission, given that the system is operated within specifications and that no failures occur. Capability is a routinely applied concept in ordnance systems where it is the product of the probability of hit and the probability of kill given hit.

Figure of merit (FOM) is a nonprobabilistic measure of capability which can be readily developed for most types of electronics and converted to Capability (C) through the following formula:

$$\frac{FOM(measured) - L}{FOM(max.\ \ specified) - L} = C.$$

FOM can be established by determining which parameters directly interplay in the system performance and determining a common unit of measure. The unit of measure may be simple (e.g., dB) or complex (bits/ms-dB). Environmental factors (such as atmospheric noise) and human factors (such as operator proficiency) may be assigned weights and included in the computation. Analysis supported by laboratory tests is usually sufficient to establish a maximum predicted FOM (FOM (specified)) which ensures satisfactory system operation and a limiting figure (L) below which the system will not operate. The capability figure established by utilizing a figure of merit derivation is not necessarily accurate, but it is a sufficiently useful concept to warrant consideration. System effectiveness can be converted to cost-effectiveness by dividing by the total life cost.

The other measure of capability is utility. A utility curve plots a functional contribution factor (utility) against a specification factor. The utility is scaled from 0 to 1. Specification values below the minimum acceptable performance are assigned a utility of 0; the minimum acceptable performance is assigned a utility derived by analysis of the specification factor's proportional contribution to total system performance (this is usually between 0.25 and 0.65). Many utility factors can be combined by using weighting factors (sum of all weighting factors equals 1). Each weighting factor represents the associated utility factor's contribution to system performance, and is obtained through analysis and testing. Although each weighting factor is a function of all utility values, a fixed nominal value is usually satisfactory in practice.

$$C = \frac{1}{N}\sum_{i=1}^{N} U_i W_i \ ; \ \ where \ \sum_{i=1}^{N} W_i = 1$$

Utility curves are also very useful in evaluating contractor proposals. In this application, proposals having any utility value of zero (less than minimum acceptable performance) should be rated as technically unacceptable.

SUPPORT PARAMETERS

The previous section stressed performance — the capability of the end product to do the desired job. Equally important to the user is the supportability of the end product. Equipments which are not up and operating are worse than no equipment at all; the down equipment is not doing its intended job, no matter how much capability was designed into it. Furthermore, nonsupportable equipments consume valuable resources in money and manpower to effect their repair. Note that of the four factors which make up system effectiveness, two, capability and utilization, are performance related, and two, availability and dependability, are support related. Besides playing a major role in system effectiveness, support parameters describe the support phase costs. Since support phase costs are a major portion of the total cost of ownership, supportability and affordability are incontrovertibly intertwined.

Underlying availability and dependability are the more familiar concepts of reliability, maintainability, and downtime and the measures associated with each. Since some of the terms involve technical shades of meaning, figure IV-3 has been provided.

Traditionally, reliability and maintainability have been the primary factors considered in supportability design. Both can be stated as requirements for which tests can be constructed. The usual measures of reliability and maintainability are MTBF and MTTR, respectively, which are combined in inherent availability (see fig. IV-3, formula 1). Inherent availability is a specification mechanism which constrains the tradeoffs between MTBF and MTTR where it is desired to achieve values in excess of minimum specified values. **Inherent availability cannot be used to predict the equipment availability in use; it is a specification tool only and must be treated as such**.

MTBF and MTTR are often considered independent of the operating environment; this is a gross fallacy. Reliability depends on two major factors — (1) the selection of reliable parts (those which are produced by mature processes under established quality control) and (2) the use of reliable design. Performance must influence design complexity, parts counts, and other factors affecting reliability; however, the reliable design will always utilize parts within their ratings even under specified stresses (temperature, humidity, electrical transients, vibration, etc.) and will allow for variations in part value arising from the production process and from aging effects. Maintainability depends on the fault isolation characteristics, accessibility of arts, testability of functions, and ease of control adjustment inherent to the design.

Since the operating environment can usually be readily specified (or readily overspecified through blanket reference of military specifications), the conscientious engineer can formulate reliable designs (i.e., within the state-of-the-art). The maintenance environment is usually not widely recognized by either the specification writer or the designer responding to a specification. Nevertheless, it is at least as important to specify and design to the maintenance environment as to the operating environment; otherwise, the equipment will experience limited availability, excessive support costs, and reduced service life.

(Source: 1 LS Implementation Guide -- NAVMAT P-4000)

Definitions

1. Availability (A): The probability that an item will be ready to perform within specification at the start of a mission.

2. Dependability ID): The probability that an item will be able to perform a complete mission within specification and, should a failure occur during that time, can be restored to operation within specification within the allowed downtime.

3. Reliability, (R): The probability that an item will be able to perform a complete mission within specification, given that it is operational at the start of the mission. Alternately, the probability at an item will operate within specification for a given period of time.

4. Maintainability (M): The probability that an item can be restored to operation within specification within a given downtime.

5. Supportability (S): The probability that all the elements necessary effect the repair of an item will be available within a specified time.

6. MTBF: Mean time between failures (or before failure).

7. MTBUR: Meantime between unscheduled removals. (Used for replaceable assemblies.)

8. MTBCM or MTBCMA: Mean time between corrective maintenance actions.

9. MTBPM: Mean time between preventive maintenance actions.

10. MTBM: Mean time between maintenance actions.

11. MTTR: Mean time to repair.

1 2. MCT: Mean corrective maintenance time.

13. MDT: Mean downtime.

14. Failure: Any item condition in which the item is unable to operate within specification.

    a. Relevant Failure: A failure with which the item cannot perform its specified mission.
    b. Nonrelevant Failure: A failure which causes degraded item performance but does not prevent the item from performing its specified mission.

    c. Partial Failure: A failure of one or more modes of operation which are not critical to the item's specified mission.

15. Ready time: The time during which the item is capable of operation but not in use.

16. MCMH: Mean corrective maintenance man-hours.

17. MPMH: Mean preventative maintenance man-hours.

18. MMMH: Mean maintenance man-hours.

Figure IV-3. Support parameter definitions and formulae.

Formulae:

1. A_i (inherent availability) = $\frac{MTBF}{MTBF + MTTR}$

2. A_o (operational availability) = $\frac{MTBM + ready\ \ time}{MTBM + MDT + ready\ \ time}$

   a. (discounting preventive maintenance by assuming scheduling of PM to not interfere with possible use)

   $$A_o = \frac{MTBCM + ready\ \ time}{MTBCM + ready\ \ time + MDT}$$

   b. (assuming 100% utilization) $A_o = \frac{MTBCM}{MTBCM + MDT}$

3. a. $D = R_m + M(1-R_m)$ (R_m = mission reliability)

   b. $D = R_m$ (no allowable downtime)

4. a. R_m (mission reliability) = $e^{\frac{-T}{MTBF}}$ (T = length of mission)

   b. R_o (operating reliability) = $e^{\frac{-T}{MTBCM}}$

5. MDT = MTTR + MDT (admin) + MDT (parts) + MDT (assistance)

6. MDT (admin) = FRD (fault recognition delay) + MDT (test equipment)
   +MDT (documentation) + SRT (supply requisition time)
   +CB (coffee breaks and other periods of technician nonavailability)

7. MTTR = Time required to procedurally fault isolate to a replaceable assembly
   +time necessary to access and replace the faulty assembly
   +time to reassemble and check out the equipment including realignments as necessary.

8. MTBM = $\frac{1}{\frac{1}{MTBCM} + \frac{1}{MTBPM}}$

Specification Terms:

	Term	Source
1.	$MTTR_O$: MTTR at the organization level	Table IV-4
2.	$MTTR_I$: MTTR at the intermediate level; no more than 2 × MTTR.	

Figure IV-3. Support parameter definitions and formulae (continued).

Formulae:

1. A_i (inherent availability) $= \frac{MTBF}{MTBF + MTTR}$

2. A_o (operational availability) $= \frac{MTBM + ready\ \ time}{MTBM + MDT + ready\ \ time}$

   a. (discounting preventive maintenance by assuming scheduling of PM to not interfere with possible use)

   $A_o = \frac{MTBCM + ready\ \ time}{MTBCM + ready\ \ time + MDT}$

   b. (assuming 100% utilization) $A_o = \frac{MTBCM}{MTBCM + MDT}$

3. a. $D = R_m + M(1\text{-}R_m)$ (R_m = mission reliability)

   b. $D = R_m$ (no allowable downtime)

4. a. R_m (mission reliability) $= e^{\frac{-T}{MTBF}}$ (T = length of mission)

   b. R_o (operating reliability) $= e^{\frac{-T}{MTBCM}}$

5. MDT = MTTR + MDT (admin) + MDT (parts) + MDT (assistance)

6. MDT (admin) = FRD (fault recognition delay) + MDT (test equipment)
   +MDT (documentation) + SRT (supply requisition time)
   +CB (coffee breaks and other periods of technician nonavailability)

7. MTTR = Time required to procedurally fault isolate to a replaceable assembly
   +time necessary to access and replace the faulty assembly
   +time to reassemble and check out the equipment including realignments as necessary.

8. MTBM $= \frac{1}{\frac{1}{MTBCM} + \frac{1}{MTBPM}}$

Specification Terms:

	Term	Source
1.	$MTTR_O$: MTTR at the organization level	Table IV-4
2.	$MTTR_I$: MTTR at the intermediate level; no more than 2 × MTTR.	

Figure IV-3. Support parameter definitions and formulae (continued).

Specification Terms (continued):

	Term	Source	
3.	$MTTR_D$: MTTR at the depot level; no more than 2 × $MTTR_I$ or as determined by a life-cycle cost model/level of repair model		
4.	Annual preventive maintenance time	Table IV-4	
5.	Cost per repair action	Table IV-4 ÷ expected # actions	
6.	MTBF	Operational requirement	
7.	MTBM	Determined by a life-cycle model	
8.	A_O	Vital equipments	0.99
		Semivital equipments	0.90
		Nonvital equipments	0.75

Figure IV-3. Support parameter definitions and formulae (continued).

Most of the maintenance environment can be described as a level of maintenance capability at the user organization. The remaining portion considers the capabilities of intermediate and depot facilities. Table IV-3 describes levels of organization maintenance capability; table IV-4 suggests some parameters which are within these capabilities. Equipments should never be designed in excess of the capabilities of the least-capable platform; table IV-5 table IV-5 is provided for guidance. Wherever possible, shipboard equipments should be designed for level 2 capabilities with the primary maintenance load within the abilities of an E-3 technician and with the most difficult tasks requiring only an E-4. The designer must be provided with constraints through the equipment specification. Constraining requirements should include MTTR at the organizational, intermediate, and depot repair levels and a total annual preventive maintenance time ceiling. A target mean cost per repair is also desirable.

Notice that there are two kinds of reliability (see fig. IV-3, formula 4). Mission reliability is based in the definition of reliability (fig. IV-3, definition 3). However, because of redundancy, multiple modes of operation, gracefully degraded operation, voting techniques, and multiple-mission requirements, many equipment conditions can occur which require maintenance without constituting equipment failure (in the MIL-STD-781 sense). Therefore, the specification should state requirements for MTBF and MTBM. The MTBF requirement is generally only important when a specific mission time is of interest. MTBM is the requirement that affects the support costs directly.

Table IV-3. Unified levels of organizational maintenance capability.

Maintenance Capability Level (1)	Fault Diagnosis Capability	Repair Capability	Highest Technician Training Level	Technician Support Availability (annual man-hours)	Extent of Supply Support	Test Equipment Availability	Service Level Designation A-Army M-Marine N-Navy AF-Air Force
0	automatic, if at all	automatic, if at all	none	none	none	none	
1	recognition of obvious faults	switch in backup units, replace lamps, fuses, etc	operator not trained technically	none	"shirt pocket" logistics	none	A-GSU AF-In Flight M-1st Echelon
2	recognize failures of assemblies and major subassemblies	replace cables, failed assemblies, minor alignments	specialized operator with some technical background or E-4 technician	4000	self-contained kit logistics; less than 3500 line items of supply support	simple meters and specialized GSE	A-DSU AF-Flight Line M-2nd Echelon N-2 (2)
3	recognize failures to the minor subassembly and piece parts	replace failed minor assembly, piece part replacement limited by the extent of supply support	E-5 technician	12,000	less than 11,000, greater than 3500 line items	meters, audio signal generators, oscilloscopes, some specialized TE	N-3 (2)
4	same as 3	same as 3	E-6 technician	24,000	less than 19,000, greater than 11,000 line items	same as 3	N-4 (2)
5	same as 3	same as 3; major alignments also	E-6/7 technician	70,000	less than 27,000, greater than 19,000 line items	same as 3; some additional rf TE	N-5 (2)
6	same as 3	same as 5	E-7/8 technician	More than 80,000	approximately 30,000 line items	same as 5	N-6 (2)

NOTES:
(1) A specific platform is only capable to the level in which it has both the required trained technician support and the specified supply support.
(2) As recognized in NAVSUPINST 4423.14A, Enclosure 1, Appendix B.
(3) Major systems which demand more than 1% of these resources may suffer degraded support. Nonmajor systems (everything else) which demand more than 0.1% of these resources may suffer degraded support.

Table IV-4. Suggested parameters compatible with maintenance capability.

Maintenance Capability Level (1)	Maximum Suggested (2) MTTR	Maximum Suggested (2) Preventive (hours/year) Maintenance Time (6)	Maximum Suggested (2) Number of System Peculiar (Nonstandard) Repair Items Required at Organizational Level (6)	Maximum Suggested (2) Total Annual Maintenance Time (hours/year) (5) (6)	Maximum Suggested (2) Annual Cost to the Organizational Level (3) (6)
0	N/A	N/A	N/A	N/A	(consider in acquisition cost for the service life of the system)
1	2 min	10	0 (4)	20	$250.
2	20 min	20	20 (4)	40	$500.
3	1 h	30	40	60	$1000.
4	1-1/2 h	40	60	80	$2000.
5	2 h	50	80	100	$4000.
6	3 h	60	100	120	$8000.

(1) See table IV-3. A system must be designed for the lowest maintenance capability represented by table IV-3.

(2) Suggested guidelines; parameters exceeding these guidelines may be justified by the benefits accrued by the system; lower values are preferred (i.e., manpower savings, grossly increased platform effectiveness, cost savings over other systems).

(3) Including the cost of operating expendables (fuel, batteries, etc.) and the cost of repair items (1989 dollars) and the cost of operating specialized test equipment required to support the system at the organizational level.

(4) Excluding self-contained kit.

(5) Equals the estimated preventive maintenance time plus the expected number of failures per year times the estimated MTTR.

(6) These values are for the "typical" system having 5-6 levels of complexity. Less complex systems should have lower demands; more complex systems may have more costs. Estimate the appropriate value using the system life-cycle cost model and normalizing to 5 levels of complexity above piece parts.

Table IV-5. Current maintenance capabilities of major ship classes.

Capability	Class
6	CV, CVA, CVN, CG, CGN, LPH, LHA, SSBN, LCC, AD, AS, AR
5	DD, DDG, LPD, SSN, AGF
4	FF, FFG-1, LSD, LST, AOE, AOR, AFS, AE
3	SS, LKA, LPA, AO, AF, FFG-7, ASR
2	PG, PHM, MSO, ATF, ARS, ATS

Returning to availability and dependability, it can be seen that reliability and maintainability do play an important role in these factors. However, a missing term is downtime. Downtime consists of active repair time, administrative time, and time awaiting parts and outside assistance. Mean downtime is the normal measure of downtime per maintenance action. The tightening DoD budget of recent years have increased the impact of downtime, especially on operational availability (see fig. IV-3, formula 2). In recent equipment improvement programs, MTBCM has been increased fivefold and MTTR halved, but operational availability has dropped from 0.75 to 0.30 because of MDT deterioration. Referring to figure IV-3, formulas 5 and 6, it can be seen that many of the factors affecting MDT are not directly related to design; nevertheless, design features can have a tremendous impact on the various forms for downtime. In order to provide a meaningful specification of operational availability, MDT must be realistically specified on the basis of design characteristics and the "facts of life" in shipboard routine. Figure IV-4 provides suggested specification values for downtime. It is useful to specify operational availability while specifying only minimum acceptable values for MTBF, MTTR, and MTBM; this allows the designer more latitude while constraining the design more closely to the desired end product. Tests can be provided for the reliability and maintainability parameters. The remaining values are assigned in accordance with the provision of certain features (as in fig. IV-A), and the expected availabil-ity is computed to check conformance with the specification requirements. The formulae to be used in this computation must be stated in the specification. Dependability is never specified; the dependability figure is derived for/from a system effectiveness model by utilizing figure IV-3, formulas 3b and 4a.

MDT = MTTR + MDT (Parts) + MDT (Assist) + MDT (Admin)

<u>MDT (Parts)</u>

$$\text{MDT (Parts)} = \sum_{i=1}^{N} \text{(part supply time in hours for the } i^{\text{th}} \text{ part)} \times \text{li}$$

$$\text{(failure rate for the } i^{\text{th}} \text{ part)} \times \text{MTBF (of the equipment)}$$

MDT = MTTR + MDT (Parts) + MDT (Assist) + MDT (Admin)

<u>MDT Parts)</u>

Part Supply Time	Part Description of Replacement Item
0.02 h	built-in spares
0.07 h	battle spares (stocked in separate spares kit)
0.5 h	preferred parts (high-usage standard parts per MIL−STD−242)
6.0 h	standard parts (per MIL−SPEC)
720.0 h	life-cycle stocked parts and nonstandard controlled parts
4320.0 h	uncontrolled parts (not system peculiar)
12,960.0 h	uncontrolled parts (system peculiar)

[based on 1/2 hour for parts onboard, 24 hours for parts not-on-board but expected to be on-board ships-in-company, 30 days for parts not-on-board but in-stock, 180 days for parts not-on-board, not-in-stock (commonly available), 540 days for parts not-on-board, not-in-stock (not commonly available)]

NOTES:

(1) A controlled part is a nonstandard part which is fully provisioned; a life-cycle stocked part is a system-pecular part which is stocked in sufficient quantity to support the expected life of the system (long-lead-time items may be included if they are fully provisioned). Uncontrolled parts include all items which are not standard or controlled.

(2) These values assume a fully implemented logistic support plan. If any part of the logistic support is not implemented, all provision parts will appear to be “uncontrolled parts.”

Figure IV-4. Mean downtime (MDT) specification values.

MDT (Assistance)

Task

Equipment Category	Organi-zational Repair	IM Repair (on board)	IM Repair (mobile assist)	IM Repair (off ship)	Depot Repair	Equipment Turnaround to on-board pool	Equipment Turnaround to IM pool	Equipment Turnaround to Depot pool	Equipment Turnaround Under Warranty
Vital	0	15 min	36 h	48 h	14 days	30 min	36 h	14 days	14-30 days
Semivital	0	24 h	96 h	120 h	21 days	30 min	48 h	14 days	14-30 days
Nonvital (5)	0	120 h	240 h	240 h	30 days	30 min	96 h	14 days	14-30 days
Notes:	(1)	(2) (7)	(2)	(3) (4)	(3) (4)	(5) (3)	(3)	(3)	(3) (6)

NOTES: (1) by definition

(2) plus MDT (parts) as computed

(3) MDP (parts) equals zero

(4) highly variable; depends on ship's schedule

(5) highly variable; depends on organizational work loads

(6) Depends on warranty provisions

(7) Applies to aircraft carriers and tenders only

Equipment MDT (Assistance) will be required as follows:

(1) Depot and equipment turnaround as determined by the equipment support concept do not add in for those items for which redundancy is provided within the system.

(2) IM repair will be required in direct proportion to the percentage of maintenance tasks which arde beyond the organization's level of maintenance capability (tables IV-3 and IV-5) assuming no special training, test equipment, or tools are required. If special training is required, add (2 $\times$ number of weeks training required $\div$ C)%, where C = 1 for nonvital, 2 for semivital, and 5 for vital equipments. If special tools or test equipment are required, add 0.15 $\times$ percent of tasks requiring these items.

(3) These values assume fully implemented logistic support and training plans. If critical elements of either plan are not implemented, support will not be available in less than 180 days.

Figure IV-4. Mean downtime (MDT) specification values (continued).

MDT (Admin)

MDT (Admin) = FRD + MDT (TE) + SRT+ MDT (Doc) + CB

	Delay	Category
FRD (Fault Recognition Delay) = S (category delay) × (% predicted faults in category)	0.02 h	Faults automatically detected and alarmed
	0.03 h	Operator apparent faults
	0.25 h	Primary mode faults, not operator apparent
	4h	Secondary mode faults

(Faults detectable only by preventive maintenance — use 0.1 the interval between applicable PMS actions)

MDT (TE) (downtime for tools and test equipment) = S (category delay) × (% predicted faults in category)	0	Faults requiring built-in test equipment and tools
	0.8 h	Faults requiring standard tools and special-purpose test equipment
	0.25 h	Faults requiring general-purpose test equipment
	0.33 h	Faults requiring special tools
SRT (Supply Requisition Time)	0	Faults requiring built-in or battle spares
= S (category delay) × (% predicted faults in category)	0.33 h	All other faults
MDT (Doc) (downtime for documentation)	0.02 h per screen	Automated TM documentation
	0.05 h per 48 pages of tech. manual	Tech manuals built into the equipment
	+ 0.05 h per volume of tech. manual not built into the equipment	

CB (coffee breaks and other periods of technician nonavailability)

Vital equipment	0.03 h + 0.08 h/2 h of (MTTR + MDT(TE) + MDT(DOC) + SRT)
Semivital equipment	0.03 h + 0.08 h/1 h of (MTTR + MDT(TE) + MDT(DOC) + SRT)
Nonvital equipment	0.08 h + 0.17 h/1 h of (MTTR + MDT(TE) + MDT(DOC) + SRT)

Figure IV-4. Mean downtime (MDT) specification values (continued).

EQUIPMENT PARTITIONING

The partitioning of a system/equipment pays an increasingly important role as the equipment design matures; this action becomes a major issue in the transition to production (see chapter VI). Ultimately, the equipment partitioning largely determines the maintainability/repairability and the availability of logistics support of the end item. The cost of supporting the equipment can be greatly influenced by the implementation of standardization; however, equipments which are procured in large quantities will benefit less from standardization, since equipment-peculiar items will be procured in sufficient quantities to attain many of the cost advantages of standard items. In general, the following guidelines should be followed in partitioning actions.

Small-Quantity Items

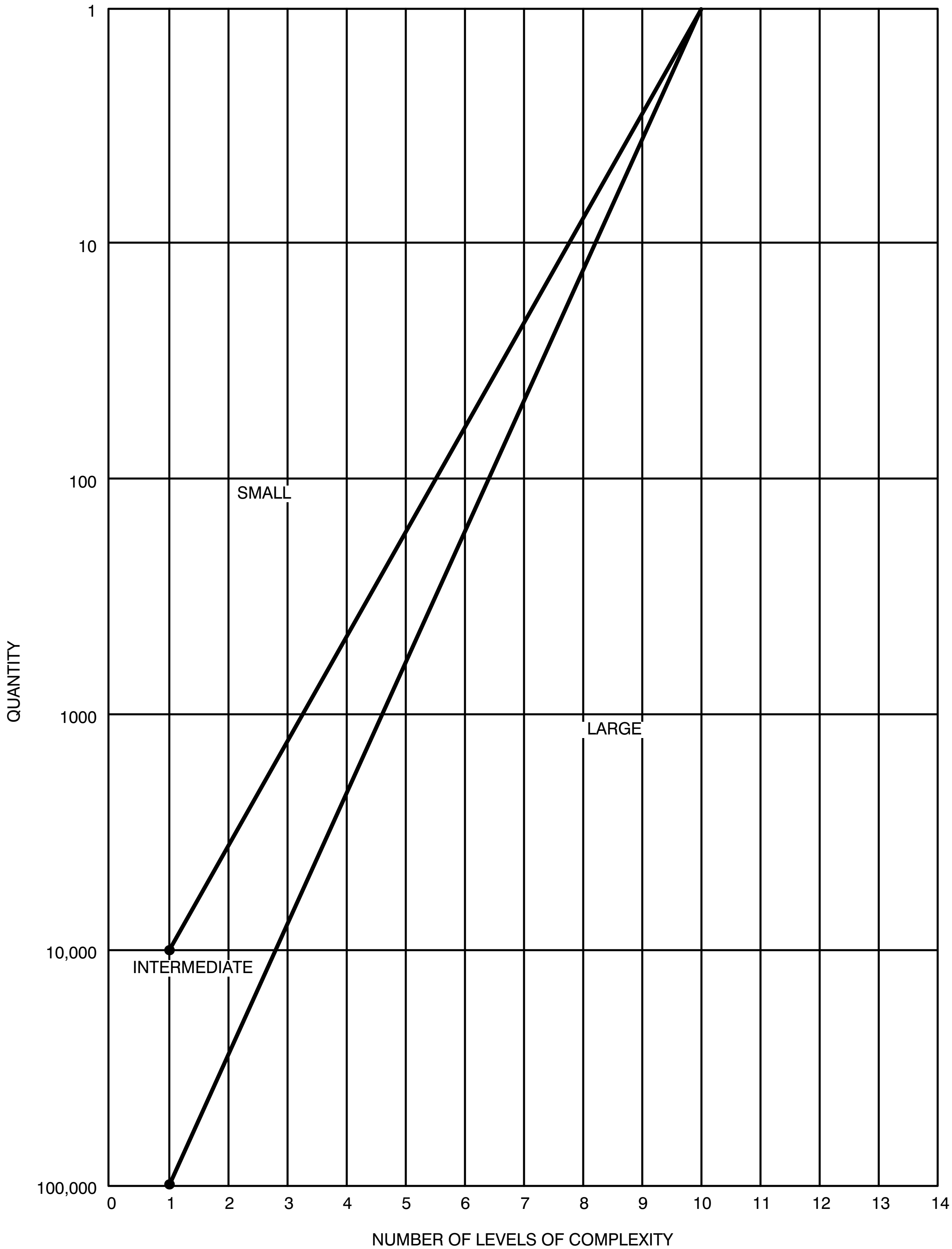
1. Partition for maximum use of off-the-shelf items and minimize equipment-peculiar items.
2. Partition for maximum internal standardization (i.e., minimize the number of different items).
3. Utilize technologies which are sufficiently mature for producibility and sufficiently state of the art to remain available through the projected equipment life.

Large-Quantity Items

1. Partition for ease of maintenance and repair, providing functions which are easily identified and isolated to a replaceable assembly.
2. Partition to obtain the most economic level of replacement; use a LOR analysis where appropriate (see MIL–STD–1390).
3. Points 2. and 3. for small-quantity items also apply.

Large-quantity items are those items for which one-time manufacturing costs amortized over the production quantity are small (under 5% of the unit cost). Figure IV-5 can be used as guidance in this determination.

The resulting equipment partitioning should be integrated into the project work breakdown structure to serve as a basis of cost planning for management control, and to exercise tradeoff models (as for life-cycle costing). (See chapter III.)



INTERMEDIATE = LARGE WHEN EACH ITEM COST IS (RELATIVELY) HIGH
INTERMEDIATE = SMALL WHEN EACH ITEM COST IS (RELATIVELY) LOW

Figure IV-5. Levels of complexity as a function of quantity.

V. VALIDATION PHASE

The validation phase serves as a vital checkpoint on decisions made during the conceptual phase and provides for a smooth transition into the development/procurement cycle. This chapter cites the tasks necessary to achieve these ends. The tasks cannot be slighted without adversely affecting the equipment total life costs.

INTRODUCTION

The purpose of the conceptual phase is spawn one or more technical approaches (system design) within the feasible limits of technology. The system design must be consistent with operational requirements, acquisition strategy(ies), and program resources. The validation phase demonstrates this consistency. Each technical approach embodies technical requirements which form the system specification. How does one know that those technical requirements respond to the operational requirements? The purpose of the validation phase is to provide an answer to that question and to provide tolerances for the technical parameters. To these ends, a validation phase is mandatory; however, its start and finish may be deeply imbedded in the conceptual phase and the transition to production with no clearly defined boundary.

The first task of the validation phase relates the technical requirements to the operational requirements. There are three ways this may be accomplished:

Analysis
Simulation
Advanced development

This task is often initiated during the conceptual phase. Analysis is a suitable method only when the technical approach has been proved by past experience to adequately address the operational requirements. Simulation entails risks of uncertainty which increase exponentially with the complexity of that being simulated. Advanced development provides the greatest degree of certainty. Validation by development is, however, rather expensive and time consuming compared to simulation techniques because an advanced development model (ADM) must be designed, built, and tested. When the technologies being employed are relatively novel, development is the only satisfactory method; thus, the atomic test program was essential to the development of atomic weapons. On the other hand, it is foolish to build one very complex item, say an aircraft carrier, to find out whether that one item is worth building or to start a war to obtain a realistic wartime environment. Usually, a balanced program utilizing both simulation and development is necessary.

For relatively simple items, the ADM and the conceptual phase feasibility demonstration might be combined for efficiency. For complex items required in small numbers, the ADM can be combined with the transition to production. In all other cases where development is indicated, the ADM should be a stand-alone phase. Furthermore, if the tests of the first ADM are not satisfactory, successive ADMs may be required until the tests are OK.

Besides the functional/technical parameters, it is also necessary to validate the suitability of the design concept to the usage environment. This is the second task of the validation phase. Since it is seldom possible to evaluate all the factors which make up "suitability" in a live environment, it is generally necessary to validate the design through analysis and simulation. The necessary tasks are incorporated into the Integrated Logistics System (ILS) tasks outlined in the lLS Implementation Guide (NAVMAT P4000) and chapter X. Formal design analyses may or may not be required depending on the complexity of the design and the familiarity of the designer with the usage environment; where the equipment is complex or the designer naive to the real-life user environment, specialists should be integrated into the design team. Some of the more important tasks are embodied in the following formal analyses:

Failure Modes and Effects Analysis (FMEA)
Maintainability Analysis/Demonstration
Hazard Modes and Effects Analysis (HMEA)
Human Engineering Analysis
Parts Selection Review
Metrology Analysis and Test Point/Provisions Review

These tasks are really basic engineering practices which need not be emphasized through a formal program but which cannot be overlooked. They are often repeated and refined many times as the design matures. Their early consideration is important because extensive design changes may be required to correct the deficiencies they reveal. The earlier these changes are incorporated, the less they impact on schedule and cost.

Documentation is essential in the validation phase in order to provide a baseline for the activities which follow. Engineering drawings are particularly important to providing design traceability through the changes which inevitably occur; change control procedures should be implemented to ensure that the documentation accurately reflects the design.

VALIDATION PHASE

This is the phase in which the major program characteristics (technical, cost, and schedule), through extensive analysis and hardware development, are validated and is often identified with advanced development. It is preferred to rely on hardware development and evaluation rather than paper studies alone, since this provides a better definition of program characteristics, higher confidence that risks have been resolved or minimized, and greater confidence in the ultimate outcome. Nevertheless, effectiveness analysis plays a critical role since it provides a structured vehicle for interrelating and evaluating the information developed as a result of hardware development, and organizes information in a form suitable for updating the Development Concept Paper (DCP), and for DSARC review leading to the decision to enter full-scale development. In an idealized case, this phase ends when a brassboard model has been demonstrated successfully.

The candidate and preferred system(s) having been defined in the conceptual phase, a sensitivity analysis is performed with the effectiveness model. This analysis will indicate the limiting parameters and priorities for each element of the system model, which are expressed in terms of technical goals or requirements. The range of the permissible parameters, properly related to estimates of state-of-the-art capabilities, establishes the degree of criticality of the element.

Along with the sensitivity analysis, the analysis of risk and uncertainty performed during the conceptual phase should be updated, extended, and carried out to greater levels of detail. Parameters which are found to drive effectiveness have a high risk consequence (see chapter XXI).

While the critical system effectiveness parameters can be defined initially during the early conceptual phases, they reach much greater definition in the latter stages of validation during the analysis effort. They provide the essential framework for the decision to enter into full-scale development.

The definition of these parameters at this point in the evolutionary cycle of a system must be sharpened to the point where the project manager can demonstrate the following:

- The operational goals and technical goals are in agreement.
- The technical, and hence operational, criteria can be met.
- The financial and schedule factors are credible.
- The development risks are acceptable.
- A definitive full-scale development contract can be entered into with the best-qualified design agent (contractor or laboratory).

To demonstrate the foregoing, not only must the parameters be clearly and concisely defined, but they must be quantitatively interrelated. This requires highly structured system models in terms of functional block diagrams with associated characteristics values and a completely structured system effectiveness/system value model with which to analyze and evaluate the system models. The former is an output of validation efforts by the design agent. The latter, however, is largely the result of the efforts of the system engineering staff. The success or failure of validation will be determined by the degree of completeness of the model and the degree to which its structuring conforms to the real-world situation.

If the system effectiveness/system value model does approximate reality successfully, the parameters can be interrelated, and the exercise of the model for each of the competing systems produced by the design agent(s) provides a framework for source selection and demonstrates the validity of entering into full-scale development, continuing with further definition or advanced development effort, or abandoning the project.

In addition to its use as a decision-making tool, the model also serves another function during this period. The sharply defined critical effectiveness parameters provide the checklist for completing the specification for full-scale development. This is particularly important in that one of the principal objectives of the validation process is to assure that a complete and unambiguous specification is developed for the full-scale development effort.

PLANNING FOR FULL-SCALE DEVELOPMENT

Through the process of validation, the project manager has been establishing a frame of reference to define the system, its technical goals and criteria, and the measures by which its effectiveness in terms of its mission life costs can be evaluated. Having established this frame of reference, the project manager plans the product assurance for achieving an effective system.

During full-scale development, the weapon system [including all the items necessary for its support (training equipment, maintenance equipment, handbooks for operation and maintenance, etc.)] is designed, fabricated, and tested. The intended output is a "hardware model" whose effectiveness has been proved experimentally together with the documentation needed for inventory use. An essential activity of the development phase is test and evaluation, both that conducted by contractors and that conducted by the Service. Documentation of the full-scale development phase, including the results of effectiveness analysis, provides the basis for updating the DCP and convening DSARC leading to initiation of production/deployment.

The ultimate evaluation of the full-scale development phase occurs during the test and evaluation of the developed system. If the system model and system effectiveness analytic model are valid and adequately defined, the system should meet its test and evaluation successfully, and the project manager will have been successful.

If the system is not satisfactory, the models have yet another function. The data accumulated during T&E should be inserted into the models. The models should then be exercised and the results analyzed to identify problem areas. These should then be recorded and made available to other project managers to assist them in avoiding similar errors. At the same time, a closed-loop management system should be implemented to correct the problems.

If the project is to be continued, whether or not the T&E is successful, the T&E data are inserted into the models to sharpen further the definition of technical goals and criteria and to validate the data for the production baseline and production specification. Here, again, the models serve to guide the effort and to assure the project manager that the baseline (specification) is complete and defined as sharply as the aggregate experience will permit. This is a necessary exercise, whether or not the R&D contractor is also the initial production contractor.

INTEGRATED LOGISTIC SUPPORT (ILS) VERIFICATION AND DEMONSTRATION

The program requirements for Integrated Logistic Support of NAVELEX procurements are contained in MIL-STD-1369. ILS verification and demonstration are covered in paragraph 4.8 and appendix C of that standard. There are three stages for verification and demonstration of maintainability and integration of maintenance resources. The demonstration and validation should be conducted on an integrated basis consistent with other related test and demonstration requirements. MIL-STD-1388-1 tasks can be substituted for MIL-STD-1369.

STAGE ONE

Stage one should be progressively implemented in accordance with MIL-STD-471 during breadboard or mock-up, and should continue through evaluation of the first production end article. For the system/equipment, with its subsystems and support equipment, the contractor will evaluate accessibility, simplicity, equipment size, working environment, maintenance resource requirements, and human engineering consideration, and determine whether the operational requirements can be met without exceeding programmed maintenance resources.

Within 30 days after the verification and demonstration, the contractor will submit a report of the verifications to the Administrative Contracting Officer. The report should include all pertinent data and observations, photographs or sketches of major problem areas, and recommendations for corrective action as required. Subsequently, maintainability predictions and maintenance resource requirements data contained in the Logistics Support Analysis (LSA) should be updated.

STAGE TWO

Stage two will occur concurrently with the test program during which the time and achievement of the end article maintainability and other logistic support requirements will be verified. The verification will be performed on a test system as specified in the test plan. The specific time phasing, and the maintainability and other logistic support requirements to be verified and demonstrated, will be stipulated by the contractor, agreed to by the Naval Electronic Systems Command, and included in the maintainability program plan. The demonstration will utilize the numbers and skill levels of personnel and maintenance resources recommended by the LSA and agreed to by the government. Publications and support equipment will be examined for adequacy, compatibility, and capability to support the established maintenance concept. Maintainability predictions and maintenance resource data requirements should be updated during this stage also.

STAGE THREE

Demonstration of the in-service end article maintainability characteristics and integration of maintenance resources will be accomplished by the Naval Electronic Systems Command. In-service verification will be accomplished using only those tools, equipment, data, training, personnel, and material resources which have been programmed and provided. The in-service demonstration will include the following elements:

1. Preparation and Application. The contractor must prepare the ILS Verification and Demonstration Plan to meet the criteria for demonstrating whether or not the system or equipment support requirements have been attained. This plan must be agreeable to both the contractor and the Navy. The demonstration will be conducted by the government in a typical operational environment with contractor participation as necessary to assure mutual acceptability of test data and the analysis thereof. The plan must

provide for assessment of system maintainability characteristics as well as support factors related to item downtime; i.e., technical manuals, personnel, tools, support equipment, maintenance concept, and availability and adequacy of required spares and repair parts.

2. Management. The ILS verification and demonstration will be managed by the government. A Demonstration Control Board will be established to provide on-site management. The board will consist of three to five government members, one of whom will be designated as the Demonstration Director, and an equitable number of contractor personnel to be provided at contractor option and expense. The board will be responsible for assuring that maintainability, maintenance, and support data are collected and documented in accordance with established Navy policy (or an approved modification thereof as may be necessary); determining the validity of data reporting; and making initial determination as to whether demonstration objectives have been satisfied and contractual requirements have been met.

3. Demonstration Location and Duration. The ILS demonstration will preferably be conducted at the naval activity which will be required to operate and support the first deliverable production system. The demonstration will commence approximately 6 months after delivery of the system/equipment to the demonstration site and may continue for about 6 months. This will allow for operational and maintenance famliarization prior to the demonstration and will provide for a demonstration of sufficient scope to evaluate maintenance and support requirements for a broad operational spectrum of the system/equipment.

4. Demonstration Test Team. The demonstration test team will consist of members of the demonstration activity and the Demonstration Control Board.

5. Demonstration System Equipment. The system/equipment to be used in the demonstration will be that regularly assigned to the activity in support of its assigned mission. No attempt will be made to segregate a specific group of systems/equipments for demonstration purposes. All assigned systems/equipments will be used, regardless of detailed configuration, provided that such systems/equipments are production configured and delivered to the Navy for fleet training and operations. No specially configured test system/equipment will be used for demonstration purposes.

6. Maintenance and Support. All maintenance performed on the demonstration system/equipment will be accomplished by demonstration site personnel or by personnel attached to the supporting intermediate-level maintenance activity.

   Organizational and intermediate-level maintenance will be performed in accordance with the approved/validated technical manuals and data and the support resources provided by the system/equipment ILS program. Depot-level maintenance will, however, be performed in accordance with such contractual requirements as may be applicable during the period in which the demonstration is performed. No organizational or intermediate maintenance will be performed by contractor personnel during the demonstration unless specifically requested by the demonstration control authority. Similarly, no contractor advice or guidance will be given to personnel performing maintenance unless so requested by the control authority.

7. Maintenance Personnel. The composition of the demonstration test team and the extent of training of the personnel involved cannot be specified except by broad parameters. It is anticipated that the activity involved will be manned with a typical mix of maintenance personnel, such mix to follow as closely as possible the maintenance and operating factors established for the system/equipment. It is also anticipated that a large portion of the organizational and intermediate-level maintenance personnel will have received either factory or Navy training. Also, time will be allocated for on-the-job training, as required, prior to commencement of the demonstration.

8. Demonstration Support Material. Initial demonstration site surveys for verification of the adequacy of logistic support status will be conducted by the Demonstration Control Board not later than 60 days prior to the scheduled commencement of the demonstration. Items to be furnished by both contractor and government, based on the approved Support Material List (SML), will be delivered to the test site at least 60 days prior to commencement of the demonstration. Thirty days prior to the start of the demonstration, the Demonstration Control Board will survey the availability and serviceability of support material and initiate action through the program management office to fill shortages and replace unserviceable material. The Demonstration Control Board will also make recommendations for add-on quantities of spares and repair parts. Basis for such recommendation should be to reduce potential program delays. Upon completion of this survey and all possible corrective actions, a report of remaining deficiencies and a recommendation concerning program start/delay will be furnished to the program manager, who will decide the advisability of program start or delay.

9. Maintenance Data Collection. The collection of accurate data and the analysis thereof are prerequisites for a successful demonstration program. The data must have a high degree of accuracy with a broad base for analysis. The data system utilized to collect the Dedicated Maintenance Man-Hours (DMMH) requirements will be the Navy 3M Data System. An allowance of 15%, or that percentage agreed to by the government and the contractor during contract negotiation, for PF&S (personal, fatigue, and supplementary) time will be used as the factor to convert all reported DMMH time to actual DMMH required time.

10. Analysis/Evaluation and Report Results. Data derived from the Demonstration Program should be screened thoroughly for accuracy, classification of data, and verification of mathematic calculation. Maintainability measurements should be computed as specified in the demonstration plan. A final demonstration report must be prepared by the demonstration director and submitted to the government program manager within 90 days after completion of the demonstration.

11. Change Incorporation. In the event change is incorporated during the demonstration period that affects the maintainability, reliability, or supportability of the system/equipment, the contractor may request a reevaluation of the applicable demonstration results to that point in time, provided the change is incorporated and demonstrated prior to preparation and submission of the demonstration report.

RELIABILITY DEMONSTRATION

All test programs require a test plan. On part of the reliability test plan is the demonstration of achieved reliability. MIL-STD-785 specifies the applicable portions of MIL-STD-781 for the demonstration test procedure. The reliability test plan, including the demonstration test procedure, must be approved by the procuring activity prior to initiation of the tests. Reliability tests should be integrated with other test programs to avoid costly duplication (e.g., performance testing, flight testing, and maintainability demonstration).

The test plan establishes ground rules for conducting tests (including GFE impact), and accept/reject criteria in accordance with MIL-STD-781. The plan also includes such items as demonstration milestones, confidence or risk levels, tradeoff curves, and sample forms.

The test level may be in accordance with MIL-STD-781, or an environmental profile, whichever is applicable.

Along with the reliability demonstration (i.e., the actual test), there is recorded data in the form of an operation log, failure reports, and failure analysis reports, plus a log of equipment failures and operating time. These are described in MIL-STD-781. This failure data can be essential because highly reliable items cannot be tested efficiently.

MAINTAINABILITY DEMONSTRATION

To prove the achievement of the specified maintainability requirement, a maintainability demonstration will normally be accomplished in accordance with MIL-STD-471. The contractor must prepare and submit a demonstration plan and report to the procuring activity. MIL-STD-471 establishes procedures, test methods, and requirements for verification, demonstration, and evaluation of the achievement of the maintainability requirement. The formal demonstration is conducted in an operational or simulated operational environment as specified in the contract. The demonstration should be integrated with other testing requirements such as proof of design, breadboard, prototype, environmental, production, and acceptance. Data from the demonstration will be used to incrementally verify the achievement of maintainability design requirements and to update the parameter values from the maintainability analyses and predictions.

HUMAN ENGINEERING TESTING

GENERAL

Tests are conducted to verify that designs of the equipment, software, facilities, and environment meet human engineering and life support criteria and are compatible with the overall system requirements. The test and evaluation program is to be included in the Human Engineering Program Plan. Detailed information on test and evaluation can be found in MIL-H-46855.

STUDIES, EXPERIMENTS, AND LABORATORY TESTS

The contractor shall conduct experiments, laboratory tests including dynamic simulation, and studies required to resolve human engineering and life support problems specific to the system. Human engineering and life support problem areas shall be brought to the attention of the procuring activity and shall include the estimated effect on the system if the problem is not studied and resolved. These experiments, laboratory tests, and studies shall be accomplished in a timely manner; i.e., in a manner such that the results may be incorporated in equipment design. The performance of any major study effort shall require approval by the procuring activity.

Mock-ups and Models

At the earliest practical point in the development program, and well before fabrication of system prototypes, full-scale, three-dimensional mock-ups of equipment involving critical human performance (such as an aircrew compartment, maintenance work shelter, or command control console) shall be constructed. The proposed Human Engineering Program Plan shall specify mock-ups requiring procuring activity approval and modification to reflect changes. The workmanship shall be no more elaborate than is essential to determine the adequacy of size, shape, arrangement, and panel content of the equipment for use by man. The most inexpensive materials practical shall be used for fabrication. These mock-ups and models shall provide a basis for resolving access, workspace, and related human engineering problems, and incorporating these solutions into system design. In those design areas where equipment involves critical human performance and where human performance measurements are necessary, functional mock-ups shall be provided, subject to prior approval by the procuring activity. The mock-ups shall be available for inspection as determined by the procuring activity. Upon approval by the procuring activity, scale models may be substituted for mock-ups. Disposition of mock-ups and models, after they have served the purposes of the contract, shall be as directed by the procuring activity.

Dynamic Simulation

Dynamic simulation techniques shall be utilized as a human engineering design tool when necessary for the detail design of equipment requiring critical human performance. Consideration shall be given to use of various models for the human operator, as well as man-in-the-loop simulation. While the simulation equipment is intended for use as a design tool, its potential relationship to, or use as, training equipment shall be considered in any plan for dynamic simulation.

HUMAN ENGINEERING IN TEST AND EVALUATION

The contractor shall establish and conduct a test and evaluation program to: (1) assure fulfillment of applicable requirements; (2) demonstrate conformance of system, equipment, and facility design to human engineering design criteria; (3) confirm compliance with performance requirements where man is a performance determinant; (4) secure quantitative measures of system performance which are a function of man-machine interaction; and (5) determine whether undesirable design or procedural features have been introduced. (The fact that these functions may occur at various stages in system or equipment development shall not preclude final human engineering verification of the complete system. Both operator and maintenance tasks shall be performed as described in approved test plans during the final system test.)

Planning

Human engineering testing shall be incorporated into the test and evaluation program and shall be integrated into engineering design tests, contractor demonstrations, R&D acceptance tests, and other major development tests. Compliance with human engineering requirements shall be tested as early as possible. Human engineering findings from early testing shall be used in planning and conducting later tests.

Implementation

The human engineering test and evaluation program, contained in approved test plans, shall be implemented by the contractor. Test documentation (e.g., checklists, data sheets, questionnaires, schedules, operating procedures, and test procedures) shall be available at the test site. Human engineering portions of all tests shall include, where applicable, the following:

A simulation (or actual conduct where possible) of mission or work cycle.

Tests in which human participation is critical with respect to speed, accuracy, reliability, or cost.

A representative sample of noncritical scheduled and unscheduled maintenance tasks.

Proposed job aids.

Utilization of personnel who are representative of the range of the intended military user population in terms of skills, size, and strength; and wearing suitable military garments and equipment appropriate to the tasks and approved by the procuring activity.

Collection of task performance data.

Identification of discrepancies between required and obtained task performance.

Criteria for the acceptable performance of the tests.

Failure Analysis

All failures occurring during, or as a result of, test and evaluation shall be subjected to a human engineering review to differentiate between failures due to equipment alone, to man-equipment incompatibilities, and to human error. The procuring activity shall be notified of design deficiencies which contribute to human error.

SAFETY TESTING

The system safety engineering activities are required to establish test requirements and ensure that safety verification of design and data are included in the engineering test program.

The System Safety Program Plan (SSPP) includes the manner of demonstrating quantitative system safety requirements; identification of special safety test data; and range, flight, and operational test safety programs.

Tests shall be proposed in the SSPP to validate the safety of the product, including those tests already specified by the procuring activity. Safety tests shall be integrated into appropriate test plans. Where complete safety testing costs would be prohibitive, partial design verification of safety characteristics or procedures may be demonstrated by laboratory test, functional mock-ups, or model simulation, when approved by the procuring activity. Safety tests shall be performed on critical devices or components to determine the degree of hazard or margin of safety of design. Induced or simulated failures will be considered for demonstrating the failure mode of critical components. The detailed test plans for all tests shall be reviewed to ensure that:

- Safety is adequately demonstrated.
- The testing will be carried out in a safe manner.
- All additional hazards introduced by testing procedures, instrumentation, test hardware, etc., are properly identified and minimized.

A system safety checklist is required as part of the Contract Data Requirements List (CDRL). The checklist provides assurance that all required and identified safety requirements have been incorporated in the design and hardware and verified by review, test, or other method approved by the agency concerned.

ENVIRONMENTAL TESTING

ENVIRONMENTAL CHARACTERISTICS

Establishing minimum requirements for environmental characteristics is especially significant to low-cost new-equipment development. At present, all equipments intended for shipboard use are supposed to be subjected to the analysis and testing rigors of MIL-STD-2036 for shock, vibration, temperature, and humidity. For many shipboard equipment applications, however, MIL-STD-2036 mission critical requirements are unnecessarily rigorous and consequently result in unnecessarily expensive equipments. For this reason, the TELCAM study has developed vibration and temperature/relative-humidity tests less severe than those required by MIL-STD-2036 — tests which will provide confidence in equipment endurance under usual shipboard environments instead of survivability under abnormal, seldom-occurring environmental conditions. (The TELCAM vibration tests, when passed, also serve to indicate acceptable performance under normal shock conditions.) These TELCAM tests can be substituted for MIL-STD-2036 tests when the equipment under development (1) is noncritical or is not vital to survival of nor essential to the mission of its ship, and (2) is to be exposed to shock, vibration, temperature, and humidity conditions found inside the ship forward of the propeller shaft(s). This will help to reduce equipment development and procurement costs and yet provide an equipment which will perform adequately under all normal environmental conditions. Appendix A discusses the TELCAM approach to environmental requirements and presents the test procedures to be used when specifying the quality assurance provisions for required TELCAM environmental characteristics.

ESTABLISHING SHOCK AND VIBRATION CHARACTERISTICS

To establish the minimum satisfactory environmental characteristics for shock and vibration, refer to figure V-l and the following options.

Option I. For noncritical equipments to be used only in Area III — the least vibrationally severe area — of the ship(s) on which the equipments are to be installed, establish vibration requirements which the equipment must meet after being subjected to the test presented in appendix A, the numerical values of which are given in table A-1 of the appendix. The test is a broad one, covering the Area III vibration characteristics of all ships. On some ships, however, these characteristics are less severe than on others. When the equipment is to be used exclusively in a ship or ships having less severe vibration characteristics than those for which the test is intended, the test (and requirements) can be made less constraining by substituting the specific ship characteristics, presented in figures A-1 through A-8 of appendix A, in place of the values in table A-1.

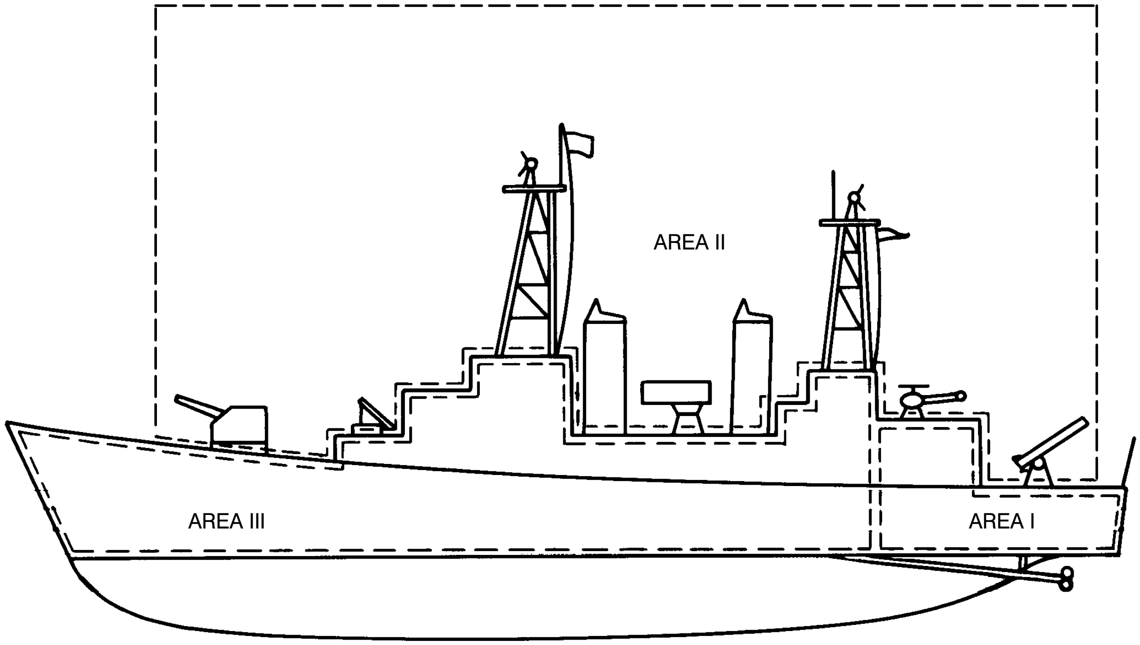


Figure V-1. Shipboard environmental areas.

Option 2. For noncritical equipments to be used primarily in Area III but with some to be located in Area I or II, establish the option 1 vibration test requirements, and, in addition, for the percentage of equipments in Areas I and II, establish separate packaging and testing requirements that will allow these equipments to meet MIL-STD-l67 (see fig A-1 in appendix A). When the costs for extra packaging for the required number of equipments equals or exceeds 80% of the cost that would be required to extra-package all the equipments, then establish shock and vibration requirements for all equipments as per the following option 3.

Option 3. For noncritical equipments to be used entirely or almost entirely in Area I or II, and for all critical equipments, establish the level and testing requirements of MIL-STD-l67 for vibration and of MIL-S-901 for shock. Instead of making general reference to these documents, pinpoint only those requirements necessary for survival by citing specific paragraphs.

ESTABLISHING TEMPERATURE AND HUMIDITY CHARACTERISTICS

To establish the minimum satisfactory environmental characteristics for temperature and humidity, refer to figure V-2 and the following:

1. For noncritical equipments to be located inside a ship (Areas I and III, fig V-1) — i.e., for those controlled (MIL-STD-2036) equipments which are not exposed directly to weather — establish the temperature-humidity requirements profiled by figure V-2 and test by making five complete cycles around the trapezoid of the figure. Each test cycle starts and finishes at 95°F and 95% relative humidity, with each of the test condition points being maintained for 5 hours and with 1 hour allowed for transition between the points — a 24-hour period.

2. For equipments to be located in more exposed areas — i.e., for uncontrolled (MIL-STD-2036) equipments — establish the temperature and humidity requirements imposed by MIL-STD-2036 for the corresponding equipment class (refer to paragraphs 5.1.27, 5.1.2.17 and Appendix D of MIL-STD-2036).

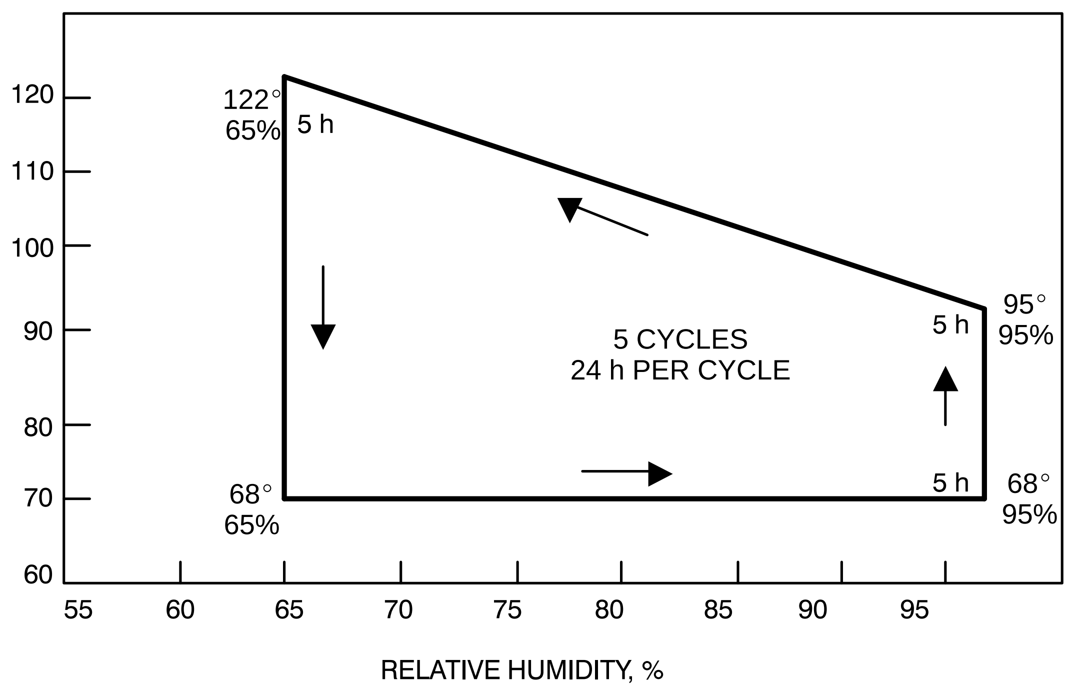


Figure V-2. TELCAM temperature-humidity test.

ESTABLISHING OTHER ENVIRONMENTAL CHARACTERISTICS

Other environmental constraints concern noise, enclosures, inclination, wind speed, EMI, etc., as covered by MIL-STD-2036. They may or may not have to be characterized and tested, depending on the operational requirements of the equipment characteristics being established. If they do, the requirements of MIL-STD-2036 should be cited. Refer to figure V-3.

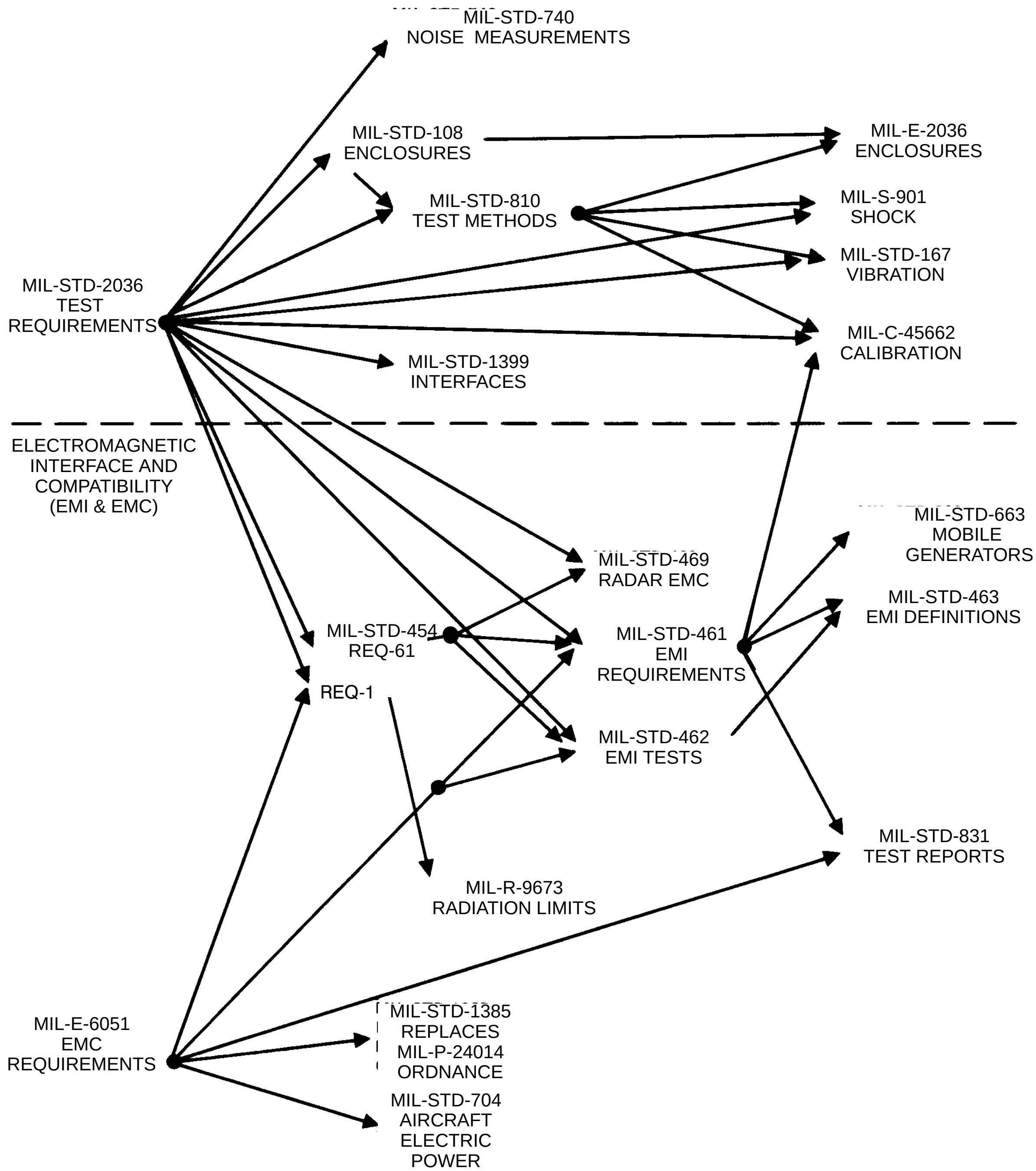


Figure V-3. Environmental documents.

To be especially noted is that airborne and structureborne noise and enclosure requirements and tests should be applied to all sheltered equipments. Inclination requirements and tests should be applied only to equipments whose proper operation depends on fluid levels, position-sensitive switches, or heat pipes, or which are otherwise position sensitive, since this constraint/test has a motion to which most equipments are insensitive.

ENVIRONMENTAL REFERENCES

1. Naval Air Systems Command
   Military Standard MIL-STD-810E,
   Environmental Test Methods, 14 Jul 89

2. Naval Sea Systems Command
   Military Standard MIL-STD-l399C,
   Interface Standard for Shipboard Systems, 2 Feb 88

3. Naval Sea Systems Command
   Military Specification MIL-E-2036D, *Enclosure for Electric and Electronic Equipment, Naval Shipboard*, 10 Mar 88

4. Naval Sea Systems Command
   Military Standard MIL-STD-45662A
   Calibration System Requirements, 1 Aug 88

5. Naval Sea Systems Command
   Military Standard MIL-STD-740-1 and -2, *Airborne and Structureborne Noise Measurements and Acceptance Criteria of Shipboard Equipment*, 30 Dec 86

6. Naval Ship Engineering Center
   Military Standard MIL-STD-108E, *Definitions of and Basic Requirements for Enclosures for Electric and Electronic Equipment*, 4 Aug 66

7. Naval Air Systems Command
   Military Specification MIL-E-6051D, *Electromagnetic Compatibility Requirements, Systems*, 7 Sep 67

8. Air Force Logistics Command
   Military Specification MIL-R-9673B, *Radiation Limits, Microwave and X-Radiation Generated by Ground Electronic Equipment (as Related to Personnel Safety)*, 15 Sep 61

9. Naval Sea Systems Command
   Military Standard MIL-STD-l385B, *Preclusion of Ordnance Hazards in Electromagnetic Fields, General Requirements for*, 1 Aug 86

10. Naval Air Systems Command
    Military Standard MIL-STD-704E, *Electric Power, Aircraft, Characteristics and Utilization of*, 1 May 91

11. Naval Sea Systems Command
    Military Standard MIL-STD-463A, *Definitions and Systems of Units, Electromagnetic Interference Technology*, 1 Jun 77

12. Naval Facilities Engineering Command
    Military Standard MIL-STD-633E,
    Mobile Electric Power Engine Generator Standard Family Characteristics Data Sheet, 22 Feb 80

13. Naval Air Systems Command Military Standard MIL-STD-831, *Test Reports, Preparation of*, 28 Aug 63
14. Naval Space and Electronic Warfare Systems Command Military Standard MIL-STD-461D, *Electromagnetic Interference Characteristics, Requirements for Equipment*, 11 Jan 93
15. Naval Space and Electronic Warfare Systems Command Military Standard MIL-STD-462D, *Electromagnetic Interference Characteristics, Measurement of*, 11 Jan 93
16. Naval Sea Systems Command Military Standard MIL-STD-469A, *Radar Engineering Design Requirements, Electromagnetic Compatibility*, 2 Dec 91
17. Naval Ship Engineering Center Military Specification MIL-S-901D, *Shock Tests, H.I. (High-Impact), Shipboard Machinery, Equipment and Systems, Requirements for*, 17 Mar 89
18. Naval Ship Engineering Center Military Standard MIL-STD-167/1, *Mechanical Vibration of Shipboard Equipment*, 1 May 74
19. Vibration Test Data Reports:

Source		Title	Report No.	Date
Boston Naval Shipyard:				
	1.	"Collection of Reports on Vibration Surveys"	—	1961
	2.	same	—	1962
	3.	same	—	1963
	4.	same	AD 458905	1964
	5.	same	AD 479764	1965
	6.	same	AD 813701	1966
	7.	same	—	1969
Long Beach Naval Shipyard:				
	1.	"Collection of Reports of Vibration Surveys"	—	1961
	2.	"Collection of Vibration Reports"	—	1962
	3.	"Collection of Reports of Vibration Surveys"	—	1963
	4.	same	AD 460569	1964
	5.	same	AD 428086	1965
	6.	same	AD 827529	1967
	7.	same	AD 847891	1968
	8.	same	—	1969
	9.	same	—	1970
	10.	"USS Iwo Jima (LPH 2) Underway Vibration Survey"	—	1972

Source		Title	Report No.	Date
Norfolk Naval Shipyard:				
	1.	"Vibration Survey Report"	—	1961
	2.	same	—	1962
	3.	same	—	1963
	4.	same	—	1964
	5.	same	AD 482035	1965
	6.	same	AD 818880	1966
	7.	same	AD 834603	1967
	8.	same	—	1968–1969
	9.	same	—	
Pearl Harbor Naval Shipyard:				
	1.	"Vibration and Noise Survey Reports?	—	1961
	2.	same	—	1963
Philadelphia Naval Shipyard:				
	1.	"Collection of Letter Reports of Local Vibration Surveys"	—	1961
	2.	same	—	1962
	3.	same	—	1963
	4.	"Collection of Vibration Surveys"	AD 809229	1964
	5.	"Collection of Vibration Surveys and Letter Reports"	—	1969
	6.	"Collection of Vibration Surveys"	—	1970
Portsmouth Naval Shipyard:				
	1.	"Reports on Vibration Surveys"	—	1962
Puget Sound Naval Shipyard:				
	1.	"Collection of Reports on Vibration Surveys"	—	1961
	2.	same	—	1962
	3.	same	—	1963
	4.	same	AD 463274	1964
	5.	same	AD 481976	1965
	6.	same	AD 809213	1966
	7.	same	AD 834332	1967
San Francisco Bay Naval Shipyard:				
	1.	"Shipboard Vibration Survey of 1962"	—	1962
	2.	"Collection of Vibration Surveys for 1963"	—	1963
	3.	"Shipboard and Vibration Memos and Surveys for 1964"	AD 466652	1964

Source		Title	Report No.	Date
	4.	"Collection of Vibration Surveys for 1965"	—	1965
	5.	same... "1966"	AD 815849	1966
Charleston Naval Shipyard:				
	1.	"Informal and Letter Reports on Vibration Problems for 1964"	AD 460923	1964
Naval Electronics Laboratory Center:				
	1.	D. Peterson, "Summary of NELC," Recorded Shipboard Vibration Data	1701	2 Apr 1970
	2.	R. H. Chalmers and D. L. Peterson, "Environmental Studies Aboard U.S. Navy Vessels in the South China and Caribbean Seas"	1577	16 Aug 1968
Naval Ship Research and Development Center, Washington, DC				
	1.	V. S. Hardy, "Surface Ship Vibration"	NSRDC 2338	June 1967
	2.	H. F. Alma and N. W. Huzil, "Surface Ship Vibration"	NSRDC 2338A	Sep 1970

20. NELC Memo Z269, Ser 4700-M205-73 dated 27 December 1973, from TA Danielson to DA Peterson (Subj: Supply Line Voltage and Frequency Test Results on Century Data Co. "Floppy Disk Memory Unit" Ser No 512)

21. NELC Letter Z269, Ser 4700-82 date 5 December 1973, from Commander NELC to Commander NUC (Subj: Results of exploratory vibration test of CALCOMP Model 565 Plotter)

INTERFACE REQUIREMENTS VALIDATION

The need for interface standards for shipboard systems has become apparent as ships and their systems/equipment have grown more complex and as discrete activities (SYSCOMs, PMs, Contractors, etc.) involved in ship/equipment design have proliferated. A Shipboard Interface Standards Program has been established to meet this need. Shipboard interfaces, when considered in their totality, confront the systems/design engineer with complex and intricate problems. Solution of these prob-lems is facilitated by defining particular selected interfaces and the constraints they impose on equipments. MIL-STD-l399 is structured to provide these definitions. This standard, and its supporting sections, defines the constraints on systems/equipment design imposed by the established characteristics of the shipboard environment. It will:

- Specify constraints for systems/equipment design imposed by the shipboard environment
- Provide for early dialog among personnel concerned
- Assist in achieving more effective ship configuration management
- Contribute to cost-effective and integrated ships by promoting interface compatibility
- Ultimately achieve interface compatibility of installed systems/equipment with the shipboard environment

MIL-STD-1399 applies to all activities involved in ship/systems/equipment design, production, and installation and requires that the interfacing aspects of ship/systems/equipment be given priority consideration by such activities. The specific interface characteristics and constraints established in the various sections of this standard are mandatory and shall be adhered to by SYSCOMs, PMs, contractors, and all others engaged in any aspect of total shipboard design, including system/equipment design, production, and installation. It is incumbent upon interested activities, in consonance with the objectives of the Interface Standards Program, to establish a dialog in a timely manner which will bring into focus and resolve any interface problems which may require attention in areas not yet covered by this standard. It is essential that interface requirements be carefully considered by all naval activities and contractors involved in ship construction/modernization/conversion throughout the entire ship life cycle. It is also mandatory that Principal Development Activities (PDAs) invoke this standard in the Development Plans (DPs) and procurement specifications for new systems/equipment destined for shipboard installation.

REFERENCE

Naval Ship Engineering Center Military Standard, MIL-STD-l399B, *Interface Standard for Shipboard Systems*, 22 Nov 77.

DEFICIENCY ANALYSIS

During the validation testing, analyze any failures or deficiencies as to their impact on the program. Quick fixes may have been incorporated during testing, and further modification may be required for service use. The extent of the deficiencies, failures, or required modifications will determine the course of action at this point. The next step can range from obtaining service approval to requesting more funds for modification or further development, or even to canceling the program.

In the event that modification is called for, the program plan will (may) also require modification. This includes new schedules, readjusting fund allocations (new or existing funds), and most of the other steps covered in chapter III, Program Planning.

The technical approach may also need modification. Refer to chapter IV, Conceptual Phase. This will ultimately lead to updating the system specification. Major changes in the technical approach will require new validation tests. Refer to the introduction to this section. Those elements of the system that do not change may still be covered by the original validation, depending on the impact of the change.

VI. TRANSITION TO PRODUCTION

The transition to production phase is simply the translation of a viable system concept into a form which can be efficiently produced in the quantities required for service use. Off-the-shelf systems or readily modified systems involve a straightforward transition; developments may cause a very complex transition. This phase is almost entirely dictated by the decisions made in prior phases; therefore, planning incorporating the considerations discussed in this chapter must be accomplished much earlier in the project cycle, usually in the conceptual phase.

Once the technical approach has been validated, the program is ready to complete the acquisition cycle. At this transition point, the decisions to build, buy, or modify equipments to suit the requirements must be finalized.

Alternative	Phase	Major Phase
Build	Full-Scale Development (EDM) Engineering Qualification	Product Development
Modify	Modifications	
Buy	TECHEVAL/OPEVAL Service Approval	Qualification
	Production Deployment	Initiation

While the actions required in each phase may differ among the alternatives, it is possible to assemble a system with equipments acquired through each alternative; in such a case, system integration is always a major issue in the qualification phase.

There are two major milestones in the transition to production — Approval for Full Production (AFP) and Initial Operational Capability (IOC). Refer to chapter VII, Approval for Production, for the requirements for meeting the AFP milestone. IOC is the date that the deployment phase is initiated. Another milestone, Final Operational Capability (FOC), delineates the completion date of the deployment phase. IOC is extremely important because the equipment logistics support must be initiated by IOC. In the many instances in which the support has not been initiated in consonance with the equipment, the result has been a degrading of the equipment, frequently leading to permanently unacceptable performance. IOC may be a firm or a flexible milestone. It is a firm milestone when the equipment must be available on a specific date such as when it is GFE to a larger contractual effort (such as new-ship construction). Flexible IOC exists when the equipment delivery is required only to meet mission deeds. The firm milestone may be slipped in actuality; however, the IOC must be assumed to be fixed for planning purposes. The flexible milestone may actually be quite inflexible because of ship availability schedules for installation and for political reasons. The IOC should be established at the initiation of the program and guide the program planning actions accordingly; therefore, the flexibility of the IOC must be known in order to assess schedule risks.

MAJOR DECISIONS

Whichever acquisition alternative is pursued, there are five major issues which must be resolved within the program objectives and constraints. These are:

- System partitioning/integration
- Design ownership
- Specification type
- Level of repair performed at the field level
- Standardization

Each of these issues may be politically volatile depending upon the sponsoring activity and the time within the acquisition cycle when a decision is made. In general, the earlier within a program that each issue is addressed, the better the prospects for a smooth transition. This is true not only from the standpoint of being able to preplan, but from the standpoint of political risk as well. An early decision point allows time to budget properly and to bring the parties involved in the acquisition to an understanding of the acquisition plans; both elements serve to mollify opposing views.

SYSTEM PARTITIONING/INTEGRATION

The first and most complex issue involves the system partitioning and the subsequent integration of the pieces into the system. The degree of partitioning possible for a system is directly proportional to the complexity of the system; a very complex system will be partitioned within a hierarchy of levels of varying degrees of complexity as illustrated below:

Level	Definition
1	Piece part
2	Module
3	Subassembly or Shop Replaceable Assembly (SRA)
4	Assembly
5	Unit or Weapon Replaceable Assembly (WRA)
6	Group
7	Set
8	Subsystem
9	System

The definitions above conform to MIL-STD-280 except for Module, WRA, and SRA. Module was added in recognition of the great increases in system complexity within recent years; additional levels could be accommodated in a like manner. WRA and SRA are defined in MIL-STD-1390. Obviously, less-complex equipments have fewer levels of complexity. A single-function simple equipment might have only two levels — equipment and piece part. See figure VI-1. The necessity of breaking down the system for cost estimating, scheduling, work package formulation, etc., is evident in the utility of the Work Breakdown Structure (WBS) (see chapter III, Program Planning). Partitioning is also an important step in resolving the other four major issues. The partitioning phase normally takes place during concept formulation (see chapter IV, Conceptual Phase).

Once partitions are established, the system integration problem begins. The primary issue to be resolved regarding system integration is where the responsibility for the tasks lies — which commands/activities within the government and which industrial companies have major and subordinate roles. The Systems Engineer, responsible as the system integrator, must do the following:

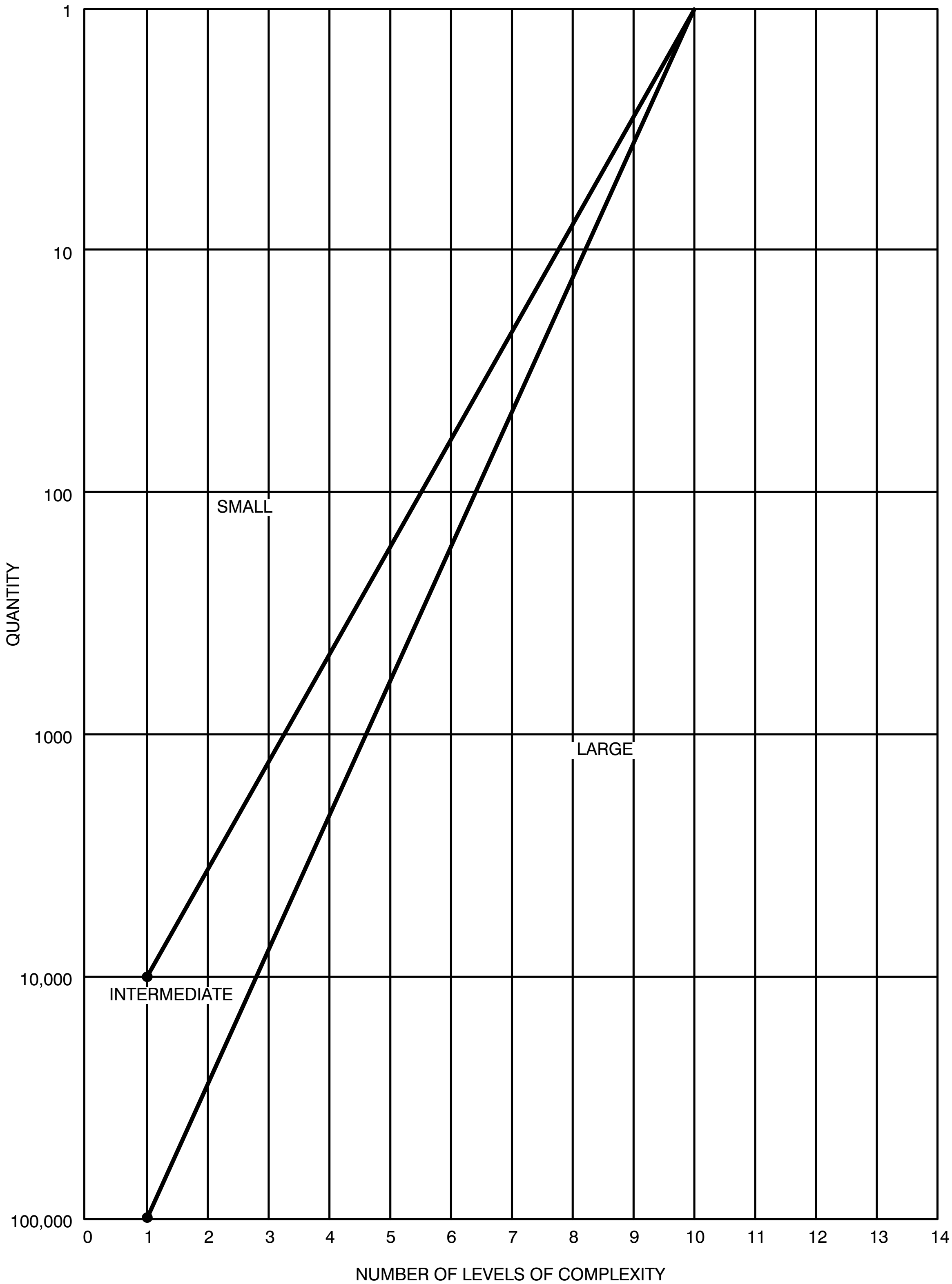
1. Transform an operational need into description of system performance parameters and a system configuration through the use of an iterative process of definition, synthesis, analysis, design, test, and evaluation.

2. Integrate related technical parameter and assure compatibility of all physical, functional, and program interfaces in a manner which optimizes the total system definition and design.

3. Integrate reliability, maintainability, safety, human, and other such factors into the total engineering effort.

System engineering effort includes, for example, system definitization, overall system design, design integrity analysis, system optimization, cost/effectiveness analysis, weight and balance analysis, and intrasystem and intersystem compatibility analysis. It also includes reliability, maintainability, safety and survivability program requirements, human engineering and manpower factors program, preparation of equipment and component performance specifications, security requirements, logistics support integration, and design of test and demonstration plans.

If the operational needs are to be met by the system design, it is virtually impossible for the government to delegate these ultimate system engineering responsibilities to industry since a detailed knowledge of the operational need is required; however, these responsibilities normally are delegated to industry for portions of the



INTERMEDIATE = LARGE WHEN EACH ITEM COST IS (RELATIVELY) HIGH
INTERMEDIATE = SMALL WHEN EACH ITEM COST IS (RELATIVELY) LOW

Figure IV-1. Levels of complexity as a function of quantity.

system below a given level of complexity. Attempts to contract the ultimate system engineering tasks will nullify the government's control of the technical effort resulting in a high degree of risk than obtaining a product acceptable to the user. Even when the operational need can be well described to the contractor, the government will not be in a position to determine optimal tradeoffs. When the need is not well defined, only the government is in a position to estimate the elements needed to fill in the holes. System integration task responsibilities should be delegated and divided along the same partition boundaries as the system engineering tasks. The division of responsibilities should be clearly established, consistent with the determinations made for the other major issued and always implying total industry accountability to the government for the assigned tasks (i.e., the government should not assume responsibility for an item which is to be integrated into an item for which industry is responsible unless the partition interfaces are fully specified and validated). This latter point is the most controversial, risky, and difficult-to-implement aspect of system integration, and it is the most important. Figure VI-2 illustrates a reasonable resolution of this issue.

One of the major decisions to be made is whether to task the physical assembly of the final system to industry or to use in-house resources. If a single contractor or prime contractor is being utilized, that contractor should be tasked; however, if the system consists largely of existing equipments from diverse sources, in-house resources should be utilized. In either case, the government must develop the documentation within its area of direct integration responsibilities.

DESIGN OWNERSHIP

The issue of design ownership is extremely controversial and politically sensitive, and therefore must be resolved with a well documented and well justified decision. The decision to be made is whether the system design should be government owned or contractor owned; the controversy arises because it generally assumed that design ownership must be either one or the other. Actually, the requirements for the government to own the design seldom dictate an exclusive decision, and practical solutions can be formulated whereby the government owns part of the design and the contractor owns the rest. The government ownership requirements are for designs meeting one or more of the following conditions:

1. The design is based upon in-house expertise which far exceeds industrial expertise.

2. Design features closely interact with service doctrine and directly affect the user's performance of duty.

3. Configuration control must be maintained for repair and standardization purposes.

4. There is essentially no commercial market, and government requirements are recurring but insufficient to support continuous production or multi-source production.

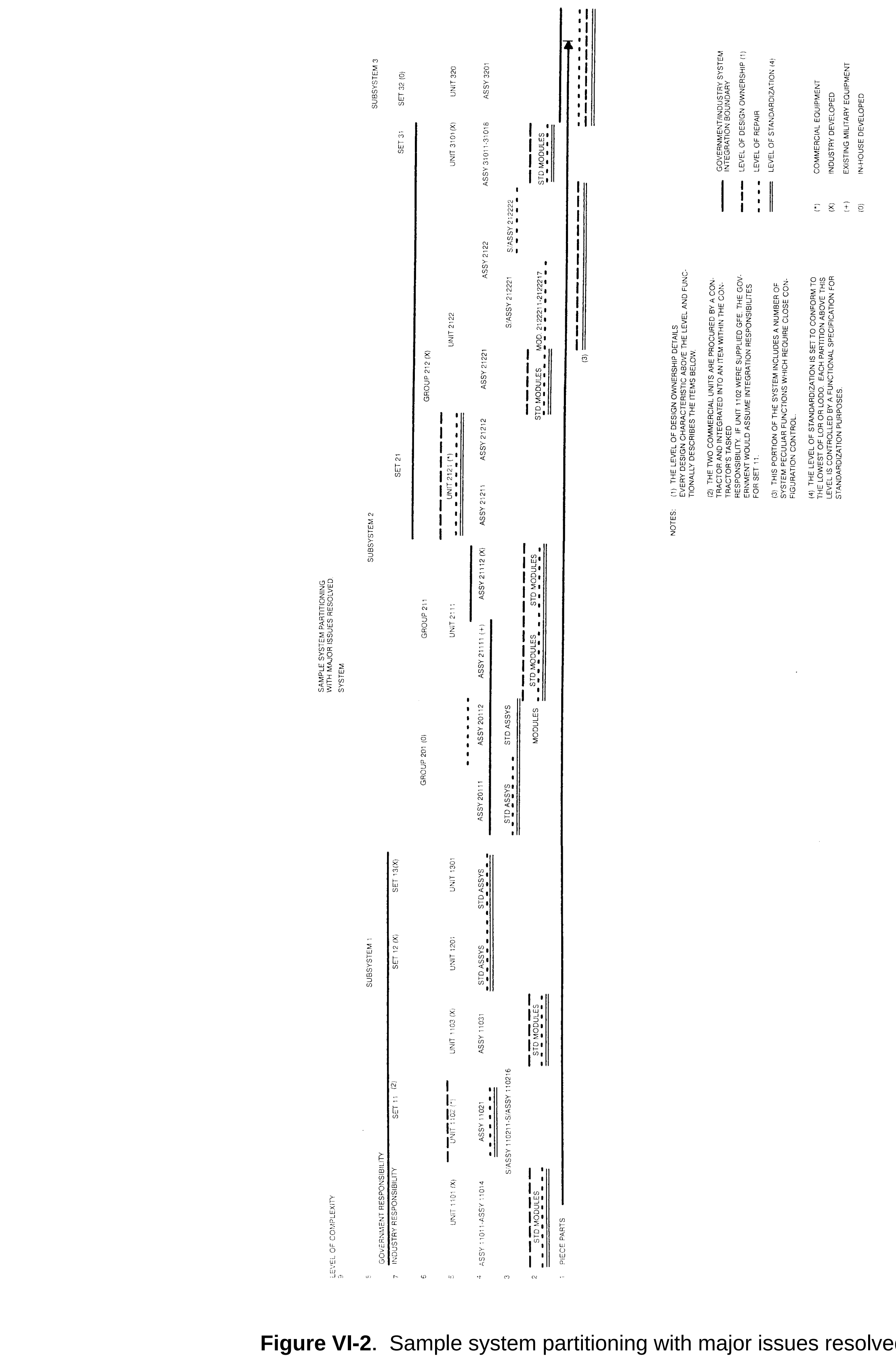


Figure VI-2. Sample system partitioning with major issues resolved.

The above conditions dictate that the government should own at least a portion of all designs. However, condition (2) features can often be specified in a functional specification without regard to the design implementing those features, and condition (3) applies only to the level of standardization which must be maintained. Therefore, under many conditions the government is only interested in owning a portion of the design — usually the functional design down to some level of complexity supplemented by the detailed (fabrication) design in limited portions of the system meeting one of the above conditions (usually (1) or (3)).

Detailed design ownership is always expensive to acquire. Furthermore, detailed designs dictate significantly more government responsibility in the development, qualification, and use of the design. Specifically, the government must procure more documentation and assume the responsibility that the documentation is accurate when it is utilized in production. Also, proprietary parts and processes which are common to sophisticated technologies must be excluded from the design or else the government must obtain license and documentation for the part or process. This negates the advantages of the proprietary feature for the contractor and therefore is hard to obtain. The other option for the government is to be satisfied with a permanent sole-source situation which will probably negate any advantage to design ownership. More aspects of detailed design ownership are discussed as part of the tradeoff between functional and fabrication specifications (see SPECIFICATION TYPE, below). In general, detailed design ownership requires close monitoring of the design development by technically knowledgeable government personnel, validation of the developed design to prove conformance to the functional design requirements and to demonstrate the reproducibility of the design, maintenance of an up-to-date configuration, and exclusion of proprietary parts and processes. The validation of the design is extremely important and consists of an unbiased analysis of the allowable tolerances of each part to ensure conformance to the functional design under worst-case conditions. This may consist of a "simple" study for straightforward designs. However, complex designs or designs utilizing complex processes may require the building of hardware by a government facility or by another contractor to proof the design data package.

As the complexity of a design increases, the risks associated with not validating the design data package increase rapidly. These risks manifest themselves as a probability that the design will not perform the required functions or that the design will fail to fit together or that the required production processes will not be reproducible. In any case, the government as the design owner must bear the costs of making whatever changes are necessary to produce a correct design. Changes under these conditions can easily double the costs of the design development. If the development costs are a significant portion of the total program costs (over 5%), a design validation phase should be considered mandatory. As an additional note, changes which occur during design validation must themselves be proofed by unbiased analysis.

On large quantity acquisitions, the design documentation can be validated through a LEADER-FOLLOWER contractual team or through other multisource procurement techniques.

The other key elements to acquiring detailed design ownership are technically knowledgeable design management and good configuration control; this is true whether the government or the contractor will own the design. If the government will assume ownership, these elements must reside within the government. If the contractor will retain ownership, his failure to provide these elements constitutes risks to the project which must be dealt with by the government. The primary defense against incurring excessive risks of this type lies in the structuring of the source evaluation criteria, placing the greatest emphasis on technical expertise in both design and production and significant emphasis on their configuration management system. Unfortunately, the vagaries of contracting will occasionally lead to an award to a contractor weak in one or both areas; the only defense the manager can provide himself is a combination of in-house resources, effective management reports (required through CDRL), and prayer.

Another pitfall exists. Large contractors sometimes develop a design in one division and produce the product in another division located 10 states away. Even though the contractor will retain design ownership, the design must be transitioned from the one division to the other, and the separate divisions take on the character of different companies. To provide for a good transition, the government should require that a preproduction model be produced, as a part of the development contract, with the same facilities (and, preferably, same personnel) which will be used for the production contract.

As with the system integration issue, when the contractor-owned/government-owned design boundaries are established, they should be clearly established and consistent with the determinations made for the other major issues and with the criteria above.

SPECIFICATION TYPE

Production items are specified by product specifications. MIL-STD-490 defines four different types of product specifications for use by DoD in seven different formats, and while industry does not necessarily conform to these formats, the different types are fairly universal. The most important types are the functional (or performance) specification and the fabrication (or detailed design) specification; the remaining two types are the Noncomplex Item Product Fabrication Specification (which, as the name implies, is an abbreviated form of fabrication specification) and the Computer Program Product Specification. Both the functional and fabrication types may be written in two formats depending upon the complexity of the item specified (i.e., prime item or critical item); additionally, the functional specification is used in another format as an Inventory Item Specification. Which specification type should be used is a major issue which must be resolved in selecting a procurement mode.

FUNCTIONAL SPECIFICATION

The functional specification requires that the finished hardware meet size, weight, external configuration and mounting provisions, external interface requirements, and overall performance of the item within a specified environment (often referred to as "form, fit, function," or F^3, parameters). When the contractor has produced the hardware, the government is obligated to accept and pay for it if it meets the specified requirements, regardless of the nature of the internal design. This approach is utilized frequently for the procurement of expendable, nonrepairable items and for readily available items (such as batteries) for which the government is not concerned about internal configuration. When used to procure repairable items, the procurement package should include warranty provisions, renewable maintenance contract provisions, and/or provisions for contractor services to set up the necessary government maintenance capabilities to support the equipment through its intended service life.

The advantages of procurements controlled by functional specifications are as follows:

1. Detailed design responsibility is clearly assigned to the contractor. If the item fails to meet specifications, the contractor must alter the design until specified operation is achieved.

2. There is no design data package for the government to procure or maintain.

3. Requirements for technical capability within the government are minimized. This is the path of least involvement on the part of the government in contracting, contract monitoring, etc.

4. Standardization can be achieved among multiple sources through two-way interchangeability of products which may differ internally. These multiple sources may be exercised simultaneously.

The disadvantages include the following:

1. Each procurement contains a development effort unless the product is off-the-shelf-unmodified. Some time and money are involved each time the item is procured for engineering, changes, production learning curves, and debugging. Since the contractor develops the product, companies without a development capability (and accompanying development overhead) are excluded. (Of course, when an off-the-shelf product is being purchased unmodified or slightly modified, the development costs (apportioned into each unit price) are shared by the entire market, of which the government may be only a small part.)

2. Each time a procurement is made, the contractor who has the least appreciation for the total significance of the specification and the effort to accomplish the task is most likely to be the low bidder. This means that the source selection criteria must be very carefully constructed to include mechanisms to demonstrate contractor awareness of critical elements as well as the capabilities to produce the item. In a simultaneous multisource procurement, the quantities to each successful bidder can be made contingent (within boundaries or as determined by a formula) upon the relative performance of each product in preproduction testing for a limited set of critical parameters (such as receiver sensitivity, reliability, and cost).

3. The costs of repair parts will tend to become excessive when a contractor realizes that he is in a somewhat sole-source position with respect to his equipment unless the total maintenance for the service life of the equip-

ment is provided for in the procurement contract or in conjunction with the procurement contract while competition is still being maintained. A side issue arises in that procurement funds and operations/maintenance funds are separate budget pots, requiring the program to resolve a potentially politically sensitive issue on the funding of the procurement prior to its execution.

4. Careful specification of all external parameters is required to ensure true interchangeability. Each parameter must be specified within tolerances; it is strongly recommended that output tolerances be tighter than the input tolerances they interface with and inversely for input tolerances. Control second-and third-order parameters (timing relationships, phase, out-band response, spurious emission, etc.); overlooked second- and third-order parameters may result in marginal or unusable equipment that the government is obligated to accept. Considerable testing may be required to derive this information.

Even if the functional specification is for a less complex item than a major system, the specification guidance provided for Type C1a, MIL-STD-490, App VII, contains the elements which should be considered even if another format is used. There are several points which may be clarified for functional specifications. The following items amplify type C1a paragraph guidance:

1. <u>Maintainability</u>. Consider test equipment/test point provisions and any special requirements such as use of ATE or limits to GPETE and the interfaces to be provided for test purposes.

2. <u>Design and Construction</u>. Specifically applicable paragraphs of the general equipment specifications (MIL-STD-2036, MIL-E-5400 etc.) should be cited. Metric/English requirements should be called out.

3. <u>Materials, Processes, and Parts</u>. Include the provisions to (a) prevent the unnecessary use of strategic and critical materials, (b) prevent the use of processes which are known to lead to an unsafe item in field use, and (c) limit the use of proprietary or other nonstandard parts as appropriate to the maintenance/logistic support plan for the item.

4. <u>Interchangeability</u>. Applicable items include type and location of connectors, connector pin allocations, and interface hardware for mounting, for cooling connections, for power, for insert keying configurations, etc.

5. <u>Human Performance/Human Engineering</u>. Drawings of specific control panel configurations, control operations, and lighting features should be referenced when appropriate.

FABRICATION SPECIFICATION

The fabrication specification requires the hardware to be built in accordance with a detailed design data package. In this manner, “form” and “fit” are tightly controlled and “function” is implicitly controlled by the design capabilities of the hardware described by the data package. Only critical functional parameters are included to ensure that the accepted hardware will be functional. A fabrication specification is always used for government-owned detailed designs (and vice versa) (See DESIGN OWNERSHIP, above). The advantages of fabrication specification controlled procurements are:

1. The government maintains strict configuration control; thus, all parts in the field are identical to their counterparts regardless of manufacturer (unless specifically authorized changes are allowed). Thus, repair parts, training, test equipment, technical manuals, and other logistics elements be standardized and maintained efficiently and cost-effectively at the organizational or intermediate maintenance levels.

2. The development costs and associated long lead times are borne only once and the government can exercise strict configuration management during design. The design can be fabricated by any contractor with the proper production facilities and competence to use them. This is a much broader source base than that for functional specifications. Also, contractors maintaining production facilities only do not have the high overhead rate associated with a development capability (usually an acceleration of 20-30%).

3. Second- and third-order parameters which are inherent in the specified design will continue to play an important but unknown, unappreciated, and unspecified role in the successful operation of the hardware.

4. Lessons learned in the production of the item by one contractor may be incorporated in the data package to preclude duplicate difficulties on succeeding contracts, thus reducing risks with each procurement.

5. Spurious reprocurements and mobilization requirements can be met rapidly and without significant risk.

6. Good cost, quality, and production time standards can be obtained and utilized on future procurements.

7. The in-house technical base is generally increased and made available for future procurements.

Most of the <u>disadvantages</u> of fabrication specification procurements relate to the fact that the government owns the detailed design and must bear the responsibilities of ownership (see DESIGN OWNERSHIP, above). Some other disadvantages include:

1. The government must pay for all development, validation, and qualification costs incurred in assembling the design data package.

2. The original developer must be honest, accurate, complete, and current in his generation of the design data package. A lack of one of these characteristics will show up in a design validation phase; however, complete validation is frequently omitted (too expensive). Even when validation is performed, large costs will be incurred correcting deficiencies.

3. The state of the technology base is inherent in the data package. Highly mobile technologies can rapidly outdate the design and cause costly, hard-

to-get spare parts and/or costly redesign of the equipment. It is very difficult to accommodate new capabilities without costly design changes.

4. Because functional parameters are largely not available, it is very difficult to create a standardization program which utilize the item in everexpanding applications and updates the capabilities to conform to dynamic operational needs.

SELECTION CRITERIA

The choice between specification types to support procurement is based on:

1. The need for detailed design ownership. (Detailed design ownership implies fabrication specification.)

2. The size of procurement <u>and</u> reprocurement requirements. (For items requiring development, functional specifications are best applied to large procurements where multisources can be utilized simultaneously; fabrication specifications are valuable to support intermittent and spurious reprocurement requirements.)

3. The maturity of product design. (Functional specifications are best applied to mature (on shelf) designs which can be used as is or with minor modifications.)

In either case, product specifications are intended for use with fixed-price contracts. If the item is repairable, the maintenance of items procured on functional specifications should be included in the contract; when this is not possible, a fabrication specification may be a better choice.

Picking one specification type over the other has long-term effects which must be dealt with. Fabrication specifications are effective establishing standardization and configuration control only at the piece part level; this fact may be inconsistent with the resolution of the standardization and level-of-repair issues. Standardization above the piece part level is best supported by functional specifications; therefore **functional specifications should be established at each level of complexity down to the level of standardization regardless of the specification type used for procurement**.

Occasionally, procurements are observed in which the government owns a detailed design data package but lacks confidence in the accuracy and completeness of the design. It has been common practice to furnish the drawings the contractor “for information only,” and require them to retain interchangeability with depicted design to a specified level. This approach amounts to procurement without specification, since functional specification is not established and the government disclaims responsibility for the adequacy of the baseline designs. The contractor assumes high risks which are translated into virtually certain failure to meet technical, cost, or schedule goals. None of the advantages of either specification type are realized.

The application of functional specifications to procurements of small-lot, government-peculiar items requiring significant development is observed, also. Primarily, the manager is attempting to procure the item without paying for the design package. This ploy works until a reprocurement of even one more item is required; then the contractor, who is in a sole-source position, must be paid again for development, tooling, etc. Usually, the procurement situation arises out of an expensive and complex development effort in which small quantities are procured initially but large quantities are eventually required — but in a number of small-quantity reprocurements. In this situation, the government should buy reprocurement rights with the initial procurement which guarantee that future procurements will be met at the same unit cost (plus escalation for inflation) as the first units and within a specified time. In this way, the government pays the contractor to maintain the design documentation and production tooling until it is needed. Essentially, the government has bought use of the design without obtaining title for custody to the data package. This ploy is not nearly as flexible as obtaining design ownership out of the development phase and is harder to implement on a firm legal basis, but costs can be significantly less in development. The tactic may not be used for process-sensitive procurements because the process yield will be lost between buys.

Functional specification implies contractor-owned detailed design, and fabrication specification implies government-owned detailed design. This is fine, but who should be responsible for developing the specified parameters? In functional specifications, the parameters are generated by the government from the requirements; additional functional parameters may be added to extend the specification to a lower level of complexity by adopting established standard interfaces or by procuring additional functional specification parameters from the contractor and verifying them during qualification tests. This latter ploy is slightly more risky because second- and third-order parameters are easier to overlook. Fabrication design data development is very much more complicated and controversial.

The final subissue related to specification type involves the level of specification; i.e., the level of complexity to which the system is specified. Functional specifications should be established to the lowest level of complexity consistent with the other major issue resolutions; fabrication specifications should be established consistent with the procurement considerations and design ownership boundaries. The specifications should be complete to the design ownership boundaries prior to starting procurement actions.

LEVEL OF REPAIR PERFORMED AT THE FIELD LEVEL

The issue of level of repair performed at the field level should be resolved before the transition to production is commenced. The field maintenance level includes the organizational maintenance levels and the field/afloat intermediate maintenance level. The level of repair (LOR) — i.e., the level of system complexity to which the system is repaired — performed at the organizational level should be determined during concept formulation in conjunction with level of maintenance capability constraints. These constraints tend to force the LOR at the organizational level toward the system level of complexity; however, practical constraints (size, weight, item cost, and failure rate) tend to drive the LOR toward the piece part level. The balance of these forces tends to resolve the system maintenance philosophy at approximately the unit (or WRA) level of complexity. However, the best level at which to discard failed items is usually simpler (such as the module or piece part level) than the level of organic repair. In order to minimize downtime and inventory quantities, some form of intermediate maintenance activity is usually employed to effect repair of the unit at a SRA level and/or to establish a rotatable equipment pool. A combination of noneconomic analysis and an initial support analysis based in the system life-cycle cost model is completed to determine the level of repair at the intermediate activities. After the product design is relatively complete, a level of repair/ logistics support analysis performed as a portion of the ILS tasks is completed to confirm and modify appropriately the initial determination.

Although tedious, the economic analysis is relatively straightforward if a viable system life-cycle cost model has been established; guidance is available from MIL-STD-1390, MIL-STD-1388, and system effectiveness personnel (such as those in NRaD's Sustainability Division). Noneconomic analysis may or may not play a significant role in the LOR decision.

The noneconomic analysis will consist of recognizing preempting factors such as safety, repair feasibility, standardization, allowable downtime, and the other non-cost constraining factors. If this analysis produces a definitive decision for LOR, the economic analysis is still completed to formulate repair/discard decisions on the basis of the design. Usually a definitive decision will not be reached until the product design is nearly complete. Nevertheless, factors which affect the noneconomic analy-sis do impact upon the build, buy, modify alternatives, the system integration issue, and the ability to achieve service approval. Of these factors, allowable downtime and standardization considerations tend to be the confusing factors. Standardization is itself a major issue (see STANDARDIZATION, below); downtime is discussed in the following paragraphs.

The downtime allowable for the system as a whole is determined by its criticality to the platform missions; the system is classified as vital, semivital, or nonvital with a system availability assigned accordingly. Downtime and mission reliabil-ity are the factors which make up availability; the formulation normally is of the form

$$A = \frac{MTBF}{MTBF + MDT}.$$

Not all failures which can occur affect mission eligibility, and the repair of those failures does necessarily cause the system to be down. Prior to the product design phase, essential equipment items (those whose failure effects mission reliability) can be identified at each level of complexity within the system. When the system is partitioned, many (ideally all) of the essential items can be lumped into a single cell, and at some level of complexity it is possible to eliminate the essential item nature through voting techniques, redundancy, etc. Unfortunately, it is not always practical, even when it is cost-effective, to partition in this way, since other factors come into play. However, a level of complexity can be identified for each portion of the system for which essential item effects are minimal and for which the allowable downtime can be notably long without affecting system availability. This level allows effective intermediate maintenance support with practical turnaround times and is, therefore, the optimum level of repair from a downtime viewpoint. Naturally, the final LOR determinations must take into account many other factors.

When the level of repair performed at the field level is identified, the information is useful in establishing tradeoffs between contractor support versus in-house support, government configuration control requirements, and other factors important to resolving the other major issues.

STANDARDIZATION

The values, policies, and tradeoffs associated with standardization are documented in chapter XIV, Consideration of Standardization. Level of standardization is a concept which recognizes the benefits of standardization while acknowledging that improper implementation can lead to gross deficiencies that negate the potential benefits. For a given operational requirement, it is beneficial to have standard system, design, logistics, etc., to meet the requirement. On the other hand, logistics items (piece parts, modules, etc.) must be utilized in many systems to become effective standard items. System designers require flexibility and acquisition managers require flexibility, but standardization implies inflexibility. In order to avoid inflexibility and to be useful, standards must be

- Functionally specified (so interface data are readily available)
- Functionally complete (can be used as a building block)
- Available in minimal variety sufficient to meet differing major applications
- Adaptable (easily maintained with the state of the art)
- Well documented and readily available to the prospective user
- Functionally flexible (possess capabilities, reliability, etc., that make it attractive to diverse applications)

Standardization has strong implications for each of the other major issues. System partitioning must be carefully constructed to use existing standards where possible and to make other partitioned portions of the system attractive as new standards. The partitions should, as much as possible, conform to industry standards (where they exist), common practice etc., to avoid "swimming upstream" and make the item easier to procure. The "standard" partitions should be consistent with design ownership and level-of-repair decisions. System partitioning which is system peculiar (unsuitable for other applications) should be confined to as small a portion of the system as is practical; this puts limitations on other partitioning considerations such as those for level of repair.

Functional specifications should be established at each level of complexity below the system level and above (but including) the level of standardization. The level of standardization will be the worst case of the design ownership boundary and the level of repair. The system-peculiar items should be specified also, since future efforts to standardize or to change an interfacing standard may have to identify critical interface parameters.

MAJOR ISSUES SUMMARY

Each major issue embodies a family of often sensitive considerations which must be dealt with before a successful transition to production can be completed.

These issues are closely related and may not be considered as isolated cases without risk of causing dire perturbations to the others. Many of the steps which must be taken to resolve (or resulting from) these issues involve time and money resources which may appear to be unnecessary when viewed in isolation; however, failure to execute these steps within the coordinated framework of the major issues will lead to greater overall program costs.

THE "BUY" ALTERNATIVE

The buy alternative describes the use of existing equipments and presumes that the equipments are readily available and in use, and that some use history might be obtainable. Such equipments will be identified by the source search and screen approach integral to the TELCAM technique (see chapter XI, Screening Techniques). This screening serves to establish qualified equipments but does not qualify the equipment for service use directly; rather, the equipments must be integrated into the system and the system support plan modified as necessary to accommodate the item (the modifications must remain within the system constraints). For the portions of the system utilizing this alternative, the major issues will be resolved as follows:

	Commercial Equipment	Military Equipment
System Integration	Government responssibility from the equipment level on up	
Design Ownership	Supplier	As previously established
Specification Type	Functional	Inventory item (functional)
LOR	At the equipment level	No lower than that previously established
Standardization	At the equipment level	As previously established

"As previously established" implies that this information is available and compatible with system requirements; incompatibilities may often be resolved by treating the military equipment as a commercial equipment. The buy alternative flow is illustrated in figure VI-3.

A sophisticated "buy" technique which is suitable for large, multiple-buy procurements (such as avionics) is documented in ARINC Publication 1313-01-1-1447, *Application of the Commercial Airline Acquisition Methodology to Department of the Navy Electronic Equipment Acquisitions*, 15 October 1975, AD/A015694.

THE "MODIFY" ALTERNATIVE

The modify alternative is usable when modifications can make an existing equipment suitable for the system application. The same steps and procedures apply as for the buy alternative except that a modification step is added. The modification may be performed by the government or by the supplier for commercial equipments depending upon the support provisions in the procurement contracts and the nature of the modifications. Modifications which can be accomplished externally to the equipment in the interfacing hardware will normally be done by the government; all other modifications are usually accomplished by the supplier. The modification is controlled by detailed design when accomplished by the government and by incorporation into the procurement specification when done by the supplier. The two modification alternative flows are illustrated in figure VI-3.

THE "BUILD" ALTERNATIVE (DEVELOPMENT)

The build alternative should be pursued only when suitable buy and modify alternatives are not available. Unfortunately, the many unique military requirements and rapidly evolving military technology force a development situation; even where otherwise suitable equipment exist, the requirement maintenance environment cannot be adapted to it.

Development is a very much more complex process than the processes of the buy and modify alternatives; therefore, there are more issues to be resolved, more things that can go wrong, more resources required, more time needed, and more risks which must be assumed and managed. Whereas each of the major issues is largely resolved for the other alternatives, the resolution of these issues is not automatic and can be critical to the success of the build alternative; also, the complexity of development includes some issues peculiar to the process. These factors may make build the least desirable alternative. It is necessary to separate requirements from desirements, to ensure requirements validity, and to research possible alternatives which can lead to a buy or modify decision if the time, expense, and risk of development are to be avoided; a strong validation phase is very important for this reason (see chapter V, Validation Phase). The purpose of the transition to production is to obtain a product for application to service needs; expansion of the technology base is an exploratory development function which only increases the risks incurred when accomplished during full-scale development.

Before entering into development, the system must be partitioned; this should normally be done in such a way that portions subject to the buy or modify alternatives can be independent of the developed portions as much as possible. Partitioning along such lines is normally compatible with the resolution of the major issues; but should conflict occur, partitioning to segregate the buy/modify portions from the build portions should normally be given precedence unless the system life-cycle cost model proves that development of the portion in question is a cheaper alternative (although rare, the situation can occur). The remainder of this section deals exclusively with development.

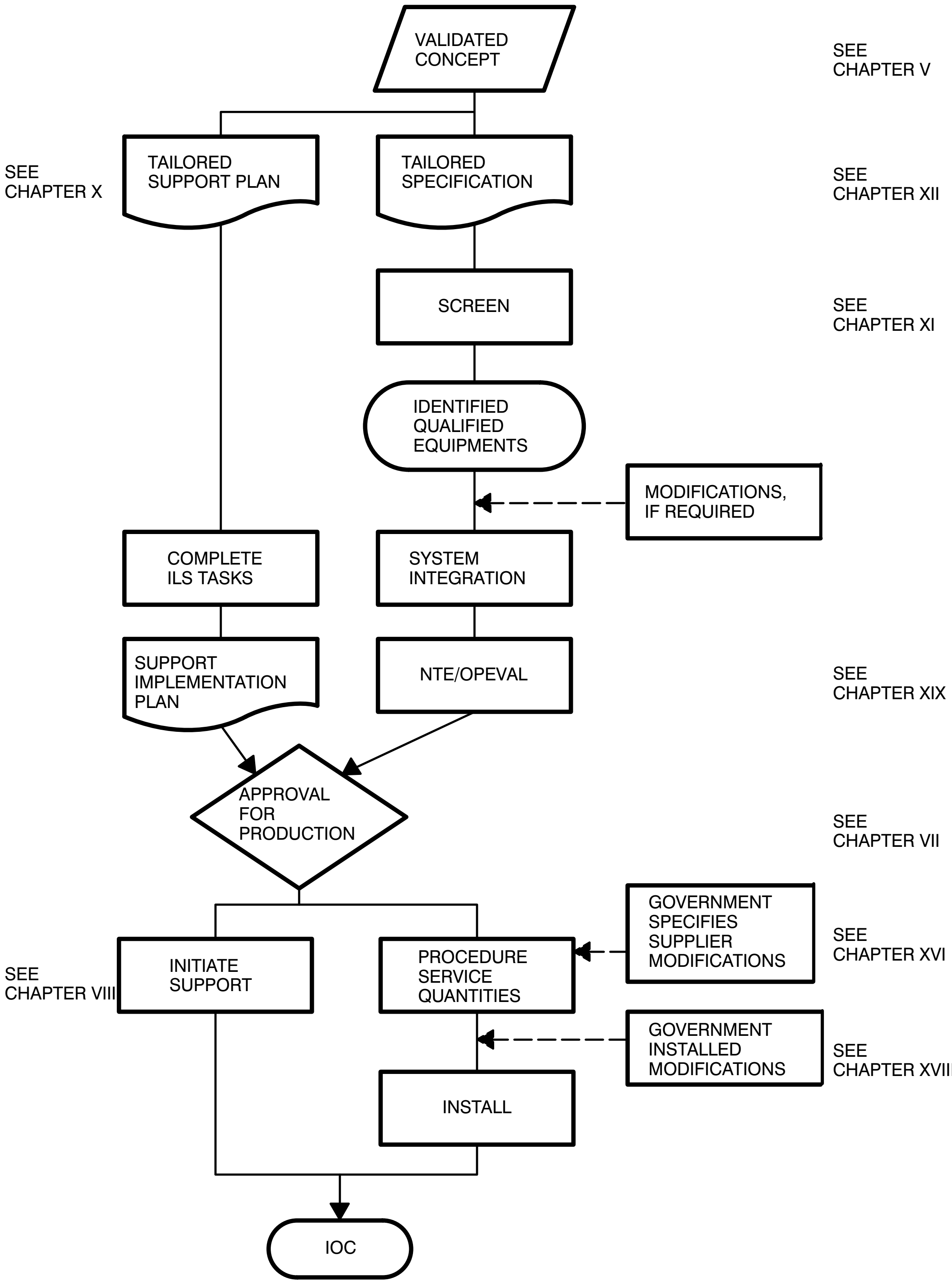


Figure VI-3. “Buy” and “modify flow.

There are two issues peculiar to development (in addition to the five major issues above):

- The development alternative to pursue
- The transition-to-industry point

The issues are interrelated and are primarily related to the resolution of the system integration and design ownership issues. The level of repair should be resolved at the most cost-effective level at which it is feasible within the mission constraints. The specification type will be dictated by design ownership and the selected procurement mode, and the standardization issue will be determined by the system partitioning, design ownership, and level-of-repair issues. The selection of the development alternative should be based primarily on the management of perceived risks and on the maintenance of competition (when the development is accomplished by industry); however, the decision may be modulated by the other issues. Transition to industry embodies these considerations plus a great deal of controversy and political risk.

Only under the special circumstances outlined in chapter XVII, Development Alternatives, can a development be pursued in-house; these same criteria may be applied to the production phase with the result that industry will almost always be the source of production resources. Once the transition to industry has taken place, the reverse transition <u>should not occur</u> unless new production resources must be recruited. Usually, the reverse transition is only a temporary one to effect transition from a sole source to a multisource situation (ref NAFI TR-1901); a permanent reverse transition normally occurs only when the government is dependent on an item in which competent industry sources are no longer interested.

The reverse transition serves to develop a data package in which the government has high confidence; it can be avoided if proper care is taken in procuring adequate documentation initially.

The transition may occur at the beginning of the acquisition cycle as in the case in which a system is wholly dependent on a technology which has been developed within industry, or it may occur following pilot production (and coinciding with the release to production decision). Or both transitions may take place with a reverse transition occurring after engineering development. Other transition points are possible (see fig. VI-4).

If the design ownership is going to reside with industry, the transition to industry point should depend on the need for competition in the procurement mode and the maturity of the design. If the design constitutes a major modification of commercial products and does not depend on new technology, competition is relatively inexpensive to achieve. However, if the design depends heavily on new technology or on technologies not commonly used in established large-market products, competition will be limited by program resources because a large amount of high-risk development will be duplicated by as many sources as are needed to support competition (at least two — more if the technical risk is considered high). Competition is important to reduce cost/schedule risks and to maintain control of the procurement. The program must have the resources and justification based on usage to support these conditions; otherwise, the design ownership should reside with the government.

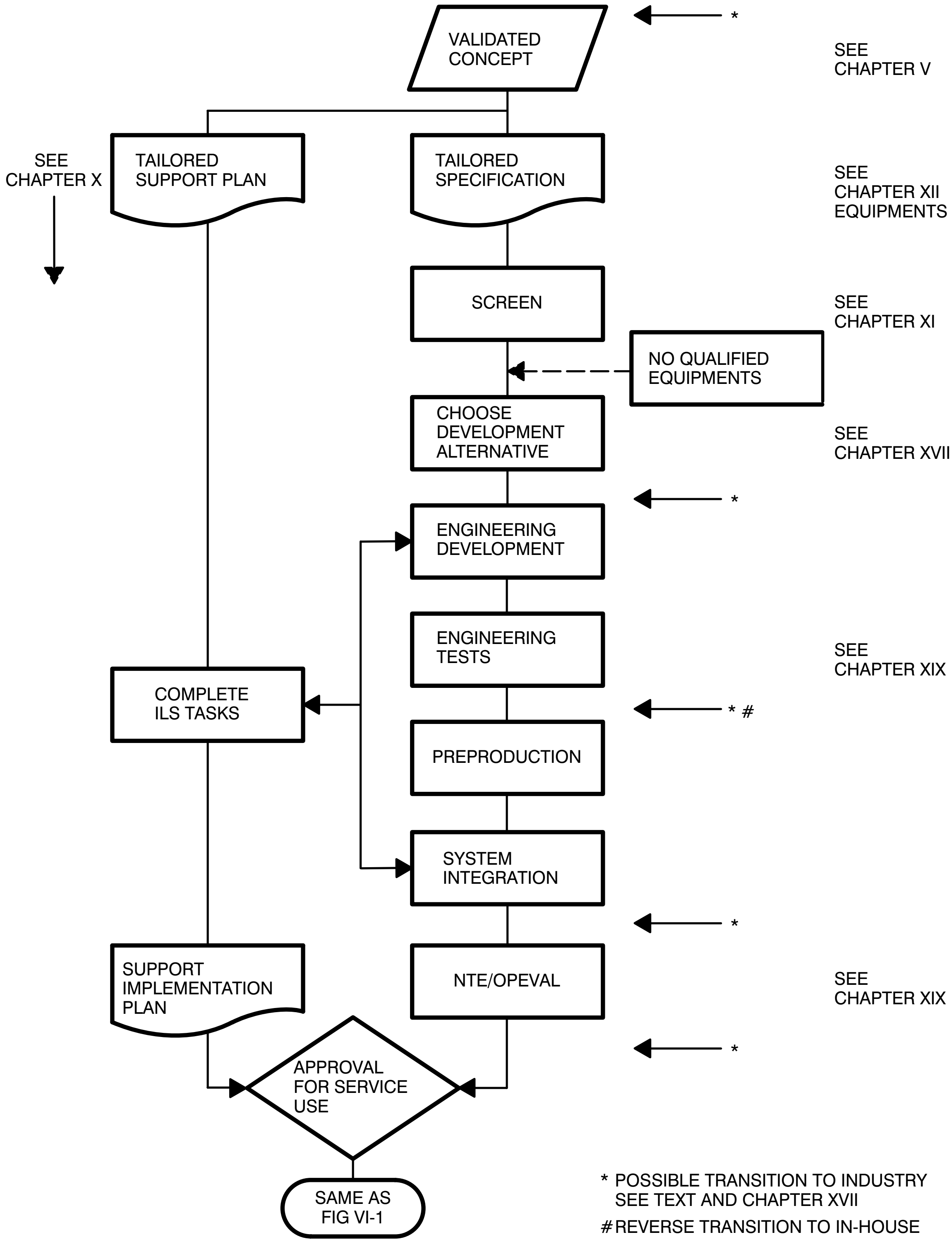


Figure VI-4. “Build” (develop) flow.

In-house resources must normally be used to develop adequate operational and technical requirements for the specification used to document the transition to industry.

Most frequently, the conditions which force the program into development will also favor the government-owned detailed design decision which is supported by a fabrication-type product specification. The transition to industry point will depend initially on whether in-house resources or industry sources are to be utilized for development (see the discussion below). In either case, a competitive development may be indicated to choose between different technical approaches which are feasible. If industry has developed a technology on which the equipment is primarily dependent, the same industry sources will probably be used through engineering development. If in-house resources have been utilized through the proof of feasibility (advanced development), a probable transition point is at the entry into engineering development.

The primary purposes of engineering development are product design and production engineering; i.e., those tasks which make an item readily reproducible. The functional design of the equipment should be complete within a high confidence level, although it is necessary for all portions of the design to have been reduced to hardware and software. Therefore, some low-risk design tasks may be incorporated into engineering development in addition to the inherent design tasks; furthermore, tasks involving any computer software associated with the equipment must be integrated into the ED effort. Also, the EDM is the first level at which the design is sufficiently mature that the ILS tasks can be completed. The coordination of these efforts requires effective <u>management control</u> by the government of the entire task package; the system integration function is a primary means of coordination and control.

Many instances of serious problems in engineering development can be cited. While failure to meet technical, cost, and schedule targets is the result, the root problem can usually be traced to one or more of the following actions:

1. Proceeding into engineering development without a complete functional design of a high confidence level; this constitutes an incomplete validation of the technical approach.

2. Failure to implement an effective configuration control program.

3. An attempt by the government to contract system engineering/integration responsibilities (at the system level, this is virtually impossible for a contractor to perform and results in not meeting the responsibilities at all). Commonly, many GFE items will be included, each with its own schedule risk, thus greatly compounding the program risk by instituting a large number of unnecessary interdependent risk elements. A failure in one affects the entire system.

4. Failure of the government to procure and validate the required design data.

5. Failure to properly partition and specify the system to the required level of complexity within elements contracted to industry (specification is required to at least the intended level of repair).

6. Failure to identify and support the in-house technical talent required to monitor and control contractual development efforts.

7. Failure to implement project controls to allow knowledgeable government management team members to make decisions within the government's system design/integration areas of responsibility.

An effort to reduce costs usually arises from a failure to estimate and budget adequately at the inception of the program. Later, as the program approaches the ED phase, accurate estimates are viewed as "cost overruns" by budgeteers. Once a grossly inadequate estimate is made and accepted, a large risk of program cancellation exists, and it grows with time; the situation can often resolved only by very strong justifications including a detailed comparison of both estimates and by presenting a program schedule which will not impact the budget figures in the next 3 fiscal years. On the other hand, gross overestimates at program inception will normally result in not establishing a program at all because relatively less justification is available so early. Unless detailed, high-confidence estimates can be made, it is better to make no estimate at all or to make highly qualified estimates in conjunction with a program plan which allows for budget revisions. Attempts to cut costs by excising such "luxuries" as in-house technical support only eliminate the tools necessary to manage and manipulate the risks present in any program. Without these tools, risks would become interdependent, and a failure in one risk element would create a chain reaction of failures.

The in-house versus contractor development controversy has its basis in the national policy that the government does not compete with industry. Therefore, even when in-house resources are capable of handling the task at costs below those of industry, industry must be selected. However, in-house resources are justified when the ability to meet requirements is jeopardized by any industrial alternative. It is important to realize that advances in the state of the art are not sought during the product development phase; these are accomplished through exploratory development. The following conditions comprise valid justifications for in-house development:

1. No qualified industrial interest expressed in the development.

2. The government cannot develop specifications adequate for contract and cannot otherwise obtain qualified contract services within the required time frame.

3. The system characteristics and development circumstances involve a special case in which in-house expertise far exceeds industrial expertise. This special in-house expertise may involve technical requirements which are closely related to volatile user requirements or service doctrine; also, special security requirements may be exclusively available to in-house expertise.

NOTE: In-house development does not preclude direct industrial support; however, the direct responsibility for detailed design decisions is retained by the government. Direct contractor participation is encouraged for developments involving high-volume production.

Whether the design is developed by industry or in house, it must still be validated; however in-house designs are easier and less risky to validate because they are inherently nonproprietary and easier to subject to configuration control meeting the government's requirements.

Policies requiring "early contractor involvement" usually originate within the systems commands either in written form or in an unstated form reflecting a normal routine of business. There are no stated policies, directives, or instructions above the systems command level supporting this position. Indeed, the Navy RDT&E Management Guide (para 0624) states, "A series of actions to contract out important activities, each wholly justified when considered on its own merits, may, when taken together, erode the Government's ability to manage its research and development programs." The decision whether to involve industry should be made on the basis of the need for services which are best provided by industry, the policy that the government does not compete with industry, and the needs of the government to maintain control of its development efforts and to execute its system integration/design ownership responsibilities (these needs do constitute competition with industry when they dictate in-house development). Where indicated, in-house production engineering capabilities reside at Naval Avionics Center, Naval Air Warfare Center Aircraft Division, Indianapolis (formerly Naval Avionics Facility, NAFI) (ref NAFI TR-I873).

Another possible transition point is following the ED phase and entering preproduction. The purpose of the preproduction phase to validate the design data package through a limited or pilot production. Changes indicated by the results of engineering tests on the EDM may be incorporated as well as changes which result from producibility improvements. The validation or proofing function is sometimes overlooked because the EDM contractor is allowed to do the preproduction; furthermore, the preproduction phase is sometimes used to correct gross deficiencies in the EDM which totally obscure the objectives of preproduction. In other words, preproduction is sometimes used to correct the sins committed in engineering development rather than validate a finished design package, which is its intended purpose. The nature of the textbook preproduction phase is such that, if a design data package is ever going to be used for competitive procurement or by a facility other than that producing the design, it must be executed through unbiased analysis and stringent change control procedures. Since the government is assuming the responsibility for the accuracy of the design package, it follows that these functions should be performed by qualified government personnel. This may vary from government production personnel acting as plant representatives for the program to execution of the entire preproduction phase inhouse. The latter approach is certainly most appro-priate for large-quantity or high-dollar-volume (greater than $20M in development) programs, and it is the lowest-risk approach to the preproduction problem. There is also a preproduction phase in functionally controlled procurements which require development, but in this situation the government is only ensuring that the production contractor can indeed produce his design (therefore, it is important to require that the same facilities be utilized for preproduction as for production).

The optimum transition to industry for in-house developed designs and for designs validated in house is following the preproduction phase. A proofed data package is available, and manufacturing specialty houses (i.e., no development capability with significantly lower overhead costs) can be solicited. The in-house technical team is in a position to provide strong support to aid and monitor the contractor, and the government has configuration control. The system integration is complete and within the control of the government. The procurement is on a fixed-price basis. The technical, cost, and schedule risks are all minimal. Since release to production cannot take place until Approval for Production (see chapter VII) is issued, there is ample time to incorporate changes dictated by the NTE/OPEVAL, to negotiate the procurement package, and to conduct first-article tests. If the transition is delayed until after NTE/OPEVAL, a long administrative lead time must be tolerated before the initial equipments are available for fleet introduction; this transition point is only recommended for small quantities being procured from one source at a time.

However the transition to industry is performed, the risks are minimized at each step if the objectives of the succeeding steps are made to influence the technical effort. This means strong system engineering control within the government and contractural incentives on industry involvement.

PROCUREMENT ALTERNATIVES

The offices and agencies of the government have evolved a seemingly limitless variety of procurement practices. In general, what has always been practiced by a group tends to be what is practiced on any procurement by that group regardless of the circumstances. When the group is dealing with a limited scope of products and with the same set of circumstances, this blind approach has generally proved successful; however, alterations in the procurement circumstances usually lead to cost overruns and inferior products unless the procurement practices are altered appropriately. This section deals with the alternatives which are available to tailor the procurement method to the circumstances.

The primary procurement variable is that which is to be procured. Various potential suppliers are organized in a number of different ways in order to promote the greatest efficiency and least risk in creating their primary products; the procurement method should favor those suppliers which are in the best position to supply the product of interest. The product consists of the end item (component, equipment, system, etc.) and of a level of service. The services which may make up part of a product are:

Research
Development
Production
Support services

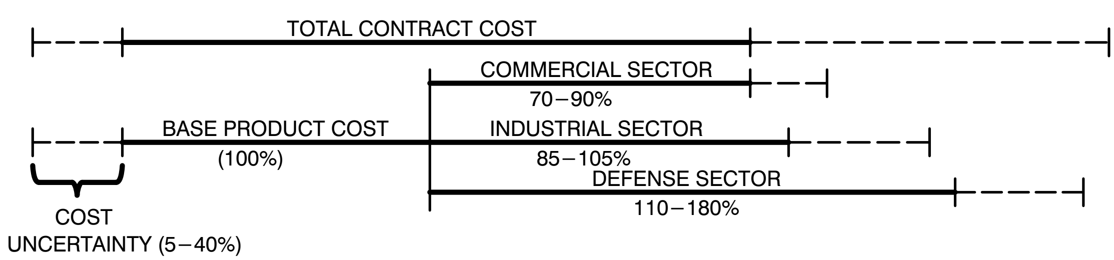
The level of service required for a product is the most significant factor in the determination of a procurement method. Each service capability requires special resources; the maintenance of those resources is a burden on the company's cost of doing business. All suppliers are primarily selling production services and maintain other services in support of those efforts. In general, the greatest investment return is in providing production services. On the other hand, research generally provides no direct return on the investment; however, very substantial returns are generally realized when a research product becomes successful in production.

The range of services provided differs substantially among the various sectors of suppliers. In the "consumer" sector of many products, companies are geared for production and offer extensive support services through warranties, field representatives, and local repair activities; development capabilities are generally minimized to those necessary to maintain a competitive product line. The “industrial” sector companies are similar to their consumer sector counterparts except that a research capability and an expanded development capability are maintained to support high-technology product lines. In both consumer and industrial sector, high-volume production is the goal and the key to product profitability. The defense sector is different.

The defense sector is characterized by intensive research and development and by low production volumes, since the products are often military-peculiar and required in small quantities. The companies participating in the defense sector have well established R&D capabilities, limited production capabilities which are set up specifically for low-volume production, and virtually nonexistent support services. Even companies which participate heavily in both industrial and defense sectors are usually organized to segregate the industrial and defense capabilities, and each part conforms to the characteristics of its sector.

In recent years, high-technology industrial/consumer markets have seen the introduction of many products which are readily adaptable to military applications, and a great deal of pressure has been applied to DoD to use both commercial end items and services, especially warranty services. The commercial sector is not prepared for the extensive documentation and quality assurance provisions nor for military standard parts requirements which are common to many DoD procurements. Likewise, the defense sector is not, in general, prepared to deal with long-term warranty clauses nor field service provisions, and large production runs will often have higher unit costs than non-DoD sector production runs.

The alternatives which should be considered to make the most efficient use of private sector talents include development alternatives which lead to an open competitive production (as opposed to closed competition which is limited to the multiple developers); closed-end contracts for each program phase (the product of each contract is sufficient for a different contractor to perform the next phase); split-tasking (each task is performed by a supplier experienced in the required service); and the use of in-house resources to plug gaps, as well as the traditional single supplier methods. Neither closed-end contracting nor split-tasking is always efficient because the data requirements to effect handovers between contractors may be excessive and impossible to obtain in the detail needed; each case must be reviewed on its own merits. Split-tasking will tend to be very efficient if a system can be partitioned into equipments requiring development and units which can be purchased. In any case, the procurement solicitations should require suppliers to show their management approach and their resources to apply toward any services which would not be in their normal market requirements; this demands some knowledge of the various probable responders to the solicitation:



The type of contract to be employed is another procurement variable. A fixed price type contract is most desirable as the risk elements are most firmly established and can be minimized. However, fixed price contracts cannot be used outside well established limits (see chapter XVI, Types of Contracts). In general, situations allowing fixed price contracting will favor commercial supplier-type services.

The selection of the procurement scheme to be used must be made in consideration of the development alternative being pursued (see chapter XVII, Development Alternatives). When the procurement quantity is low, the development considerations will predominate, but high procurement quantities demand attention the potential costs of each development procurement combination. Getting industry involvement early in the program may be important to the ultimate cost of the product. Obviously, pursuing a development alternative which transitions the technical tasks to industry early in the program gets industry involved; however, only the limited and parochial views of one company or a few (for parallel developments) companies may be obtained rather than an industry-wide view. Another method uses multiple-step procurements which obtain industry views through the formal procedures of solicitation, proposal, and evaluation-negotiation; multiple step procurements can only obtain a limited amount of precontract industry involvement because each company has limited time to review, react, and respond and because the legal restrictions can hamper an open technical exchange. Under some circumstances, the various industry associations can provide limited information which can guide a development-procurement approach; on large projects, this method can be effective when it is supplemented by "independent" studies of industrial capabilities, processes, and limitations. Another approach which gets industry involved is an adaptation of the commercial airlines acquisition methodology. This method can only be applied under certain well defined circumstances including large in-service quantities, multiple buys, and mature technologies, but its advantages include very low development dollar involvement and competitive incentives maintained well into the support phase. ARINC Research Publication 1313-01-1-1447, "Application of the Commercial Airlines Acquisition Methodology to Department of the Navy Electronic Equipment Acquisitions," dated 15 October 1975 (AD/A 015 694), details the steps, advantages, and restrictions of this method.

When considering the procurement alternatives, there are three points to remember:

1. Be a good customer
2. Remember the ultimate user
3. Maintain competition as long as possible

Particularly when working with commercial suppliers, it is important to consider their normal modes of operation, and to conform, as much as possible, to the characteristics of their usual market. Minimize unusual requirements such as abnormally tight tolerances, heavy data and documentation requirements, and extensive quality assurance provisions. It is desirable always to work with the suppliers and to avoid adversary circumstances. In working with industry and getting industry involvement, do not forget the requirements of the ultimate user. It may be necessary to trade off some of the desirable characteristics of the product if they cannot be incorporated cost-effectively — but do not compromise any of the required characteristics. If conferences are held to obtain industry involvement, invite user participation, also.

Every supplier is in business for gain and is entitled to a fair and reasonable profit; however, the government as the buyer is entitled to product with value. Competition is the most effective regulator of suppliers in assuring a continued product with value. Whenever possible, maintain competition through multiple procurements from multiple suppliers based on past experience of supplier performance; the details of future procurement based on past performance can be established contractually. This method can obviate the need for restrictive specifications used to weed out potentially weak suppliers. It is important, also, to avoid requirements which are proprietary to one company or which greatly advantage one company over all others; this is a particularly important point to monitor when industry involvement is solicited because one company's "good idea" can represent a proprietary advantage. When it becomes necessary to end competition, all future costs should be fixed contractually with incentives and penalties established as appropriate. This is not possible in total for most situations, but it is a goal to be approached. LCC and DTC procurements are examples of contractually fixing future costs.

The procurement approach is an effective tool for reducing costs and promoting product value when it is selected to bridge the conditions of the product development with the circumstances of the potential suppliers. It should be selected with attention to the user requirements as well as quantities, costs, technical risk, and potential supplier capabilities.

VII. APPROVAL FOR PRODUCTION (AFP)

Approval for Production (AFP) 15 granted only after certain set conditions have been met; AFP must be granted before equipments can be introduced into the Fleet. Each Systems Command maintains instructions conforming to DoD policy. This chapter summarizes these instructions. Because the conditions for AFP are mandatory, plans to achieve them must be integrated into project planning early to ensure timely approval.

Approval for Production must be granted before an equipment or system can be committed to major production. AFP can be granted until the following prerequisites have been completed. Each of these items is reviewed by an Acquisition Review Board (ARB) which certifies readiness for production. A satisfactory production readiness review and an approved Acquisition Plan/Strategy Paper for the production contract(s) are required for ARB certification.

1. At least the initial operation test evaluation is complete and methods for correction have been confirmed. A Test and Evaluation Master Plan is required, and OPTEVFOR concurs the system is ready for production.

2. At least the minimum performance requirements (including reliability and maintainability (R&M)) of the approved developments proposal have been achieved and a planned maintenance system has been developed. The R&M and QA programs have been certified to comply with policy, and reliability design review actions have been closed out.

3. Integrated logistic support planning has progressed to the point that there is assurance that all elements of logistic support will be available in approved form upon delivery of the first production item. A Logistics Review Group (LRG) must review and certify that the ILS implementation is satisfactory.

4. Technical documentation necessary for support of the system or equipment has been identified and technical manuals have been assured with first deployment of production item.

5. Personnel requirements are assured for fleet operation and maintenance.

6. The configuration management product base line has been established for identification and future configuration changes. Specifications and provisioning documentation meet the logistics requirements and are consistent with the system configuration.

7. A system safety program (MIL-STD-882) has been established. When explosives are utilized, a safety review and recommendations by the System Explosive Safety Review Board are required.

8. The production phase has been properly budgeted to meet requirements.

When the above prerequisites have been met, the Systems Commander or SECNAV-designated Project Manager will prepare the AFP recommendations. These recommendations are submitted in accordance with OPNAVINST 5000.42.

The final approving authority depends on the magnitude of the project. ACAT I and II programs are approved at the SECNAV level. ACAT III programs are approved by the OPNAV Program Sponsor. ACAT IV programs are approved by the Systems Command Commander with information to the OPNAV Program Sponsor. If OPTEVFOR does not concur in the recommendation, the Vice CNO resolves the decision for ACAT III and IV programs.

Once an equipment or system is AFP, reapproval will not be required unless

1. The equipment or system proves deficient,
2. The equipment or system is to be used in a different operational environment, or
3. The equipment or system undergoes a significant alteration. SYSCOM Commanders and PMs notify the system/equipment OPNAV Program Sponsor if an AFP file number is to be canceled because the equipment or system
    a. Has been modified or altered to the extent that a new AFP has been obtained,
    b. Is no longer in use, or
    c. AFP has been withdrawn.

    ASN(S&L) is responsible or the maintenance of records of AFP actions.

DEVIATIONS

In cases of extreme urgency or military necessity (such as QRC or RDC), limited production approval may be obtained in advance of AFP. SECNAV (ASN (S&L)) must approve the waiver of the AFP, and, in case of major programs, final approval must be obtained from the SECDEF. All such requests shall include

1. Quantities to be produced or procured and justification for limited production in advance of AFP,
2. Minimum quantity needed to accomplish evaluations on which to base AFP,
3. Analysis of all feasible alternatives waiver,
4. Cost, schedule, and performance impact of each alternative on the program,
5. Results of T&E conducted,

6. Proposed revised test plan, including plan for obtaining AFP,

7. ILS plans, and

8. Statements of risks, including alternative courses of action.

APPROVAL FOR LIMITED PRODUCTION (AFLP)

When sufficient operational testing to support a final determination of AFP cannot practicably be accomplished prior to making initial production commitments, an AFLP can be granted for initiating orderly first-lot limited-production runs.

The procedure for obtaining a AFLP is the same as the procedure for obtaining an AFP except that the requirements on the prerequisites are less stringent. An AFLP requires the following prerequisites:

1. Completion of Test and Evaluation Master Plan with corrections on deficiencies to be considered and

2. Production specification requirements and procedures for confirming that the reliability and maintainability will be achieved.

3. Approved plans for achieving AFP.

VIII. INITIATING SUPPORT

Introduction of equipments into the Fleet is entirely determined by the prior phases. The planning for a smooth phase-in of the new equipments and phase-out of obsoleted equipments must be accomplished at least 3 years prior to the actual task commencement. Therefore, the tasks described in this chapter must be planned during the validation phase or early in full-scale development.

After the new equipments are phased in, their performance should be monitored to ensure that no unforeseen problems have been introduced and to assure satisfaction of the operational requirements. Deviations from expected performance may require correction — at least in future acquisitions, if not immediately. The knowledge gained through the acquisition cycle should be retained and applied to future acquisitions, not cast away; often the greatest savings are those realized on future projects which can benefit from the experience gained by project personnel.

SUPPORT REQUIREMENTS

System support elements include everything needed to operate and maintain the system over its life. Some of these elements are:

Operator and maintenance personnel

Repair spare parts

Test equipment and tools

Technical manuals (both operation and maintenance)

Facilities (depot, IMA, overhaul, calibration, etc.)

Transportation and handling equipment

Training courses and materials

Technical data for provisioning and reprocurement

Technical data for support management effectiveness systems

Installation support

These elements may be required in varying degrees over the life of the system, which for support purposes is phased as follows:

Acquisition

Phase-in

Operations

Phase-out

The various support requirements for the acquisition phase vary widely and usually differ markedly from those for the other phases. The planning for each portion of the acquisition phase should be started with the first program planning effort and completed prior to the initiation of that portion. Since it is so integral to program planning, no further discussion is offered here.

The phase-in support period starts with the IOC date and ends whenever the full operations support is initiated. Phase-in support is normally procured at the same time as the equipment and most often will consist of contractor-supplied training and initial spare parts. Warranty service and maintenance contracts also fall into this support category. The planning for phase-in type support must be accomplished during the preproduction phase for developed equipments and prior to the procurement solicitation for on-shelf or modified equipments.

Operations phase support is the normal service-provided support which lasts most of the service life of the equipment. The operations phase support requirements are initially predicted by the ILS tasks performed during the acquisition phase and then constantly corrected by the various support management effectiveness systems utilized by the supply system, training commands, operations commands, systems commands, field support activities, etc. The support system is set up for long-term, continuous operation; therefore, it is extremely important to properly plan the transitional support for an equipment. The planning requires not only the accurate execution of the ILS tasks but also ensuring the funds and other resources are available to implement the ILS recommendations. Identifying funds requires budgeting actions which require at least 3 years to produce the allocation. Identifying personnel resources may require changing manpower allocations, recruiting quotas, setting up training courses, scheduling a training pipeline, and so forth — all of which may take 4 or more years before the personnel are available. Obviously, these are long lead times which may exceed the time needed to procure the equipment; this puts great importance on the phase-in support planning.

All too often the planning for the operations phase is incomplete, especially in the identification of funding for spare parts and training. When the new system is put into the Fleet without proper planning or providing the initial support, it looks like a mammoth step function to the support system; the support system "rings" for many years trying to cope with the perceived discontinuity. The budget cycle ensures that this period will be at least 3 years longer than the equipment phase-in period; this may constitute a significant portion of a single equipment's service life. The unsupported equipment suffers abuses that often permanently degrade performance and reliability; atrocious availabilities are realized (sometimes under 10%), thus cheating the user out of a needed capability and expending resources (manpower and dollars) better spent elsewhere. This cycle is commonly caused by paying for cost overruns in the acquisition phase with funds initially identified for support procurement. From the standpoint of overall damage to the service, it is far better to reduce the number of equipments procured or to delay their introduction until support is made available.

When personnel training is indicated and supply system support is utilized (almost always), two milestones are mandatory in the acquisition phase:

- Training Plans Conference convened by the cognizant systems command at least 4 years prior to IOC (table VIII-I)
- Provisioning Conference chaired by the Ship Parts Control Center (SPCC) at least 3 years prior to IOC (table VIII-2)

These conferences reach agreement on the actions to be taken and the resources required to support the equipment. When the acquisition program is such that these conferences can't take place at the proper time, they should be held as early as possible, and the program should plan and budget for the phase-in support. Where feasible and cost-effective, long-term warranty service provides an excellent transition vehicle. The equipment may mature and realize reliability growth in service without being a maintenance burden to the user organization. Contractor depot services are usually implemented after the warranty period (3-6 years, 4 typically).

Table VIII-I. Training plans conference prerequisites.
(REF: OPNAVINST 1500.8 SERIES)

Operator concept

Maintenance concept

Skill and experience level estimates — especially if new skills or high experience levels may be needed

Estimate of manpower requirements

Plans for Fleet introduction

Training requirements estimate

Table VIII-2. Provisioning conference prerequisites.
(REF: SECNAVINST 5000.39 & MIL-STD-1561).

Support concept

  Availability requirements

  Risk and hazard assessment

  Level of Repair/Logistics Support Analysis results

Estimated demand requirements

Essential components listing

Long-lead-time item listing

Standard parts/parts-peculiar requirements

Plans for Fleet introduction

Tentative support management plan

A frequently overlooked support requirement is the technical data needed to set up and utilize the support management effectiveness systems. The most important of these systems is the Maintenance Data Collection System (MDCS) portion of the Maintenance and Material Management (3M) System. MDCS takes maintenance reports from the Fleet and computes logistics parameters and reliability, maintainability, and availability (RM&A) parameters. The logistics parameters are straightforward calculations of usage data and parts demand data used to isolate and correct supply system deficiencies. The RM&A parameters are used to isolate latent design problems, support documentation problems, training and manning problems, insufficient test equipment allocations, and installation problems. In order to effect the discrimination needed to isolate such problems, the measured/computed RM&A values must be compared to "should perform" values. Unfortunately, the required values, which are available during the acquisition cycle, are frequently not made available to the logistics coordinators responsible for tracking the equipment. The problems are further exacerbated by the failure of the acquisition community to coordinate the RM&A parameters specified and tested in the acquisition phase with those parameters which can be measured in the support phase (see chapter IV, Conceptual Phase) and by the failure to require equipment identification reporting codes to be nameplate data, to provide reporting guidance in the technical manuals, and to coordinate with the MDCS system coordinators. The required actions are straightforward and simple when coordinating actions are initiated prior to the equipment qualification phase.

PROJECT PHASE-OUT PLANNING

The most overlooked support phase is phase-out. Usually, an equipment is phased out because a replacement equipment is being phased in. It seems that old mission requirements continue forever, although they may be integrated into new missions. As an equipment nears the end of its service life, various support elements become uneconomic and are dropped. Special training courses are dropped, maintenance contracts are terminated, etc. Nobody much cares except the poor user who still has one of the old-timers. In today's austere budget environment, the acquisition program for the replacement equipment can hardly be expected to assist a lame duck. Most of the problems which can occur during phase-out can only be addressed early in the acquisition cycle by establishing levels of repair and standardization such that system-peculiar items are minimal and are not system critical and minimal skills are required to operate and maintain the system. A maintenance contract should be constructed on a cost-per-unit basis. Consideration of the phase-out problems which may occur for an equipment being replaced by the current acquisition may make it desirable to alter the phase-in rate of the new equipment.

The project phase-out plans provide for the transition of continuing system tasks into functional organizations and for documenting the project history. The phase-out plan should incorporate the project WBS and should annotate each task as completed or continuing (or recurring). Completed tasks should show the completion date and the person or organization responsible. Continuing or recurring tasks should show who was responsible in the project organization and the person or organization assuming the responsibility. The coordinating plans or documents and any pertinent data should be referenced, and storage points and holders should be cited. Common documents would include the ILSP, training plans, configuration baseline and data, and reprocurement data as a minimum with many other documents supporting as required. The historical section should include a listing of all permanent project documents, reports, and data from beginning to end. These items should cover the design and development, testing, acquisition, ILS, installation, initial field data, quality and workmanship, and actual costs and schedules compared to the planned targets. Any significant achievements of the project, any significant problems, and any lessons learned should be incorporated in a narrative; certainly any innovations or patents should be mentioned. The project's successes and failures provide valuable lessons for the many similar projects which will undoubtedly follow and can also point to areas in which organizational policies should be improved.

MONITORING THE PERFORMANCE OF EQUIPMENTS IN THE FLEET

There are many requirements for tracking the performance of equipments in fleet use. Operations planners need to know which ships are capable of performing a particular mission, support planners need to know the types and quantities of support needed, and acquisition planners need to know how past acquisitions are performing. There are two primary systems for tracking equipment performance — the CASREPT (Casualty Report) system and the Maintenance Data Collection Subsystem (MDCS) portion of the Maintenance & Material Management (3M) system. The two systems are distinct in their methods and purposes of reporting, and both systems serve a multiplicity of purposes.

The CASREPT is a message report sent whenever a failure degrades the ability of a ship to perform its missions. Since a CASREPT implies the ship is not "ready and willing" to take on any task assigned, reports are frequently not made unless specifically required by the operational command or a mission assignment is jeopardized by a failure. Vital equipments are CASREPT'd for a higher percentage of failures than semivital equipments and semivital more than nonvital. No amount of encouragement has seemed to influence commanding officers to CASREPT in all required situations because of the imagined stigma attached. Failures which are expected to be corrected within a reasonable time (usually 24 hours) are not reported. Besides notifying operations planners of the ship's reduced capabilities, the CASREPT also mobilizes support elements to assist the ship. There are three basic CASREPT categories — CASREPT for parts, CASREPT for outside assistance, and CASREPT to notify the chain of command "my equipment is down and I'm working on it." The first two types are by far the most prevalent. Once a CASREPT is made, status reports are made periodically and when new information is available until the CASREPT is closed out by a CASCOR (casualty corrected) message. The reporting system is specified by NWIP-l0. The primary benefits of CASREPT derive from its timeliness of reporting, its close association of equipment failures to ship capability, and its ability to marshall timely support.

The CASREPT Master Data Bank run by the Fleet Material Support Office (FMSO), Mechanicsburg, can supply historical CASREPT records by equipment for the last 3 years containing the severity, reason for report, time to repair, parts usage data, etc., for each CASREPT made. Summary data are also available. Also, a Material Condition Index, which is a weighted mathematical factor based on the number of CASREPTS, severity, and time to repair for an equipment over a fixed period, is useful in analyzing trends and the impact of failures on fleet operations and can be requested from the data bank. A few cautionary notes: time to repair is measured in calendar time rather than actual active repair time, parts usage reflects those parts thought to be needed at the time of failure and may not be representative of actual failures, and the CASREPT system only receives reports of significant failures.

CASREPT data can be requested through the cognizant system command coordinating office or directly from FMSO.

The MDCS records all nonpreventive-maintenance actions on all equipments on the CNO's selected equipment list or in the Current Ship's Maintenance Program (CSMP) and all deferred maintenance actions. There is constant pressure on the Fleet to report thoroughly, accurately, and in a timely manner; as a result, virtually all (nonpreventive) maintenance actions are reported on virtually all equipments by most ships. A great wealth of information is reported through MDCS. MDCS reporting is in accordance with OPNAV 43-P2. The primary benefits of MDCS arise from the broad range of detail information available on most fleet equipments.

The detailed information includes grade and rate of the reporting technician, manhours expended, when the failure was discovered, the indication of trouble, whether the equipment was up, down, or partially down, part failure data, an estimate of the cause of failure, mean down time (MDT), the causes of down time, mean time between corrective maintenance actions (MTBCM), mean time to repair (MTTR), and technician narratives. This information is collected on written formats from each ship, key punched by a coordinating center (one on each coast), and entered into a central data bank run by the Maintenance Support Office Department (MSOD) of FMSO. Reliability, maintainability, and availability (RM&A) parameters are derived from the raw data by the Naval Ship Engineering Center, Norfolk Division, or by the Ordnance Maintenance Management Information Center, NWS Concord, depending on the type of equipment; logistics parameters are derived by MSOD. MDCS data can be obtained from MSOD or through the cognizant system command coordinator.

Both systems are useful in performing trend analysis on equipment problems. Maintenance and parts usage data are available through the CASREPT system, but reliability data are not available other than what can be inferred from CASREPT frequency. Very specific maintenance and parts usage data are available from MDCS; additionally, reliability and equipment usage data can be derived with MDCS. MDCS has nearly 20 times more reports over any particular period than CASREPT, but CASREPTs are extremely timely whereas MDCS requires 5 to 6 months to collect all its reports for a particular month. Both systems are capable; however, most RM&A tracking requirements are best met by MDCS.

Operations planners and support planners make extensive use of the CASREPT and MDCS; however, the acquisition community has traditionally ignored both systems except when forced to support "get well" programs under DART. This situation is unfortunate since most support problems are created within the acquisition phase and many problems can only be remedied by the acquisition phase. In truth, the acquisition community has demonstrated its lack of concern for the equipment or its user once the procurement is complete.

A number of programs are run by the support community utilizing MDCS data to identify parts availability problems, training problems, and equipment reliability problems. The program to identify equipment reliability problems is Project Intercept. Project Intercept tracks key equipments and identifies potential maintenance and logistics problems by measuring four RM&A indicators against established standards. The project includes all equipments on the CNO selected equipment list. The Intercept indicators are MTBCM, MTTR, MDT, and A_O. The MDT parameter is further divided into MDT (outside assistance), MDT (parts), and MDT (ships ops). MDT (parts) is used to determine the percent of parts not on board when required. Safety-related maintenance actions are counted also. Parts supply problems require a response by NAVSUPSYSCOM; all other problems require a response by the cognizant systems command for the equipment. The standards for each parameter are established as a "level" (should perform) and "limit" (worst acceptable). A_O has a limit set by CNO at 75%; percent parts not on board has a limit set by NAVSUP at 35% (this limit is consistent with the rules governing the ship's parts allowances). The cognizant SYSCOM establishes levels and limits for MTBCM, MTTR, and gross MDT. The system would work well if it were not for the serious problems which undermine the project.

The most obvious problem lies in the fact that the SYSCOM participants in Intercept are the 3M codes within the logistics directorates. If a problem is intercepted which is determined to require design changes, some developmental effort, or other major engineering effort (i.e., beyond the capability of designated field maintenance activities), the SYSCOM logistics code is unable to respond since it does not have cognizance or funding in these areas. Rather, the SYSCOM acquisition code should respond; however, the acquisition code either responds by assigning a low priority or by ignoring the problem. The SYSCOM acquisition code is reinforced in this posture by OPNAV acquisition priorities and by the lack of "charter responsibilities" for "support problems."

Ideally, levels and limits for each indicator would be derived for the operational requirements; however, the sources of this information were not made available to the logistics codes responsible for setting the standards. Therefore, levels were established by measuring a mean value over a 2-year period, and limits were established at the 90% confidence level in the "bad" side of the level standards. This methodology is incapable of detecting steadily poor performance.

The inconsistencies between the way RM&A parameters are specified and the way they are measured require that the raw MDCS data be manipulated to produce the indicators. The most serious problem lies in the derivation of MTBCM, which also affects the calculation of A_O. Since very few equipments are time metered, equipment operating time must be estimated from ship steaming times. On some equipments, this methodology is no doubt quite accurate; however, large uncertainties exist for many equipments. Equipment operating time is used with the observed failure rate to calculate MTBCM, so large uncertainties can exist in MTBCM. This is not quite so bad as it seems since the same criteria are applied consistently on a given equipment, so long-term trend analysis is still valuable. However, short-term reports and the comparison of the calculated value to the specified value of reliability are virtually meaningless for some equipments. Furthermore, MTBCM is used to calculate A_O rather than MTBF. This is because MDCS cannot distinguish between a noncritical failure and a "relevant" failure. The mechanism is available in the MDCS to make this distinction through the "as discovered status code"; however, no guidance is provided to the reporting technicians in determining what constitutes a "partial failure" and what constitutes a “complete failure'' in a sense that will provide reporting consistency and a meaningful distinction between MTBCM and MTBF for a given equipment. If time meters were provided for equipments and if each equipment technical manual defined partial and complete failures, these major problems in tracking reliability could be overcome sufficiently to produce results with a usable confidence level.

Reporting accuracy is a most important issue in the MDCS. An extreme amount of pressure has been applied by operational commanders through inspections to cause heightened command attention to 3M. Nevertheless, the conditions under which reports are produced sometimes are not conducive to reporting accuracy. This accuracy can be improved if the equipment reporting codes (EIC, APL, serial number) are part of the nameplate information and if the equipment technical manuals define areas which otherwise cause confusion to the technician (such as the distinction between a partial and a complete failure).

The selected equipment list is promulgated by CNO with the intention of reducing reporting requirements. While this is a tenuous premise for many ships, care must be taken to avoid not tracking significant problems and potential problems. The present method seems to be based on an arbitrary accept/reject decision made for each equipment nominated by the SYSCOMs. TELCAM recommends that the selected equipment list include all vital and semivital equipments, all new equipments for at least 4 years after IOC and until the equipment performance consistently tracks at acceptable levels based on, the operational requirements, and all warranted items.

The use of MDCS data to support warranties is a natural application of the system. However, the problem areas discussed above must be resolved by prior planning for an equipment before MDCS is a valuable warranty tool. An additional feature to the system is to structure a special “deferred action taken” code — say “KW” — for warranty reporting and to put this code on the warranty notice on the equipment.

If information is desired from both the CASREPT and MDCS data banks, it is best to forward the request to the cognizant system command coordinator for that equipment. If the information is specifically to support a SYSCOM-sponsored project, the request should be forwarded through the sponsor. At NRaD, the Sustainability Engineering Division assists in formulating information requests, particularly those directly to MSOD or FMSO.

UTILIZING CONTRACTOR SUPPORT

There are two levels of contractor support — interim and long-term. Interim support is frequently used during the phase-in period as a stop-gap while operations phase support is being set up. Long-term support is intended for the entire service life of the equipment.

A contractor may not be particularly well prepared to provide all the support elements which may be required, especially some forms of training, depot-type maintenance, and test equipment; requiring these elements of a contractor will cost much more than if the contractor is set up to provide them. However, the supplier of the equipment is always the best source of interim support; the relative inefficiencies of a contractor in some services can usually be tolerated for the extent of a phase-in period. Although the contractor may not desire to be held responsible for interim support, there is actually little choice in most cases. Contractors not familiar with warranty clauses will tend to balk at their application, for instance. The contractual clauses requiring interim support should be clear and concise. The division of responsibility between the government and the contractor should be clearly defined, and the length of the contractor's responsibilities should be fixed. Complex contractual requirements will tend to undermine the contractor's ability to plan, estimate, and execute his support responsibilities.

Long-term support brings with it potentially great benefits and equally great pitfalls. It is almost always economically advantageous to make use of a contractor's commercial distribution and maintenance system, if one exists. There are innumerable hidden costs in setting up any support system, so when one already exists, it is virtually assured that it will be less costly. Equipment which has been developed for military use should be supportable by the government's facilities if the equipment has been properly designed. Equipments which have been developed for a commercial market may not be at all adaptable to the government's system; therefore, the commercial support system is most appropriate. Commercial support is not without its problems; the equipment operational requirement must be reviewed to ensure that the existence of commercial support pitfalls is tolerable. Some of these pitfalls are:

- Poorly implemented commercial support
- Labor strikes
- Financial failure of the company
- Susceptibility to disruption during conflict

A poorly implemented support system should be discovered during a screen of candidate equipments (see chapter XI). Customer comments will generally reflect the competence of equipment support. A system may be poorly implemented for government purposes even though it is excellent for a particular market. For instance, a market confined to the Great Lakes region might be serviced quite well from Cleveland, but the service would be deplorable for Diego Garcia. An economic analysis of the pipeline assets required for adequate support may be necessary to resolve this problem. Obviously, some requirements, especially vital systems, do not lend themselves to nonorganic support, much less contractor support. However, many requirements could tolerate the relatively short delays that some commercial worldwide support systems can provide. These systems may remain intact even during a major conflict, but use of their support services may be disrupted. An enemy would not call a truce to allow you to take your broken gidget to the authorized factory service center in his occupied territory, nor could you depend on a service center run by belligerent partisans. These factors must be taken into account in the support planning; generally, these problems should be resolved by accepting or rejecting a candidate equipment on its supportability criteria.

Any support system could conceivably be affected by a labor strike, although government facilities should be considerably less susceptible. Strike tolerability is a function of the criticality of the equipment. Nonvital equipments can tolerate long shutdowns of some support elements while vital equipments cannot. Several options are available to diminish the impact of a strike:

1. An injunction can be imposed, for reasons of national security.

2. Additional pipeline assets can be required.

3. A secondary service agreement can be employed.

4. The government can take over support of the item.

An injunction can be employed only in rare cases during peacetime because of its political effects; it is primarily a wartime tool. Additional pipeline assets can normally be made available only by very-high-volume industries, since the assets come out of inventory. Low-volume industries which are subject to frequent labor problems may warrant a greater initial purchase in order to provide reserve pipeline assets; this is subject to the scrutiny of an economic analysis. Secondary service agreements are frequently employed in commercial practice; in this case, a second company takes over the support load when the primary system cannot meet its demands. The existence of such agreements should be investigated during the screening process; if none exists, a requirement that much an agreement be created might be negotiated into the contract provided that the government's business is sufficiently large to contain the necessary economic incentives. Highly proprietary items usually cannot employ blanket secondary service agreements independent of the parent company; however, systems of independent factory-authorized service representatives are very effective. Instances in which the government might take over support of its items are limited because of the investment required. A notable illustration of such a case involved the overhaul of Polaris guidance sections, which was originally performed by the contractor. An 18-month strike threatened to cripple this vital system, so the government took over the overhaul responsibilities. There are a number of arrangements whereby the government becomes a secondary service agent for a company. Normally, only a fraction of the government's support requirements are met by government facilities, but some protection is provided at the expense of the cost of maintaining the capability. Some savings are still realized over full government support.

The financial collapse of the contractor could also destroy the support system for his equipment. Secondary service agreements are the most effective protection against this problem. However, equipments containing sole source parts-peculiar can defy virtually any protective ploy. The government can require the posting of a surety bond, but this only provides monetary compensation for loss. Meanwhile, the support of the equipment is still nonexistent. The government can also require that all product and process documentation be turned over in event of contractor failure. In theory, the government can then set up its own support; in practice, the documentation is seldom adequate to allow support to be reestablished. In the final analysis, the only solution proved practical is the second service agreement, short of government rescue of the company.

There is a legal problem with second service agreements between a contractor and the government if an equipment contains proprietary pacts or designs. The government can become liable to damages if it discloses the proprietary information. Even when the government is faultless, it may still become embroiled in protracted legal proceedings. In such cases, the government has been found at fault for not taking adequate measures to protect the information.

PART B: KEY DISCIPLINES

IX. LIFE-CYCLE COSTING (LCC)

In system development programs, cost is a major consideration in decisions involving selection of candidate systems or design alternatives. Therefore, the cost concept and the methodology of cost analysis to be chosen and used in support of such decision making are of basic importance. In the past, cost considerations in system acquisition were generally narrow in perspective, with emphasis being limited primarily to the area of hardware development and procurement, while deployment costs associated with system operation and maintenance and support were given little attention or completely ignored. This traditional cost approach often resulted in equipments that were costly to maintain and support.

An alternative approach is to consider system life-cycle costs as a basis for decision making. Based on the total-cost concept, the life-cycle costing technique can be a useful analysis tool and a decision-making aid throughout the system development process. As a basic advantage of using this technique, visibility is ensured for all major components of the system total cost. This permits decisions to be made on the basis of the complete system, and allows attention to be focused on those system parameters and support factors with influence on system operating costs as well as hardware acquisition costs. However, implementation of life-cycle costing implies certain requirements, such as basic cost data and support expertise. In addition, the decision maker or project manager must be familiar with the underlying concept and methodology involved.

The basic elements and applications of life-cycle costing are addressed in this chapter, the purpose of which is to provide the project manager with an understanding of life-cycle costing and its applications in system development.

SYSTEM LIFE-CYCLE COSTS

System total life-cycle cost is composed of many elements representing the various resources which are required for system acquisition and operation throughout the entire life of the system. In the order of their occurrence, the different system cost elements may be separated into the following categories:

- <u>Research and development</u>. Costs primarily associated with the development of a new system or capacity to the point at which it is ready for procurement and operational use

- <u>Investment</u>. Costs beyond the development phase to introduce a new system or capability into operational use, including installation and checkout

- <u>Operation and support (O&S)</u>. Recurring costs of operation, maintenance, and logistics support of the system

The purpose of identifying and displaying system costs as separate categories is to facilitate their evaluation by the decision maker or planner, since the costs associated with each phase of the system life cycle bear a different relationship to time and to the number of units of the system to be procured. R&D costs are relatively independent of both time and the number of system units to be procured. Investment costs are also independent of time, but are directly related to the number of system units to be deployed and to the expected service life of the system. Because of their relative independence of time, R&D and investment costs are considered as one-time costs. By contrast, recurrent O&S costs are long-term costs which, for systems with long service lives, may account for the major part of the system total life-cycle cost.

COST ESTIMATING METHODS

Besides identification of system cost elements, the major effort of life-cycle costing is the development of cost estimates. The means for making cost estimates are many and varied, ranging from the use of expert opinions and informed judgment as the only basis for an estimate to the application of more formal methods. The more formal methods used are generally of three types — statistical, engineering, and accounting.

The statistical method of cost estimating is based on the use of historical cost data of past or existing systems and the application of selected statistical techniques, such as multiple regression and correlation analysis and scatter diagrams. By use of the statistical techniques the historical data are analyzed to find functional relationships between system costs and specific elements of system description, such as weight, speed, activity rates, and number of personnel. The derived relationships, often referred to as cost estimating relationships (CERs), are used to estimate or project costs for new systems. It is assumed that the historical data used are valid if the systems which generated such data are sufficiently similar to the new systems under consideration. This type of cost estimating method is usually applied at relatively high levels of aggregation for cost studies of advanced systems, particularly during the early development stages of the system.

The essence of the engineering method of cost estimating is to successively break down the system or item of hardware into lower level components until meaningful conjectures about the cost implications of the various components can be made. These estimates are usually based upon past experience, analogies, rules-of-thumb, and expert opinion. CERs are often applied at this lower level of detail. The resulting estimates for the individual components, together with the cost estimates for integrating the components, are then combined to obtain the total estimate. One of the useful features of the engineering method is that it helps to separate those parts of the system or problem which require novel treatment from those which can be dealt with by conventional means. However, a disadvantage of this method is that it frequently leads to underestimating because inadequate allowance is made for the cost of integration. Therefore, when the engineering method is used, the statistical method is often also applied at a higher level of aggregation to ensure against underestimating. Chapter XXI includes a method of improving engineering cost estimates.

The accounting method relies on the fact that certain factors or estimating relationships are inherent in the books of account, financially or otherwise. Overhead rates, labor rates, and material consumption rates are examples. The method is conceptually simple, but it does usually require that estimates be made at a relatively lower level of detail than is generally practical. Furthermore, when the accounting method is used, it is necessary to exercise extreme caution so that misleading impressions arising from using the relationship out of context are not conveyed.

The different cost estimating methods may be applied singly or in combination, depending on the given problem. Selecting the method or methods to be used is dependent on many factors, including time available to make the estimate; level of detail and preciseness needed; type of analysis to be performed; availability of system descriptive information; form and availability of relevant historical data; and extent of departure from experience of the system for which cost estimates are to be obtained. Ultimately, the final choice is dependent on the experience and preference of the individual cost analyst.

SYSTEM COST ANALYSIS

There are two types of system cost analysis which are particularly applicable to decision making in system development — "intrasystem" and "intersystem." The first involves the comparison of different designs for a given system, while the second involves the comparison of a set of competing candidate systems.

In "intrasystem" analysis, the emphasis is on the selection of the configuration or characteristics of a system. Costs are used to assist in the selection. System characteristics are sought which provide the minimum cost for various performance levels or, conversely, costs are used to indicate those achievable characteristics which maximize performance for various possible funding levels. This type of analysis can be useful in evaluating the cost impacts of alternative design specifications and system operating characteristics. It provides an in-depth consideration of a single system, and may be used to help put together an initial system description.

In "intersystem" analysis, the emphasis is on comparing two or more systems competing for the same mission. Effort is concentrated on isolating those features of each of the competing systems that cause costs to differ. It is assumed that each of the competing systems has been optimized, or suboptimized, as to configuration so that the comparison is meaningful, or "fair." This type of analysis is applicable for selecting the preferred system, and is often applied during the conceptual phase of the system life cycle.

RELIABILITY, MAINTAINABILITY, AND SUPPORT FACTORS

Traditionally, consideration of reliability and maintainability during system development is concerned primarily with meeting operational requirements rather than reducing system support costs. As a result, there is often a tendency to specify minimum levels of reliability and maintainability that will satisfy the system availability requirement without considering the effects on the life-cycle cost of system support. On the other hand, it has been generally indicated by results of studies on past and existing systems that higher levels of reliability and maintainability are warranted in order to reduce the high cost of system maintenance and logistic support which, for systems with long service life spans, is the predominant component of system total life-cycle cost.

A list of elements associated with the cost of system support is shown in figure IX-1, together with the principal factors which contribute to mission readiness. Note that the support elements are not independent of each other, but are defined by the total support plan. Each element must be properly related with every other element in order to provide adequate maintenance and logistic support for the system equipments over the life cycle of the system. If the definition or scope of one of the elements is altered, changes are induced in others which may significantly affect the coherence of the support system and cause redundancy, mismatch, or omission of vital factors.

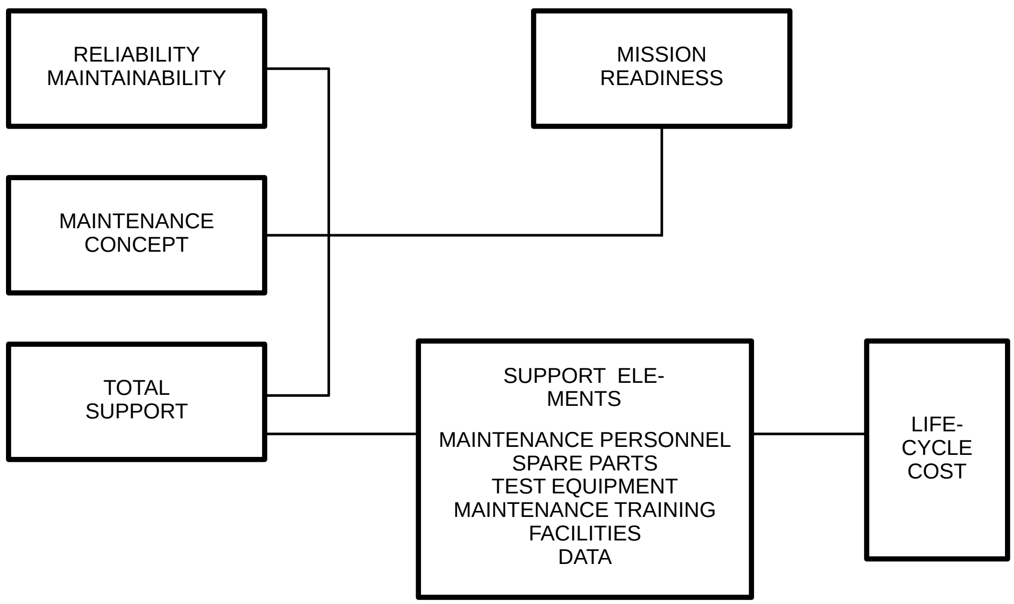


Figure IX-1. System support in life-cycle cost.

Such changes may have impact not only upon the effectiveness of system support but also upon the total life-cycle cost of the system.

The effects of reliability and maintainability on support cost can be seen by considering the largest item in the support cost package — the cost of maintenance, which is the combined cost of maintenance personnel and spare parts used for repair. The number of spare parts used for repair is directly related to the number of equipment failures which occur during a given period, while the workhours needed for corrective maintenance is related to both the number of failures during the period and the mean time to repair (MTTR), which is a measure of maintainability. Since the number of equipment failures occurring during any time period is a function of equipment reliability, or the mean time between failures (MTBF), it follows that the costs of maintenance personnel and spare parts will be high for low reliability and maintainability. Furthermore, a low-reliability system will also, over the life cycle, require more test equipment, technical manuals, and other support items such as facilities and spare parts transportation.

Thus, reliability affects all support cost elements, directly or indirectly. Maintainability is important for similar reasons. In general, it may be shown that the system acquisition costs (R&D and investment) increase with reliability, while the recurrent costs of operation and support decrease. These relationships are shown in figure IX-2.

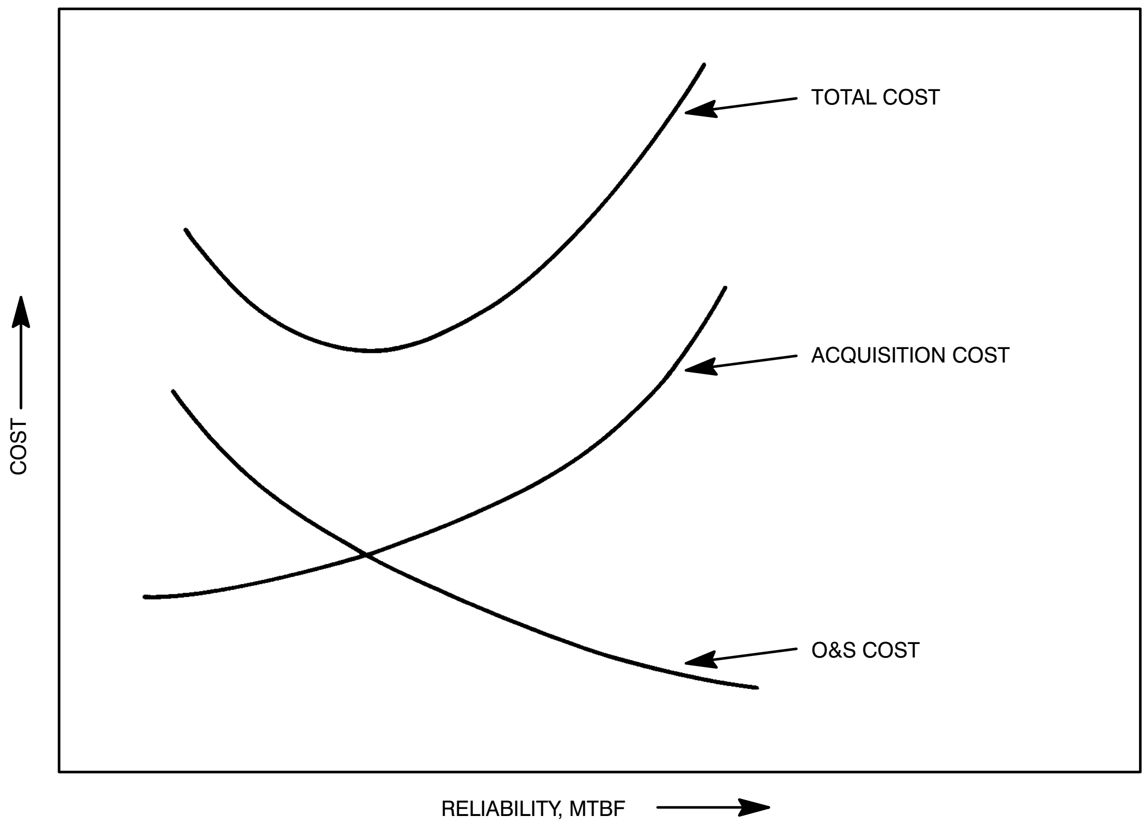


Figure IX-2. Life-cycle cost vs reliability. (Relationships for maintainability are similar.)

Maintenance and support planning is another area with important influence on system total life-cycle cost. Its function is to provide a total support program for the system being designed and developed. Ideally, the total support program should be well balanced and tailored for the system under development in the interest of efficiency and economy. However, the impact of maintenance and support planning on support cost is felt far upstream from equipment delivery. Therefore, the maintenance and support effort should be started early in the development program if it is to have an opportunity to explore the various concepts for supporting the system and to influence design decisions in system maintenance and support features. System support cost must also be emphasized early and must be included as a basis for evaluating and selecting the maintenance and support alternatives during the various planning stages, while cost analysis and tradeoff (such as level of repair analysis) should be performed to help establish the repair strategies and logistics support requirements.

As the system development progresses and information necessary for spelling out the support program becomes available, the maintenance and support plans should be appropriately defined at each stage. This will provide a base from which life-cycle cost of system support can be evaluated for use in program decisions.

SYSTEM DEVELOPMENT

System development is a process involving a series of engineering activities and management decisions the aim of which is the successful selection and specification of a preferred system design for procurement and production. System life-cycle costs must be a part of the basis of decision making involving the selection of system candidates or design alternatives. The decision maker must take into account the future cost implications of system operation and support as well as the near-term costs of hardware procurement and installation. The primary purpose of life-cycle costing is to help define and describe these cost implications.

CONCEPTUAL PHASE

The conceptual phase consists of many activities, including identification and definition of conceptual systems; technical feasibility and tradeoff studies; and experimentation and test of operational requirements, key components, and critical subsystems. The output of this phase includes a set of alternative technical approaches or candidate systems. As indicated in figure IX-3, the role of life-cycle costing during the conceptual phase is to assist in the selection of the preferred system. Depending on the type of system development involved, a candidate system may be evaluated according to preestablished criteria (such as design-to-cost goals), or its cost performance may be compared with that of an existing system that is to be replaced. Since systems in the early stages of the system life cycle are described in terms of broad performance parameters and concepts, cost estimates of the candidate systems will be provided at relatively high levels of aggregation. Such cost estimates are usually obtained from empirically derived cost estimating relationships; that is, by statistical methods. The main purpose of the estimates during this phase is to detect cost differences among the candidate systems. The emphasis is on indicating the cost impacts of the major system features rather than on the detail elements of the individual systems.

The type of analysis used for comparing the candidate systems and their costs depends on whether other factors besides cost, such as system effectiveness and performance, are also included as criteria for the preferred system selection. Some form of cost-effectiveness analysis will be indicated, for example, if system effectiveness is a consideration and can be meaningfully quantified. For cases in which emphasis is on minimizing cost rather than maximizing performance (or effectiveness), a method for comparing the candidate systems and selecting the preferred system is simply to fix or specify the level of system performance required and identify the system with the lowest cost among the alternatives. The system identified is the minimum-cost

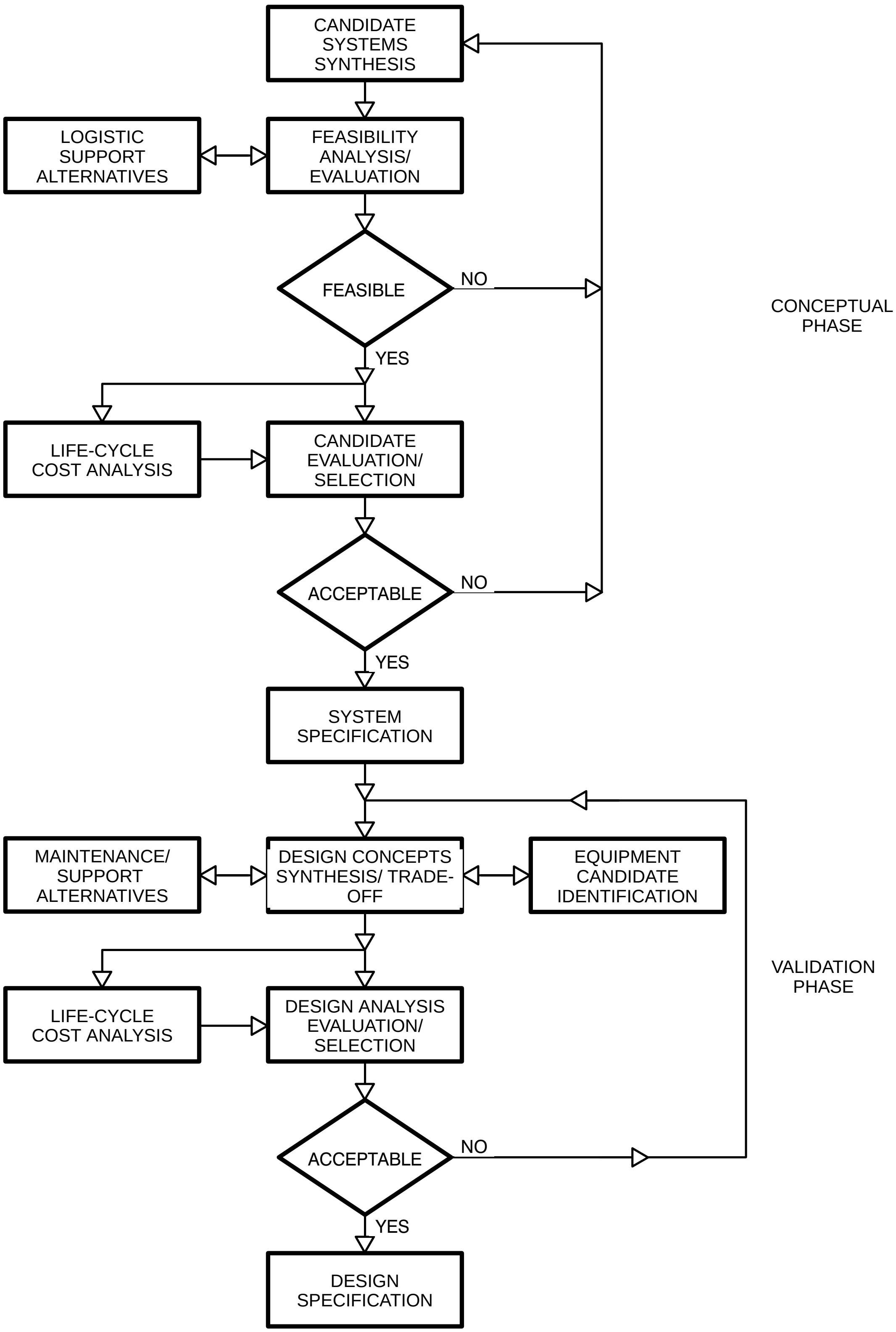


Figure IX-3. Life-cycle costing in system development.

solution for the specified level of performance. It is assumed, in this type of system comparison, that any extra performance possessed by an individual candidate above the level required is of little value and, therefore, does not warrant extra cost.

Since the stress is on comparing system costs, application of life-cycle costing during the conceptual phase depends on whether alternatives are available. In addition, since cost estimates during the early stages of the system life cycle are usually coarse, application of life-cycle costing during the conceptual phase is most meaningful when there are significant differences among alternative systems. In any event, life-cycle costs should be considered as early as possible for maximum influence on the system and the associated costs of operation and support.

VALIDATION PHASE

The validation phase begins with system requirements established in the conceptual phase (fig IX-1), examines different design concepts and approaches, and identifies a cost-effective system design for the following engineering effort. The validation phase is also concerned with system maintenance and support concept alternatives as well as system operating modes. The outputs include the selected system design specifications (development specification) and the technical and program plans for the next phase.

Specifically, life-cycle costing may be applied during the validation phase to assist in the following:

- Evaluation and selection of system designs
- Design analysis and tradeoff
- Evaluation and selection of maintenance and support concepts
- Evaluation of cost impacts of parameter changes (such as reliability and maintainability)
- Assessing cost implications of equipment selection options (commercial vs military equipment, build vs buy or modify, etc.)

Application of life-cycle costing during validation is also useful in evaluating and selecting maintenance and support concepts. This is particularly important since this is the stage at which system maintenance and support concepts are initially defined and considered. Note, however, that as more detailed elements of the system are being considered, the life-cycle costing effort required during the validation phase is expected to be much greater than that required for the previous phase. Therefore, a life-cycle costing model is generally necessary in order to reduce the cost estimating burden as well as to ensure the availability of timely results.

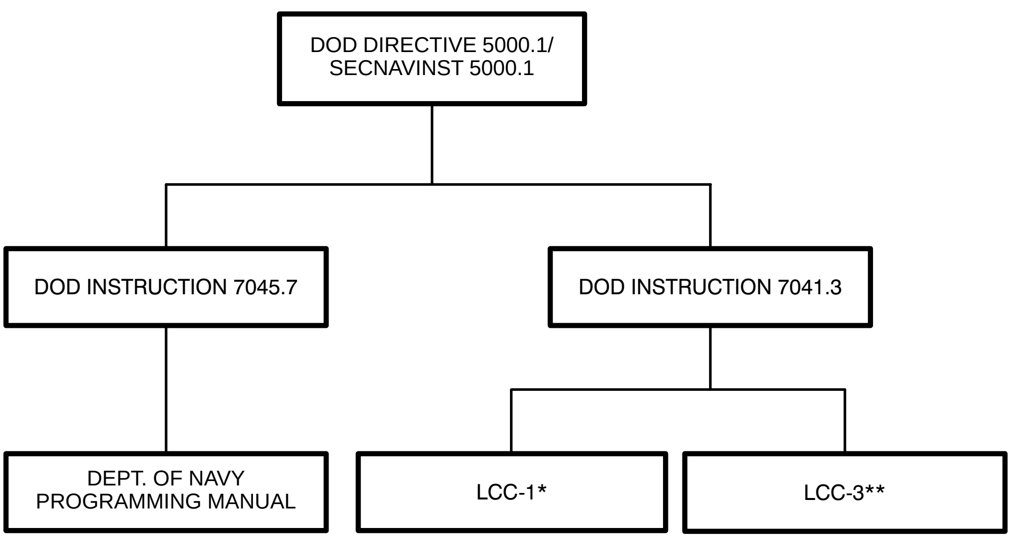
FULL-SCALE DEVELOPMENT

The full-scale development phase is the intensive engineering phase during which the system, including all the items necessary for its support, is designed, fabricated, and tested. The output is a model of the system configuration which is demonstrated and evaluated to meet all requirements based on the specifications generated during validation. The chosen system design concept is examined in detail, and changes or modifications necessary to complete and optimize the system configuration are introduced. The original design concept may even be replaced, if its pursuit proves to be undesirable or if it is found to have serious shortcomings as it is refined during the engineering stage. The role of life-cycle costing during this phase is primarily to help evaluate such major design changes by assessing their cost impacts, particularly in the areas of maintenance and support. Life-cycle costing may also be input to decisions such as the choice of standard or nonstandard parts. Since engineering design entails many changes, it is apparent that there are many areas involving a choice among alternatives where cost is a consideration. However, the emphasis in life-cycle costing must be on major items or areas, as it is not practical to optimize every detail element of the system.

ADDITIONAL AREAS OF APPLICATION

Two additional areas for possible application of life-cycle costing are (1) source selection and (2) contractual commitments in material procurement and system acquisition. They are covered by the following DoD documents (fig. IX-4):

- Life Cycle Costing Procurement Guide (LCC-l)
- Casebook, Life Cycle Costing in Equipment Procurement (LCC-2)
- Life Cycle Costing Guide for System acquisitions (LCC-3)



* LIFE-CYCLE COSTING PROCUREMENT GUIDE (INTERIM), JULY 1970
**LIFE-CYCLE COSTING GUIDE FOR SYSTEM ACQUISITIONS (INTERIM), DOD, JANUARY 1973

Figure IX-4. Life-cycle costing reference documentation.

LCC-l addresses life-cycle costing in the procurement of material and hardware other than complete weapon systems. It presents a set of general guidelines which may be modified to suit the needs of a specific application. Examples of applications of the general guidelines are given in LCC-2. LCC-3 addresses life-cycle costing in the acquisition of material at the complete system level. It covers the application of the life-cycle cost concept to the various acquisition strategies and contains an operating and support cost model for predicting system ownership cost.

IMPLEMENTING LIFE-CYCLE COSTING

Certain basic requirements or preparatory steps which will help to assure useful results from the application of life-cycle costing are described below.

PROBLEM DEFINITION

Defining the problem is the first step in a life-cycle cost analysis. During the problem definition phase, close cooperation between the cost analyst and the system engineer is required so that the system to be studied can be adequately described for costing purposes. Before the analysis effort can begin, the cost analyst must have (1) a description of the system to be costed and (2) cost ground rules for the particular study. As part of the system description, all relevant cost-significant elements including system performance characteristics, physical characteristics, and operational assumptions — must be identified and described. Since the system descriptions needed by the cost analyst can differ considerably from those used by the system engineer, direct communication between the cost analyst and the system engineer is usually necessary. A complete understanding of the ground rules is also necessary. Examples include the type of cost index to be used (e.g., 15-year system cost); rules regarding amortization or discounting; date for which all prior costs are to be considered as sunk costs; and special rules regarding base pay of operating personnel and attrition rates.

DATA ACQUISITION

The types of data needed are identified from the system cost elements list which is based on the system description. The data acquisition effort must begin long before the data are needed, and the data must cover the needs for specific systems, including the types of resources, cost equations, and cost factors. The data collected should be organized, with means for indexing and classifying cost and related data and means for ready access to the data by users.

DERIVATION OF ESTIMATE

This is the step in system costing which is concerned with the actual calculation of the cost estimates. The cost estimates are developed within the framework of cost element lists, the purpose of which is to identify and account for all elements of cost associated with the system. The cost elements are subdivisions of the major cost categories, including development, investment, and operation and support costs. There is no single cost element list which can serve the needs of all problems. Lists have to be flexible in their makeup, as they must be adapted to the type of system, the nature of the problem, and the type of analysis considered. The list should highlight the key features of the system and permit maximum use of the data collected. Once a satisfactory cost element list is developed, calculation of cost estimates is accomplished through cost estimating relationships, cost models, or other means.

PRESENTATION OF ESTIMATES

This step is concerned with the communication of results to the user, and it is related to the first step, problem definition. For ease of understanding, the cost estimates must be presented in terms and formats as well as at a level of detail appropriate for the type of decision to be made. The terms and formats vary with the application, and they should be given early consideration.

ANALYSIS DOCUMENTATION

Proper documentation of the cost analysis is important to both the analyst and the users of the analysis. In addition to its use for review and evaluation, the documentation may serve as a record of the study and a source of data which can be used for other studies. For review and evaluation purposes, the documentation should clearly describe and discuss the procedures and data, as well as the data sources used. It should also permit the cost estimates to be reproduced, if necessary, via the procedure or process described.

REVIEW AND EVALUATION

The user has the critical task of judging the cost estimates and evaluating them as to suitability and credibility. Since direct verification for accuracy is impractical, particularly when cost estimates are used for decisions involving systems far into the future, emphasis must be placed on evaluating the validity of the cost study itself and the analysis underlying it. In particular, areas such as data, data sources, methods, procedures, and conclusions should be closely reviewed and evaluated. It is by understanding the manner in which the cost estimates are derived that a measure of confidence may be obtained for using them.

REFERENCES

1. DoD Directive 5000.1, "Defense Acquisition"
2. DoD Instruction 5000.2, "Defense Acquisition Management Policies and Procedures"
3. Life Cycle Costing Procurement Guide (interim): LCC-l, Dept. of Defense, July 1970
4. Casebook Life Cycle Costing in Equipment Procurement: LCC-2, Dept. of Defense, July 1970
5. Life Cycle Costing Guide for System Acquisitions (interim): LCC-3, January 1973

6. DoD Instruction 7045. “The Planning, Programming, and Budgeting Systems (PPBS)”
7. Department of the Navy Programming Manual
8. DoD Instruction 7041.3, “Economic Analyses of Proposed Department of Defense Investment”

X. INTEGRATED LOGISTICS SUPPORT (ILS)

The ILS functions are essential to the successful integration of an equipment into operational use. The ILS concepts must be initiated in conjunction with the equipment design concept. All too often, the consideration of the ILS is postponed into the development phase or later; at this late stage, the ILS tasks become little more than analysis of an existing design to determine what must be done to support it. The support system resources are limited, and design chases are expensive to implement. So, the most effective way of implementing ILS is to design-in the necessary equipment features initially. This requires integrated planning of design for performance and design for support.

The ILS disciplines include the following:

Reliability

Maintainability

Human engineering

Safety engineering

Transportability

Personnel and training design

Test equipment, tent criteria, facilities, and technical data planning

Logistics design (including logistics support analysis, level-of-repair analysis, and standardization engineering)

Assistance in these disciplines is usually available. NRaD, for example, has specialists in the Product Assurance Division and the Sustainability Engineering Division. Their participation should be included to an appropriate degree in any project developing equipments for fleet use. The project manager should become familiar with ILS concepts; the Integrated Logistics Support Implementation Guide for DoD systems and Equipments (NAVMAT P4000) is a readily available reference.

THE ILS CONCEPT

CONCEPT

The ILS concept is concerned with definition, optimization, and integration by systematic planning, implementation, and management of logistic support resources throughout the system life cycle. The concept is realized through the proper integration of logistic support elements with each other and through the application of logistics considerations to the decisions made on the design of the hardware system and equipment as part of the system engineering process.

OBJECTIVE

It has long been obvious to those responsible for the operation of military systems and equipments that support problems are a limiting factor on operational capability availability. Much effort is expended in trying to increase mean time between failures or decrease periodic maintenance, and to reduce maintenance downtime. Operational commanders watch carefully the statistics on those items of equipment which are not operationally ready because of maintenance or supply difficulties. They recognize the importance of having personnel who are adequately trained to operate the equipment properly and to maintain it efficiently in order to reduce the number and frequency of failures and to reduce the adverse effect of such failures and maintenance time on operational readiness. They know the importance to their operation of adequate facilities and support equipment.

The ILS concept must be applied throughout the acquisition cycle to ensure that systems are designed to meet operation requirements. Frequently systematic consideration of the solution to the problems of support does not begin until the system is in the production/deployment phase. While some elements of support may receive early attention, it is rare that total support planning has a major impact on system design. This lack of timely and systematic planning adversely reflects operational availability and cost of ownership.

Under the ILS concept, the importance of trading off operation and support requirements from the earliest phases of the life of a system has been recognized. As DoD Directive 4100.35 states: “Over the life cycle of a system, support represents a major portion of the total cost, and is sometimes the principal cost item.” By integration of logistics considerations into the conceptual planning and through the entire design and development process, either support costs during the operation may be significantly reduced, or operational availability of the system may be increased without a significant increase in cost.

In addition to integrating support planning into the entire design and development process, it is also fundamental to the ILS concept that the elements of logistic support (as listed and defined in appendix B) shall be integrated with each other into a total support system. When the baseline of any one logistics element is changed or proposed to be changed, the effect on all other logistics elements and on the total system must be formally considered and necessary adjustments made.

In applying the concept of ILS to a system/equipment acquisition, it is important to maintain a proper perspective — to bear in mind that logistics support is not an end in itself, but exists only to support the operation of the system/equipment to which it is related. The support problem will vary according to the complexity and value of the system/equipment. Planning for support must be tailored to each acquisition individually; this guide addresses the differences of approach for major acquisition, less-than-major acquisitions, off-the-shelf items, and modification programs.

It is also necessary to bear in mind that in any acquisition which includes development, there are two entirely different types of effort: first is the conceptual and broad planning stage; second is the period from full-scale development through final disposition, in which the actions contemplated in the first stage are refined and implemented. Just as support planning must be tailored to the type of acquisition, it must also be tailored to the time phasing of the acquisition process.

The first part of the logistics problem in an acquisition is to establish basic characteristics which will enable the operational requirements to be achieved. Program managers must keep the operational mission clearly in view during the early stages, and they should recycle and refine their planning to determine what is the minimum which must be accomplished prior to full-scale development. Once the basic logistics system characteristics are formulated, they must be stated to the design engineers in a "design to" or "design constraint" fashion. When requirements are stated in this format, they may be used in analytical and tradeoff studies. In the development of the logistic support concepts and the early planning for support, program managers must assure that logistic and design personnel work together in an atmosphere of maximum cooperation and communication. Thus, the ILS function must be closely identified as an integral part of the total system engineering process.

The logistics effort in the early stages must be confined to development and formulation of inclusive but broad logistics plans and support characteristics. The result should be a road map of what specific steps will be taken, at what time, and in what detail as the development progresses and the design matures. The detailed planning and preparation of detailed data packages must be deferred until the configuration of the hardware has been reasonably stabilized. Detailed support planning which is accomplished prior to the establishment of the basic configuration and dependent on that configuration is almost certain to require extensive rework to become valid and usable.

The techniques for the application, testing, and demonstration of ILS planning and the requirements for the management of the logistics effort at various stages of the acquisition process are covered in greater detail in the ILS Implementation Guide (NAVMAT P4000) previously referenced.

RELIABILITY PROGRAM

Reliability is the probability that an item will perform its intended function for a specific interval within a stated operational environment. To achieve the required level most effectively, the project manager must establish a reliability program in the early phases of the development. He must ensure that the designer achieves the maximum in reliability which is available to him; that the most reliable components available are used; that reliability is emphasized in all succeeding phases of development; and that design revisions to incorporate modern technology are incorporated at the appropriate stage of maturity. He must, in short, program reliability from concept formulation to production.

A reliability program consists of plans and tasks scheduled in a manner to provide control over all factors affecting the reliability of equipment during conceptual design and feasibility demonstration, development, preproduction, and production to ensure that the quantitative reliability requirements of the equipment are met.

The project manager bases his reliability program on two basic commandments:

- Keep equipment simple — eliminate the superfluous.
- Determine minimum acceptable performance levels — specify nothing that exceeds them.

Observance of these commandments simplifies design, fabrication, operation, and support; lowers development, purchase, and support costs; and maximizes reliability.

Detailed reliability program requirements are provided in MIL-STD-785. See figure X-1.

THE RELIABILITY PROGRAM PLAN

Management Tasks

The reliability program plan should:

- Identify the organizational elements and the key personnel responsible for managing the overall reliability program.
- Clearly define the related responsibilities and functions, including both policy and action.
- Stipulate the authority delegated to the organizations to enforce its policies.
- Identify the relationships between line, service, staff, and policy organizations.

Specific management tasks called out in MIL-STD-785 for the reliability plan include:

A detailed listing and description of each task.

A reference list of detailed procedures, with summary descriptions, to evaluate the status and control of each task including identification of the organizational unit with the authority and responsibility for executing each task.

The anticipated man-hours required for each task.

Identification of known reliability-oriented problems to be solved, an assessment of the impact of these problems on specified program requirements, and the proposed solutions or the proposed program to solve these problems.

Procedures for recording the status of actions to resolve the problems.

Designation of progressive reliability value and milestones, definition of interrelationships, and estimation of times needed for each reliability program activity or task. (Where PERT is used in the total program, appropriate reliability milestones should be included in the overall network.)

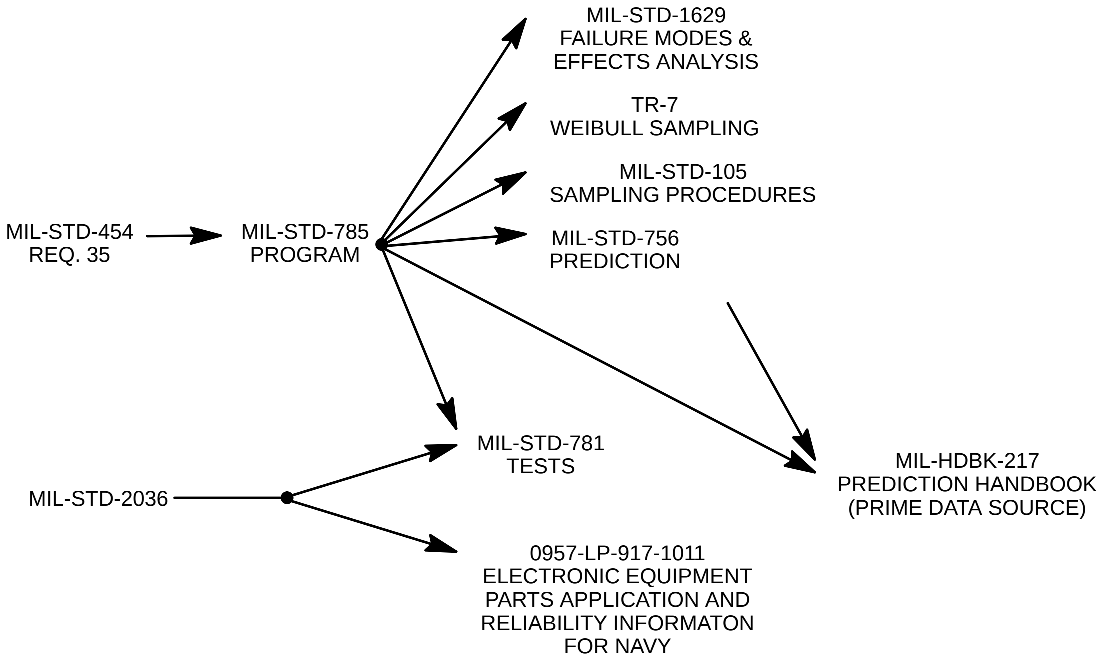


Figure X-1. Reliability documents.

Method by which the reliability requirements are disseminated to designers and associated personnel.

Provisions for reliability indoctrination and training in connection with the project.

Reliability Tasks

Reliability tasks germane to a reliability program are:

Program planning

Design guides

Mathematical modeling

Allocation

Prediction

Failure modes and effects analysis

Parts program

Tradeoff studies

Contractor control

Documentation and data control plans

Design reviews

Developmental test planning and testing

Failure analysis during testing

Most of these tasks are performed during the concept design and developmental stages of a program before a preproduction design is formulated. Application of the tasks during each acquisition phase is described in MIL-STD-785. A number of these tasks are further described below.

Allocation

Allocation is apportionment of equipment reliability from an individual equipment specification to lower limits within the equipment. This is accomplished by allocating numerical reliability goals to each assembly and subassembly down to each nonrepairable part. When combined with the mathematical model, the allocated goals should yield an equipment reliability not less than that required in the individual equipment specification. A reliability group usually performs this task and the results provide the project manager with his numerical reliability requirement.

Prediction

Prediction is the determination of equipment reliability from the reliability characteristics of its components. Reliability predictions, performed early in the design phase, are used as a basis for determining the adequacy of the equipment configurations and models for meeting the allocated design goals. Prediction makes it possible to determine the weak links in an equipment's reliability and to determine the necessary changes, their costs, and the reliability improvement to be expected from their accomplishment. Subtasks of prediction are: (1) reliability logic block diagram (which shows the relationships between equipment operation/failure and constituent equipment or component operation/failure) and (2) mathematical model of the logic block diagram in equation form. MIL-STD-756 shows how to construct the logic block diagram and make predictions, while MIL-HDBK-217 provides amplification, elaboration, and a data base. See figure X-1.

Failure Modes and Effects Analysis (FMEA)

FMEA determines the effects on hardware (circuit) outputs when constituent parts fail in different modes. Typical part failure modes are fail open, fail closed, and parameter drift. Examples are given in NAVSHIPS 0967-316-8010. See figure X-1. This task points out to the project manager the effects each item failure has on the design and the manner in which the item fails. Failures which might appear to be simple could be critical to system operation. This task allows the designer to soften or remove the impact of the failure on his design if the item is determined to be critical to system operation. The FMEA results combined with the prediction task will provide information to the project manager on the reliability worthiness of the design and the weak links in the reliability chain.

From this information he can make more reasonable decisions as to the need for design changes and, if needed, the types or are as of change that will yield a significant improvement in reliability. FMEA is used as a tool for design improvements to eliminate or reduce item criticality by providing redundancy, alternate modes of operation, or increased personnel and material safety.

Use MIL-STD-1629 to perform FMEA.

Test Planning and Testing

The proof of achieved reliability and, conversely, the uncovering of deficient areas of design, lie in the testing of the item. The designer should gather appropriate data for reliability purposes during the development and testing stages. Measures such as accept/reject criteria, the definition of a failure, and instrumentation and data requirements should be established.

The designer should also supply information which indicates the types of tests to specify, test equipment required for the test, acceptable limits of operation, and type of test report required. Testing should be performed at the environmental stresses listed in the individual equipment specification. These inputs allow the test and evaluation group to develop a reliability test plan as described in MIL-STD-781. See figure X-1.

Failure Analysis During Testing

This task determines the following: (1) estimates of the reliability of hardware from test data, (2) whether the equipment is to be accepted or rejected, and (3) causes of failure and weaknesses in design. (See MIL-STD-781.) It provides the basic data for the design analysis and redesign of equipment. It provides the feedback loop to project managers so they can effect a design change that eliminates the uncovered deficiencies.

Design Reviews

Formal and informal design reviews provide the necessary interaction between designers, project managers, sponsors, and users that permits an insight into the designer's ideas and allows an appraisal of his approach, progress, and problems. Design reviews provide the designer a more precise understanding of the user's requirements and problems and of whether or not his design approach will fulfill the reliability needs of the user. Formal design review usually consist of a Preliminary Design Review, held during the preliminary design of the equipment, the Critical Design Review, usually held 30 days prior to formal design release, and the Final Design Review.

RELIABILITY REFERENCES

Naval Sea Systems Command NAVSHIPS 0967-LP-597-1011, *Electronic Equipment Parts Application, and Reliability Information for Navy*

Naval Ship Engineering Center Military Standard MIL-STD-105D, *Sampling Procedures and Tables for Inspection by Attributes,* 29 Apr 63

Naval Air Systems Command Military Standard MIL-STD-756B, *Reliability Modeling and Prediction*, 18 Nov 81

Naval Air Systems Command Military Standard MIL-STD-781D, *Reliability Testing for Engineering Development, Qualification, and Production*, 17 Oct 86

Naval Air Systems Command Military Standard MIL-STD-785B, *Reliability Program for Systems and Equipment Development and Production*, 15 Sep 80

Naval Electronic Systems Command Military Handbook MIL-HDBK-217E, *Reliability Stress and Failure Rate Data for Electronic Equipment*, 20 Sep 74

Failure Modes & Effects Analysis, MIL-STD-1629A, 24 Nov 80

TR-7, DoD Quality and Reliability Assurance Technical Report

MAINTAINABILITY PROGRAM

GENERAL

Maintainability is that part of equipment design which contributes to the rapidity, ease, and economy of maintenance and repair. It provides design features and functions for simplifying or expediting the maintenance tasks which must be performed in order to keep an equipment in its specified operating condition or to restore it to that condition in the operating environment. A high level of maintain-ability not only reduces equipment downtime but also helps reduce the life-cycle cost of maintenance and logistic support.

Early in equipment design, the project manager arranges for a maintenance engineering analysis to be performed in accordance with MIL-M-24365. See figure X-2.

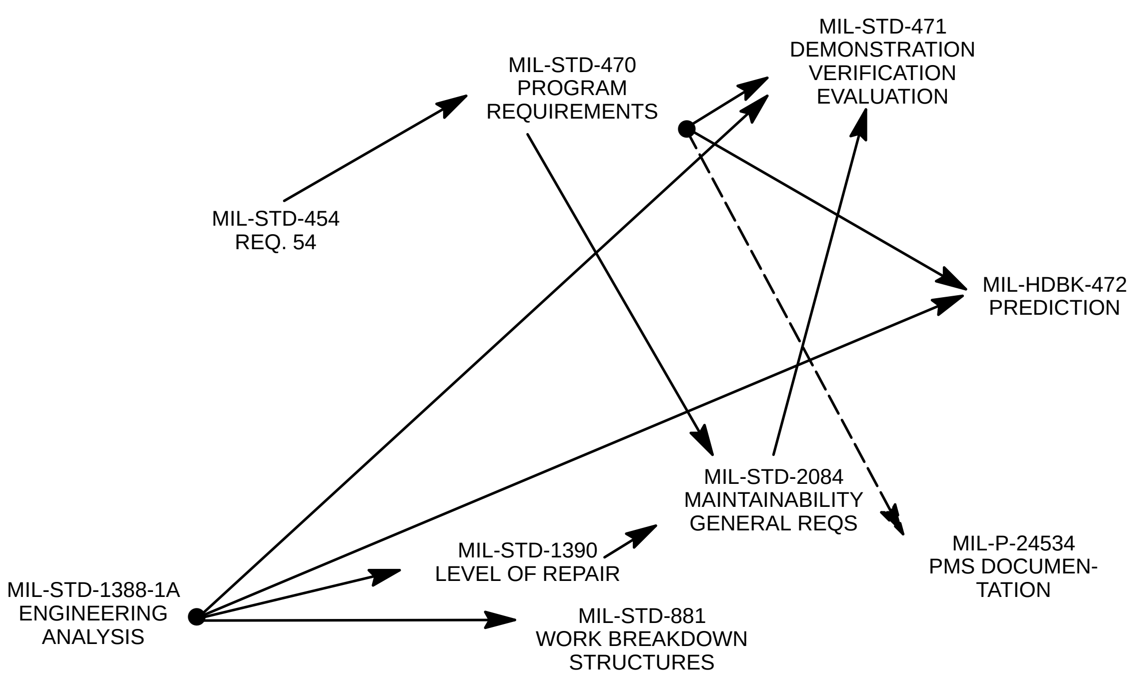


Figure X-2. Maintainability documents.

The project manager makes certain that the designer is aware of both the established shipboard maintenance procedures and the physical conditions under which maintenance is to be performed; and that he is aware of the qualifications and limitations of the technicians who will maintain the equipment.

Early in equipment design, the project manager arranges for a maintainability program to be set up in accordance with MIL-STD-470.

The maintainability program provides that the contractor must:

Prepare a maintainability program plan.

Perform a maintainability analysis (distinct from the maintenance engineering analysis). A major task of the maintainability analysis is the allocation of quantitative maintainability requirements to all significant levels of the system.

Prepare inputs to the detailed maintenance concept and detailed maintenance plan.

Establish maintainability design criteria.

Perform design tradeoffs.

Predict maintainability parameter values. Techniques for prediction are found in MIL-HDBK-472.

Incorporate and enforce maintainability requirements in subcontractor and vendor specifications.

Integrate items other than the contractor's items into the maintainability program.

Participate in design reviews held at appropriate stages of the equipment development.

Establish a data collection, analysis, and corrective action system.

Demonstrate the achievement of maintainability requirements. MIL-STD-471 gives the procedures, test methods, and requirements for verification, demonstration, and evaluation of the achievement of the specified maintainability requirement.

Prepare maintainability status reports at determined or approved by the procuring activity.

MAINTAINABILITY REFERENCES

Naval Air Systems Command Military Standard MIL-STD-470A, *Maintainability Program Requirements (For Systems and requirements)*, 3 Jun 83

Naval Air Systems Command Military Standard MIL-STD-471A, *Maintainability Demonstration,* 27 Mar 73

Naval Air Systems Command Military Handbook, MIL-HDBK-472, *Maintainability Prediction,* 24 May 66

Naval Air Systems Command Military Standard, MIL-STD-2084, *General Requirements for Maintainability of Avionic and Electronic Systems and Equipment*, 6 Apr 82

Naval Ship Engineering Center Military Standard MIL-STD-881A, *Work Breakdown Structures for Defense Materiel Items,* 25 Apr 75

Naval Sea Systems Command Military Specification, MIL-P-24534, *Planned Maintenance Subsystem; Development of Maintenance Requirement Cards, Maintenance Index Pages, and Associated Documentation,* 26 Apr 76

HUMAN ENGINEERING PROGRAM

GENERAL

Electronic equipment should be designed to permit full utilization of human capabilities, to compensate for human limitations, and to eliminate the possibility of human error.

The project manager arranges for comments to be solicited from operating and maintenance personnel during the early planning stages.

The project manager arranges for operator interaction with equipment during advanced and engineering development to aid in finding and eliminating human engineering problems before the service test demonstration and final production design specifications.

The project manager administers the human engineering program. He is conversant with the provisions of MIL-H-46855, which presents human engineering requirements including analysis, test and evaluation, program plan, physical models, procedure development, and coordination with other programs.

The project manager is also conversant with the provisions of MIL-STD-l472, which presents human engineering design criteria. See figure X-3.

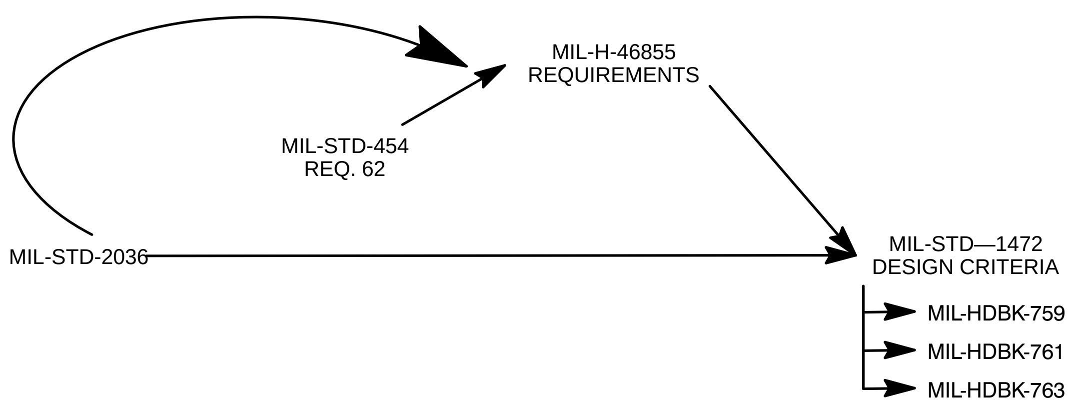


Figure X-3. Human engineering documents.

HUMAN ENGINEERING REFERENCES

Naval Air Systems Command Military Specification MIL-H-46855A, *Human Engineering Requirements for Military Systems, Equipments and Facilities*, 2 May 72

Naval Air Systems Command Military Standard MIL-STD-l472D, *Human Engineering Design Criteria for Military Systems, Equipment and Facilities*, 14 Mar 89

US Army Military Handbook MIL-HDBK-759A, *Human Factors Engineering Design for Army Material*, 30 Jun 81

Department of Defense DoD-HDBK-761, *Human Engineering Guidelines for Management Information Systems*, 28 Jun 85

Department of Defense DoD-HDBK-763, *Human Engineering Procedures Guide*, 27 Feb 87.

SAFETY PROGRAM

GENERAL

The chief objectives of the safety program are the prevention of injury to personnel and the prevention of damage to equipment.

The project manager determines whether not to specify that the equipment contractor develop and maintain an effective system safety program. Preparation of the program is covered in MIL-STD-882. The primary reference for safety criteria is requirement 1 of MIL-STD-454. See figure X-4.

The project manager is willing to expose himself to the worst-case personnel hazards the equipment he is responsible for is capable of presenting to Navy personnel.

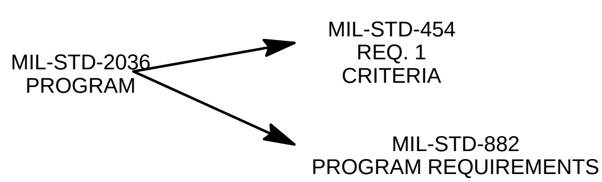


Figure X-4. Safety documents.

Whether or not a formal system safety program is established for the project, safety should be an issue integral to all design reviews. The equipment design and operational procedures should be scrutinized for conformance to safety criteria. The actions considered should include, but not be limited to, the following:

1. Avoiding, eliminating, or reducing identified hazards by analysis, design selection, material selection, or substitution

2. Controlling and minimizing hazards to personnel, equipment, and material which cannot be avoided or eliminated

3. Isolating hazardous substances, parts, and operations from other activities, areas, personnel, and incompatible materials

4. Incorporating "failsafe" principles where failures would disable the system or cause a catastrophe through injury to personnel or damage to equipment

5. Locating equipment parts so that access to them by personnel during operation, maintenance, repair, or adjustment shall not require exposure to hazards such as chemical burns, electrical shock, cutting edges, sharp points, or toxic atmospheres

6. Avoiding undue exposure of personnel to physiological and psychological stresses which might cause errors leading to mishaps

7. Providing warning and caution notes in operations, assembly, maintenance, and repair instructions; and distinctive markings on hazardous parts equipment, or facilities for personnel protection

8. Minimizing damage or injury to personnel and equipment in the event of an accident

In satisfying safety requirements, the design solutions should follow this order of precedence:

1. Design for minimum hazard

2. Safety devices

3. Warning devices

4. Special procedures

MIL-STD-2036 specifies the following tasks (they are worthy of consideration even when MIL-STD-2036 does not apply):

1. Safety testing

2. Design review using a system safety checklist

3. Safety analyses

    a. Conceptual safety analysis (CSA)

b. Design safety analysis (DSA)

c. Functional safety analyses considering, as a minimum,

Installation requirements

Testing requirements

Operating and maintenance requirements

Safety supervision

Handling requirements

Training requirements

d. Hazard Mode and Effects Analysis (HMEA)

4. Integration with other project tasks

SAFETY REFERENCES

Naval Sea Systems Command Military Standard MIL-STD-2036, *General Requirements for Electronic Equipment Specifications*, 18 Jun 91

Naval Air Systems Command Military Standard MIL-STD-454K, *Standard General Requirements for Electronic Equipment*, 31 Aug 73

Naval Air Systems Command Military Standard MIL-STD-882B, *System Safety Program for Systems and Associated Subsystems and Equipment: Requirements for*, 15 Jul 69

PACKAGING, HANDLING, STORAGE, AND TRANSPORTABILITY (PHST) PROGRAM

GENERAL

The PHST program considers all the problems of transporting the system or equipment from the development site to the test site, from the production line to storage, and from storage to service use. MIL-STD-1367 contains the PHST program requirements. The program can be viewed as being in two phases — analysis and design. The analysis phase determines what transportation, handling, and storage actions will be used through the life of the equipment. The design phase determines the detailed PHST requirements and develops testing, packaging, and handling procedures for use with the equipment as well as incorporating design features into the equipment to facilitate the procedures. Figure X-5 shows the relationships of the primary reference documents.

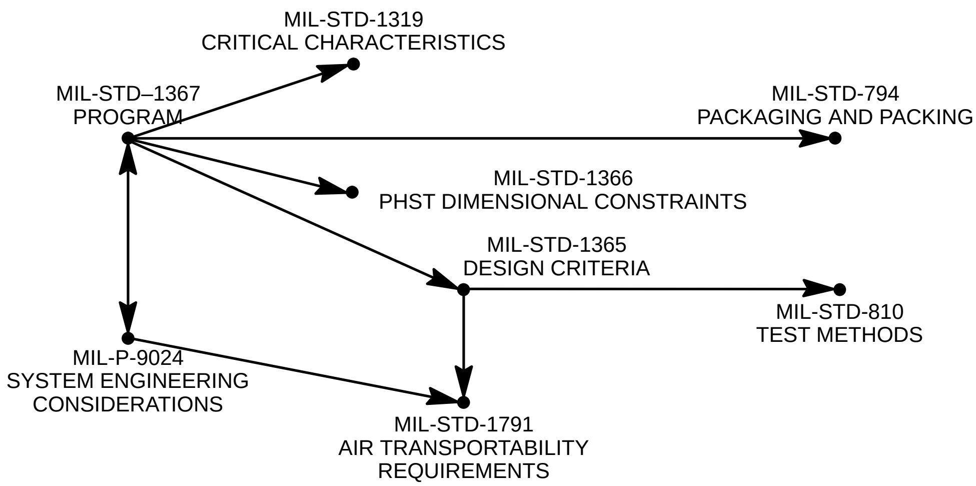


Figure X-5. PHST documents.

REFERENCES

DoD Military Std, MIL-STD-1791, *Designing for Internal Aerial Delivery in Fixed Wing Aircraft*, 13 Oct 85

DoD Military Std, MIL-STD-1367, *Packaging, Handling, Storage, & Transportability Program Requirements*, 27 Apr 77

DoD Military Std, MIL-STD-1366B, *Packaging, Handling, Storage, & Transportation System Dimensional Constraints*, 15 May 81

DoD Military Std, MIL-STD-1365A, *General Design Criteria for Handling Equipment Associated with Weapons and Weapon Systems*, 20 Jul 81

DoD Military Std, MIL-STD-794E, *Procedures for Packaging and Packing of Parts and Equipment*, 16 Jul 82

DoD Military Std, MIL-STD-810D, *Environmental Test Methods*, 31 Jul 86

US Air Force Military Std, MIL-P-9024G, *Packaging, Handling, and Transportability in System/Equipment Acquisition*, 6 Jun 72

Naval Air Engineering Center Military Spec, MIL-P-116J, *Methods of Preservation Packaging*, 8 Apr 88

DoD Military Std, MIL-STD-1319A, *Item Characteristics Affecting Transportability and Packaging and Handling Equipment Design*, 2l Aug 74

Naval Ship Engineering Center Military Spec, MIL-E-17555H, *Packaging and Packing of Electronic and Electrical Equipment, Accessories, and Provisioned Items (Repair Parts)*, 15 Nov 84

PERSONNEL AND TRAINING PROGRAM

GENERAL

The personnel and training program implements the "human equation" of the operation and maintenance concepts. The program starts with an analysis of O&M concepts to determine the skills and skill levels needed to support the system. Reliability program inputs help to establish the man-hour demands for each skill. The man-hour demands are used to determine whether additional personnel will be required in the user organization and at support facilities. The user and support organizations are then compared to the projected skill requirements to determine tentative training requirements.

A training program plan is then prepared in accordance with OPNAVlNST 1500.8 series. OPNAVINST 1500.8 and OPNAVINST 1500.44 together establish the procedures for coordinating project requirements with the training commands. It takes 1 year or more to establish the final training requirements and 2 years to budget and to start training implementation. The training plan also addresses interim training measures for teams to support test and evaluation and for instruc-tors and the initial students to cover the gap between the equipment IOC and the establishment of the final training support.

OPNAVINST 1500.2 dictates the policies and procedures for the "factory" training programs which are normally needed to meet interim training requirements. Detailed training plans, course plans, training aids, and course materials are prepared in accordance with MIL-STD-1379. Interim training is an essential project task which must be fully integrated into the overall project plans, budgets, and schedule This training provides key support to final operational testing and for phasing the equipment into service use.

REFERENCES

US Navy Military Std, MIL-STD-1379D, *Military Training Programs*, 5 Dec 90

OPNAVINST 1500.8M, *Preparation and Implementation of Navy Training Plans (NTPs) in Support of Hardware and Non-hardware Oriented Developments*

Bureau of Naval Personnel NAVPERS 18068D, *Manual of Qualifications for Advancement*, Jan 77

Naval Education and Training Command NAVEDTRA 10,500, *Catalog of Navy Training Courses,* (updated frequently)

Bureau of Naval Personnel NAVPERS 16103C, *Manual for Navy Instructors*, 1964

TEST & MEASUREMENT PROGRAM

GENERAL

The T&M program encompasses a broad base of tasks required to support the maintainability program. These tasks include conducting tradeoff studies between test and measurement methods, selecting test equipments, coordinating the equipment design to incorporate test features and test points adequate for maintenance, and generating and documenting test procedures for organizational and depot use. The T&M program and the maintainability program are major determinants of the maintenance design and of the effectiveness of the maintenance concept implementation.

The primary standards used by the T&M program are MIL-STD-2165, MIL-STD-l388-1, and MIL-STD-415. Tradeoffs are established between different test methods using maintenance time, calibration requirements, skill requirements, equipment reliability, and cost criteria. The final design may incorporate any or all of the following general methods:

Automatic Test Equipment (ATE)

Built-In Test Equipment (BITE)

Test Points with General-Purpose Electronic Test Equipment (GPETE)

Test Points with Special-Purpose Electronic Test Equipment (SPETE)

The use of general-purpose ATE systems such as the Versatile Avionics Shop Tester (VAST) or the Integral Sensor Test System (ISTS) may be dictated by platform maintenance requirements. The use of software diagnostics within the system may be very desirable. There is no best solution for all cases, so these project tasks are important. In each case, special design provisions will be dictated by the test methods employed. The impacts on training, technical manual, logistics, and facility requirements need to be considered and coordinated with those ILS tasks. Unless justified by other characteristics, the T&M program will endeavor to eliminate special tools, test equipment, and facilities.

REFERENCES

DoD Military Std, MIL-STD-415D, *Design Criteria for Test Provisions for Electronic Systems and Associated Equipment*, 1 Oct 69

Department of the Navy Military Std, MIL-STD-1345B, *Test Requirements Document, Preparation of*, 10 Feb 81

Naval Ship Engineering Center Military Std, MIL-STD-1326, *Test Points, Test Point Selection, and Interface Requirements for Equipments Monitored by Shipboard On-Line Automatic Test Equipment*, 15 Jan 68

US Navy Military Std, MIL-STD-1364C, *Standard General Purpose Electronic Test Equipment*, 30 May 75

DoD Military Std, MIL-STD-2165, *Testability Program for Electronics Systems and Equipment*, 26 Jan 85

LOGISTICS PROGRAM

GENERAL

The logistics program consists of three subprograms — the support analysis program, the provisioning program, and the standardization program. The purpose of the logistics program is twofold:

- To drive the equipment design toward the most economic methods of support
- To plan and to implement the effective support of each equipment component

The many tasks of the logistics program are so intertwined with the other ILS programs that it is normally managed directly by the project ILS manager. Like the other ILS specialties, the logistics program can be very complex or relatively simple, and it should be tailored to the project requirements. The extent of the support analysis program is especially susceptible to tailoring techniques. However, the goals of logistic program must be satisfied in order to transition the equipment into service use.

The standardization tasks are so intimately connected with the management of the design effort that they are provided separate treatment in chapter XIV, Consideration of Standardization. Also, parts selection and management concepts are discussed in chapter XXIII. Refer to these sections for a detailed discussion of standardization program tasks and issues.

SUPPORT ANALYSIS PROGRAM

The support analysis program verifies the general support concepts and synthesizes detailed support plans by analyzing the requirements imposed by operational, design, and the other ILS programs. Support effectiveness and costs are the main decision factors; life-cycle costs comprise 90% of the cost factors. In the conduct of the analysis program, alternative methods of support are investigated, and the implications on designs are fed back to the system engineer. System engineering conducts the necessary trade studies and either imposes design changes or design freezes sufficient to establish the support concept baseline.

There are two primary analysis techniques employed in the support analysis program: the logistic support analysis (LSA) and the level of repair (LOR) analysis. The LSA is a readily tailored management technique for coordinating ILS functions as well as accomplishing the support analysis itself. MIL-STD-1369 contain LSA requirements, but a more detailed breakdown of tasks and procedures is documents in

MIL-STD-l388. The LOR analysis is a life-cycle-cost based technique for establishing the best location for accomplishing repair tasks. MIL-STD-1390 contains the detailed formulas used for LOR analysis. Many of the LOR inputs come from LSA computations, and the LOR output is used in later LSA tasks.

PROVISIONING PROGRAM

The provisioning program provides for the detailed analysis of each repair part support requirement and documents the results in the appropriate lists and codes for by the supply system. The support analysis program will determine the general sparing philosophy, but the provisioning program fills out the details. The various codes assigned to each part will determine the cost and supply effectiveness of supporting that part. The provisioning program attempts to maximize the support effectiveness for the equipment while minimizing the costs of inventories. These goals are greatly facilitated by effective standardization program and by designs which incorporate built-in spares. The provisioning program also prepares plans for the provisioning conference (see chapter VIII) and plans for interim support until the normal support system is established. The interim support plans may include warranty provisions and contractor support and will describe the controls and procedures for monitoring the support. In the past, each service has had its own unique procedures for provisioning. However, many standard parts are now managed by the Defense Supply Agency or are supported by a lead service. Therefore, uniform procedures have been imposed for all new equipments and systems through MIL-STD-1561. MIL-STD-1388-2 establishes the formats and preparation instructions for provisioning technical documentation. MIL-STD-1517 prescribes the procedures and conditions for the phased provisioning of interim and initial spares and repair parts. The coding of repair parts is specified by MIL-STD-789.

The most challenging tasks of the provisioning program involve investigating and recommending special support actions. These include spare support during development and methods of supply for parts-peculiar, critical technology parts, and long-lead-time items. Spare support during development is normally very low risk and is usually accomplished by purchasing some comfortable number of spares over known requirements. Special methods of supply may require purchasing all the life-cycle requirements at once and setting up a central stock point (life-of-type (LOT) stocking) or designating a support manager to store, manufacture, or assemble repair items from standard or commercially available parts.

REFERENCES

Naval Electronic Systems Command Military Standard MIL-STD-1369, *Integrated Logistic Support Requirements*, 31 Mar 71

DoD Military Standard MIL-STD-1388-1A, *Logistic Support Analysis*, 11 Apr 83

DoD Military Standard MIL-STD-1388-2B, *DoD Requirements for a Logistic Support Analysis Record*, 28 May 91

Naval Weapons Engineering Support Activity Military Standard MIL-STD-1390a, *Level of Repair*, 8 Jul 88

DoD Military Standard MIL-STD-1561, *Uniform DoD Provisioning Procedures*, 11 Nov 74

DoD Military Standard MIL-STD-1517, *Phased Provisioning*, 1 Jun 71

DoD Military Standard MIL-STD-789C, *Contractor Technical Information Method Coding of Replenishment Spare Parts*, 14 Oct 83

XI. SCREENING TECHNIQUES

INTRODUCTION

The development process is an expensive and time-consuming way to acquire equipment; wherever an existing equipment can be utilized off-the-shelf or after incorporating a simple modification, it will likely prove to be a more cost-effective alternative than any development alternative. However, there are some important tradeoffs which must be evaluated to establish this fact for each specific acquisition. These tradeoffs imply questions which include the following:

1. What additional functions, performance levels, or features are valuable to incorporate over the minimum requirements? (It is likely that existing equipments will lack those features which might extend the practical service life of the equipment significantly or make operation and maintenance simpler.)

2. Will existing equipments be supportable in the field?

3. Will existing equipments be available in the future to support future acquisition needs?

The effective screen obtains the information necessary to answer these questions and to establish the tradeoff decision points between development and off-the-shelf alternatives; even if development is indicated, a great deal of valuable information can be gained through the screen to help avoid subtle pitfalls.

A screen consists of the following elements:

- Locating candidate equipments
- Eliminating unlikely candidates
- Conducting visual inspections
- Reviewing technical manuals, operating instructions, and other data associated with the equipment
- Contacting manufacturers, dealers, and users
- Conducting performance and environmental tests

The screen depends heavily on adequately stated technical requirements for its success. Usually the screen will not produce a black-and-white decision, so an economic analysis will be necessary to reach a final conclusion.

CONSTRUCTING THE SCREEN

The screen is derived directly from acquisition requirements consisting of:

- Technical requirements contained in the system specification
- Procurement requirements (the number of units needed in the near term and in the future)
- Peculiar features of the intended application (see the five major issues discussed in chapter VI, Transition to Production)
- Support requirements
- Cost constraints

The technical requirements must fully embrace the interfaces, human engineering criteria, reliability, maintainability, safety, transportability, environmental conditions, and so forth which are dictated by the operational requirements. Normally, the system specification is not adequately formulated until near the end of the conceptual phase and not validated until the validation phase is nearly complete. The screen can be applied in the conceptual phase, but not without some risk resulting from inadequate technical requirements. The end of the validation phase is the recommended time to implement the screen, because the technical requirements must be grouped into "hard" requirements and "soft" requirements. Hard requirements are all the characteristics, functions, and parameters which are essential in the equipment; hard parameters must be toleranced. Soft requirements consist of the desirable characteristics and functions and of the parameters which may be "sloppy." It may be difficult to group requirements prior to the validation phase. The acquisition requirements can now be applied to the screening steps in the manner described in succeeding sections.

LOCATING CANDIDATE EQUIPMENTS

Candidate military equipments can be obtained by determining the proper nomenclature(s) for the desired function using MIL-HDBK-140 and then searching these nomenclatures in the Joint Electronics Type Designation File (available on microfilm in the Library). The alphabetical listing of military specifications may also prove useful. Some candidates may be rejected and new ones found through discussions with cognizant personnel in the appropriate Naval Systems Command, the Army Electronics Command, or the Air Force Electronics Command. The GSA catalog also lists possible candidates.

Candidate commercial equipments can be isolated through the Design Engineering File of the Visual Search Microfilm File (VSMF) service, which is a compendium of supplier catalogs. Other candidates may be supplied by the appropriate technical or industrial society and by known commercial users of like equipment. The Conover-Mast Purchasing Directory (a Cahners publication), Defense Marketing Services, the Directory of Engineering Document Sources (Global Engineering Document

Services publication), Electronic Industry Telephone Directory (Harris Publishing Company, Cleveland, Ohio), and the Thomas Register are also useful. For items over $10,000, a "sources sought" can be issued in the Commerce Business Daily (CBD); the CBD advertisement should specifically restrict respondees to existing products when it is used for this purpose.

In either case, the "hard" technical requirements are the governing criteria for conducting the search. When sufficient information is not available, the manufacturer should be queried directly; however, it is necessary to take care not to disclose information which would give the manufacturer an unfair advantage should a development be necessary (to do so is a violation of the Armed Forces Procurement Regulations).

ELIMINATING UNLIKELY CANDIDATES

The following candidates should be eliminated:

1. Any candidate not meeting the hard technical requirements which cannot easily be modified to do so.

2. Any candidate which cannot be supported adequately in the field (this normally applies only in situations where depot-level maintenance cannot be employed).

3. Any candidate which is not truly off-the-shelf. Some military equipments are available only after a sufficient quantity is needed and must be "redeveloped" for each buy. Some commercial manufacturers advertise and take orders for equipment still under design; the design may be canceled due to lack of interest or altered by a large user with substantially different needs.

4. Candidates not conforming to the Buy American Act (41 USC 10B(b)) unless there is no domestic candidate available, the item is for use in the country of origin, or the item is a Canadian Military Supply (such supplies are exempted from the Buy American, Act; see ASPR 6-103.5(a) and NPD 6-103.5). (Many NATO sources are exempted from the Buy American Act.)

5. Candidates obviously not meeting project cost constraints.

If a substantial number of candidates remain, the list can be further narrowed by requiring further compliance to soft technical requirements. Also, it is desirable to eliminate unreliable manufacturers; however, this action must be in compliance with ASPR Section 1, Part 6 (1 July 1974).

Prepare a priority list of candidates based upon their conformance to all acquisition requirements, their success as products (talk to users and distributors), their apparent ability to perform in applications closely related to the intended use, the availability of long-term warranties on them, and other general indicators of ruggedness, reliability, availability, and suitability.

CONDUCTING VISUAL INSPECTIONS

Candidate equipments should be inspected visually for workmanship, enclosure effectiveness, human engineering, safety design, maintainability, operability, and thoughtfulness and vintage of design. Major and minor discrepancies should be noted. Major discrepancies are cause for rejection if they cannot be corrected through simple modifications. An archaic design may be cause for rejection unless the manufacturer can guarantee supply parts support. Too new a design (experimental or unproved) should be rejected unless the manufacturer is willing to offer a long-term warranty.

REVIEWING DATA

All available specifications, technical manuals, instructions, schematics, and other equipment data should be reviewed to determine whether they are adequate to support the project needs. Technical manuals should meet the standards of MIL-M-7298, *Manuals, Technical, Commercial Equipment.* Obtain copies of schematics, parts lists, and technical manuals wherever possible. Determine if there are any deviations or waivers of specifications; especially for military items. Review the schematics for apparent capability of meeting the specification and interface requirements. Review the parts list to determine the reliability and availability of the parts. Review the operations and maintenance procedures to determine their clarity and completeness.

Using a combination of hardware and documentation, evaluate the following items:

- Net input power/volume (an indication of heat buildup).
- Operating temperature (an indication of component design limitations and humidity resistance).
- Cooling capability/net input power (an indication of cooling effectiveness).
- Internal voltage levels (another indication of humidity resistance).
- Equipment weight, volume, shape, and mounting provisions (indicators of shock and vibration resistance, and interface or installation problems).
- Manufacturer's claimed environmental specifications, if any.
- Component weight, volume, shape, and mounting provisions (further indicators of shock and vibration resistance).
- Electronic component count (an indication of reliability, maintainability, and cost of logistics support). (Mechanical parts also fail, but such failures tend to be negligible in electronics equipment. A relative parts count between competing equipments cannot tell as much as a weighted parts count based on parts failure rates. However, all that is necessary the first time through this step is a rough approximation.)

CONTACTING MANUFACTURERS, DEALERS, AND USERS

Sales brochures and data sheets often simplify or exaggerate specifications. They may make claims that cannot be substantiated. Performance specifications may apply only to limited circumstances and ideal conditions, or may be valid only with special options. Certain specified performance levels may not be realizable simultaneously.

- Contact the manufacturer's marketing an engineering departments. Discussions with technical experts from the company may reveal hidden defects or additional capabilities not apparent from sales literature. New products may be in production. Perhaps variations of the advertise equipment or special options are available.

- Ask the manufacturer to explain specifically why his product is better than the others under consideration. An alert manufacturer knows his competition and is eager to show off his product's advantages. Such comparative information will point out subtle problems not readily visible in product sales literature and not likely to be raised by a manufacture with regard to his own product.

- Sift through the comparisons furnished by all companies. Give each manufacturer a chance to defend his equipment or to offer solutions to any serious problems pointed out by competitors, without identifying the source of your information.

- Obtain the names of dealers who supply the product. Solicit dealer comments on the suitability of his equipment for the application, his experience with the manufacturer, and customer comments or complaints he has received. Obtain, if possible (from dealer or manufacturer), a history of the item's usage and failure, and a list of purchasers.

- Request information from purchasers regarding performance, problems, or failures versus usage. Determine whether the purchasers' mounting locations, operational requirements, and environments are comparable to those of the intended application so that these comments can be effectively evaluated.

- Interrogate the Government Industry Data Exchange Program (GIDEP) for information on each product (if any is available).

OBTAINING UNITS FOR TEST

Usually, it is not necessary to actually acquire equipments until the performance and environment tests are conducted. The equipments can often be viewed and inspected at a user's facility or the manufacturer's plant. However, the equipments must be "in hand" for testing.

If the procurement requirements offer the prospective suppliers the promise of reasonably large sales, there will be sufficient incentive to the supplier to make a unit or two available (on loan) for testing. If a formal “sources sought” has been used to find candidates, and if it appears reasonably certain one or more candidates will be acceptable, a bid sample can be requested. In either case, equipment is acquired for test at no cost to the government. However, the supplier still owns the equipment, and the government cannot test modifications or test to extreme environments without the supplier’s written permission. Also, the supplier has the right to witness the screening process; this can present problems of security in keeping multiple suppliers away from a competitor’s equipment.

The alternative method is to buy sample equipments of the leading candidates. This presents the problem of funding the procurement if a large number of candidates or if expensive equipments are involved. If every fully preliminarily qualified candidate is not included, the screen’s effectiveness in gathering data for procurement is defeated. Tight specifications and accurate and complete records are needed to keep the number of candidates within reasonable limits; these same items are required to guard against challenges resulting from procurements based on the screen results. This disadvantage is usually balanced by the advantages of the government’s owning the equipment; early budgetary planning is needed to ensure adequate funding for the test cycle.

CONDUCTING PERFORMANCE AND ENVIRONMENTAL TESTS

Screening tests should normally include the following steps:

1. Initial performance test to the manufacturer’s specifications; where several parameters interreact, choose “worst case” test conditions.
2. Testing to project specifications including environmental limits.
3. Burn-in for 100 hours.
4. Combined-environment test to specified environmental limits for temperature, humidity, vibration, and electrical transient response as a minimum. Add stresses which may be encountered in use from environmental cycling, repetitive shock, and EMI as appropriate.

It is desirable to test at least three units of each candidate.

Normally these steps conclude the screening tests; the entire test cycle can be completed in as little as 3 weeks for simple equipments. The combined-environment test (CET) requires 120 hours. The total test time may be extended for more-complex equipments, by repair time should failures occur, or by problems in scheduling the test apparatus.

The screening tests measure the design suitability of the equipment in the intended application; they do not directly measure reliability. Reliability predictions in conjunction with the screening process are normally sufficiently accurate for planning purposes; however, reliability tests may be required if a particular minimum acceptable reliability is essential. The cost of reliability testing can be reduced markedly by combining the reliability test and the CET, using multiple equipments and extending the test time as necessary to accumulate a sufficiently high equipment "on" time.

The Screening Acceptance Criteria are as follows:

1. No repeatable failures for any single tent sequence. (Example: A unit which fails a vibration test twice is not acceptable.)

2. No pattern failures (two or more failures of the same part in identical or equivalent applications which are caused by the same basic failure mechanism).

3. Measured MTBF meets or exceeds project requirements (see table XI-1) with an acceptable confidence. High MTBF requirements may dictate using failure-free trial acceptance criteria (see table XI-2). All units must pass failure-free within three trials of the CET phase.

4. Predicted performance remains within required limits when weighted by quality factors. (See PREDICTING PERFORMANCE.)

EVALUATING THE RESULTS

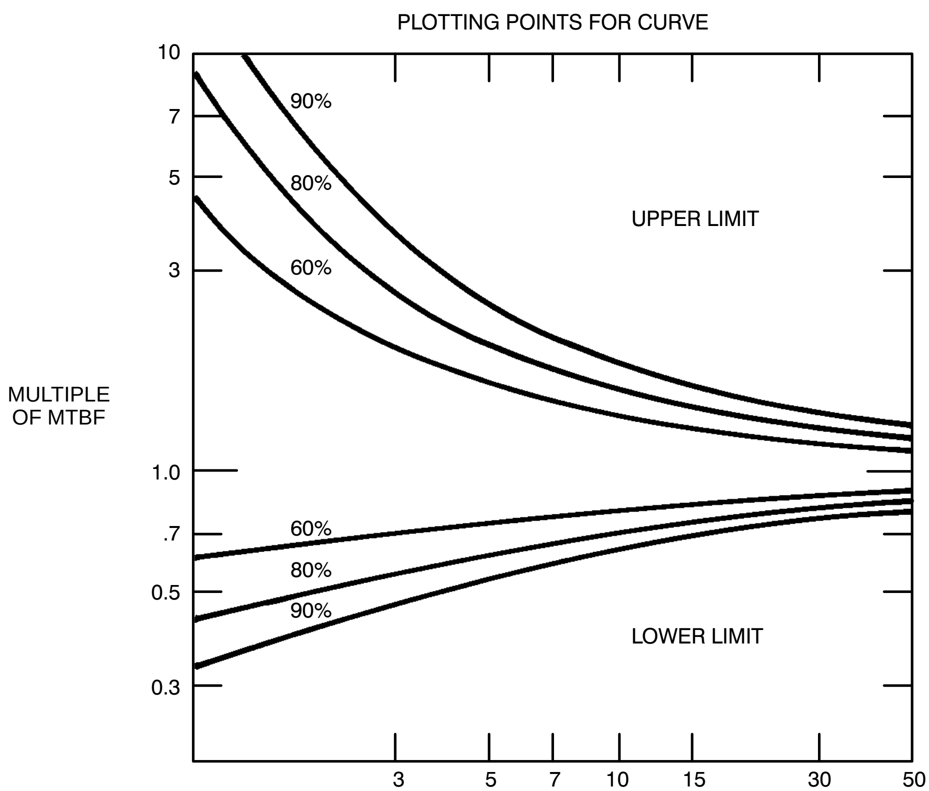
Ideally, multiple candidates will be qualified by the screen without reservation. The screen results can then be used to procure equipments for service use (see chapter VI). However, elements of the intended application and of the equipment design generally do not mesh perfectly, so the screening decision is not clearly determined. An economic analysis is normally required to determine the acceptability of each candidate. By adapting the system life-cycle cost model, a sufficiently accurate analysis can be completed. Subjective evaluations will be necessary to develop some of the inputs to the model; however, maintenance and logistic support data can be improved in quality by using information supplied by current users and obtained from experiences during the test cycle. The data are further fixed if warranties are available. In general, reliability/failure rate data are most difficult to obtain.

The reliability of established products is already designed and built in; talks with the manufacturer, observing his production quality assurance, and user acceptance of the product in similar application environments combine to give qualitative assurance that the reliability of the equipment is adequate. However, quantitative values are required for further project planning. Reliability predictions can supply sufficiently accurate values when weighted by the screening data.

It is important not to overlook the five major issues which must be resolved for any acquisition (see chapter VI). These qualitative decisions may exclude one or more candidates. The purpose of the screen is to avoid development wherever possible and economical; however, the satisfaction of the operational requirements must be the paramount goal of the project.

Table XI-1. Table of values for MTBF confidence range curve.

	Upper Limits			Lower Limits		
Number of Failures	**90%**	**80%**	**60%**	**60%**	**80%**	**90%**
1	19.2	9.44	4.48	.620	.434	.333
2	5.62	3.76	2.43	.667	.515	.422
3	3.68	2.72	1.95	.698	.565	.476
4	2.92	2.29	1.74	.724	.598	.515
5	2.54	2.06	1.62	.746	.625	.546
7	2.13	1.80	1.48	.768	.667	.592
10	1.84	1.61	1.37	.800	.704	.637
15	1.62	1.46	1.28	.826	.746	.685
20	1.51	1.38	1.24	.847	.768	.719
30	1.39	1.29	1.18	.870	.806	.756
40	1.32	1.24	1.16	.884	.826	.787
50	1.28	1.21	1.14	.892	.847	.806



$$\text{MBTF} = \frac{\text{TOTAL TEST TIME}}{\text{TOTAL RELEVANT FAILURES}}$$

TOTAL TEST TIME = ACTUAL TEST TIME X NUMBER OF EQUIPMENTS TESTED

Table XI-2. Failure-free acceptance criteria for CET trials.

$$N = \frac{n}{1 - \frac{t}{\theta}}$$

n = lot size
t = CET test time (normally 120 h)
θ = specified MTBF (must be $t \times 4$ or greater)
N = number of trials allowed to pass the entire lot (round up to the nearest whole number)
(N-n = number of allowable failure trials)

For intermediate ranges of θ, a trial length can be assumed at 1 CET cycle (24 hours). For θ greater than 1200 hours, additional test time should be added, if possi-ble, in 24-hour-cycle increments. It is desirable for the lot size to be at least 3 but less than 12. A maximum of two failure trials is allowed for any single equipment.

PREDICTING PERFORMANCE

There are three elements of field performance which are important to program planning and system implementation:

Operational performance
Field reliability
Useful service life

The operational performance is essential because the equipment is not worth procuring without it. To predict operational performance, the figure-of-merit (FOM) discussed under PERFORMANCE PARAMETERS in chapter IV should be utilized. Taking the values measured for the critical performance factors and applying the FOM model, a FOM can be computed for each unit tested; this number becomes FOM(m). L is the limit computed from the minimum specification parameters using the FOM model. Find the expected service quantity in table A-2 of MIL-STD-414 and convert the inspection level code to a sample size using table B-3. Using the computed QL resulting from the table XI-3A procedure and the sample size corresponding to the expected service quantity, table B-5 of MIL-STD-414 will give a lot percent defective which equals the percent risk of an unacceptable unit going into service use without further screening. Generally, a 1-percent risk of this nature is very acceptable.

The most reliable method of predicting field reliability is through reliability testing. MIL-HDBK-781 provides test plans with various degrees of statistical accuracy ranging from risks of 10% to 50% or more. (See fig. XI-1.) However, the accuracy of these predictions is determined by the accuracy of the specified test environment in simulating the field environment including input/output conditions caused by failures in interfacing equipment and including all failure conditions during the test. Even a properly run test will tend to overestimate field reliability significantly simply because the tests measure MTBF as a design characteristic rather than MTBCM, which includes maintenance-induced failures, false removals, and pseudo failures and also quality- and workmanship-related failures. Compute the workmanship factor in accordance with table XI-3B. Compute the relationship between "inherent MTBF" and "base MTBCM" using table XI-3C, but temper the results with engineering judgment. The predicted field reliability is the product of the predicted MTBF from the test results, the quality level (from table XI-3A), the workmanship factor, and the MTBCM/MTBF ratio. If test results are not adequate to give a valid reliability prediction, use the parts stress analysis prediction procedure in part 2 of MIL-HDBK-217 to establish a baseline. Determine the parts count predic-tion in accordance with part 3 of MIL-HDBK-217, and establish the parts stress analysis prediction to parts count prediction ratio (this ratio is a measure of the derating factor used in the design). Multiply the stress analysis prediction by the prediction ratio to establish an approximate equivalent to a prediction based upon test results, and predict field reliability as above.

The useful service life of an equipment is an important but frequently neglected element of field performance. If the useful service life is exceeded, the operation and support costs will rise markedly, often tripling annually. There are many factors which affect service life such as usage environment, design technology, changing user requirements, and the time-to-wearout characteristic. If the equipment was designed for a usage environment comparable to the actual one and assuming that the design technology and user requirements do not cause obsolescence, the time-to-wearout becomes the primary determinant of the useful service life.

The factors which influence time-to-wearout include design features and production quality and workmanship. Many of these factors are incorporated in the prediction of field reliability as the time-to-wearout is a function of (1) the number of repairs required and (2) the deterioration caused by the repair action. The time-to-wearout can, therefore, be expressed as a product of the field reliability and a repair factor. The repair factor can be calculated in accordance with table XI-3D; it includes repair features, training levels, and support system characteristics which are determined by the design of the equipment and of the support system. The results will be stated in hours and must usually be converted to years by dividing by the expected usage (operating hours per year).

Experience has shown that there are essentially three distinct grades of equipment: commercial, industrial, and military. Each grade, when used in military applications, exhibits useful service life characteristics as follows:

Commercial	1−2 years and as high as 5 years
Industrial	5−6 years and as high as 10 years
Military	10−12 years and as high as 30 years

In considering service life, cost and operational performance should be taken into account. An equipment with a long expected service life may not exhibit the necessary performance to meet expected future requirements. A short-lived equipment may be so inexpensive in comparison to a long-lived equivalent that lower lifecycle costs will result from multiple procurements. However, multiple procurements of small quantities of peculiar items will not be cost-effective. If the technology or user requirement factors are very unstable, a relatively short service life equipment may be indicated; conversely, an equipment inextricably associated with a ship or air platform must serve for the life of the platform.

Despite the deterministic methods of predicting these field performance factors, an equipment will not begin to meet predictions without thorough planning and execution of the acquisition and support steps. The ILS tasks must be completed properly to make the assumptions valid which underpin these prediction methods. Of the predictions, operational performance will tend to be most accurate (usually 2-place accuracy is provided), and service life will tend to be least accurate (±30%). Although not precise in absolute terms, the predictions will tend to provide accurate comparisons between alternatives. No prediction can completely replace experienced engineering judgment, but the methods presented here can be useful tools in program planning and system implementation.

Table XI-3. Performance prediction calculations.

A. Quality Level Calculation For the i^{th} Unit

X_i =FOM(m) - L

Calculate the mean $= \frac{\sum_{i=1}^{n} x_i}{n} = M$

Calculate the variance $= \left[\frac{\sum_{i=1}^{n} x_i^{\ 2} - \frac{\sum_{i=1}^{n} x_i^{\ 2}}{n}}{n - 1} \right] = V$

Calculate the standard deviation = S $\sqrt{V}$

Calculate the quality level = QL = $\frac{M}{S}$ (derived from MIL-STD-414)

B. Workmanship Factor Calculation

D = number of performance-relevant major defects cited by workmanship inspection in accordance with an established standard such as MIL-STD-252

N = number of units inspected

P = number of projected service units

C = level of complexity of unit inspected (per chapter VI)

WF = $\left[\left(1 - \frac{N}{P}\right) \ or \ \frac{1}{2} \ , \ whichever \ is \ greater \right] \ In \ (C + 1.5) = log \frac{D}{N}$ - .82

(derived from MIL-STD-105)

C. MTBCM/MTBF Ratio Calculation

Inspect the design for the characteristics listed and sum the indicated values.

Table XI-3. Performance prediction calculations (continued).

Characteristic	Yes	No	Notes
1. Failure alarms	10	2 1	1, 2
2. Built-in diagnostic test	20	3	1
3. Test points and adjustments are easily accessible and protected from short circuits to ground and to surrounding circuitry	30		

Notes: 1. multiply by fraction of equipment functions covered
2. double for redundant functions

A = sum of indicated characteristic values

B = fraction of functions with redundancy built in

$$\frac{MTBCM}{MTBF} = \frac{A}{60}(1\text{-}B)^2 \qquad \text{(derived empirically)}$$

D. Repair Factor Calculation

Evaluate the equipment in accordance with the values below to establish the maintenance life factor.

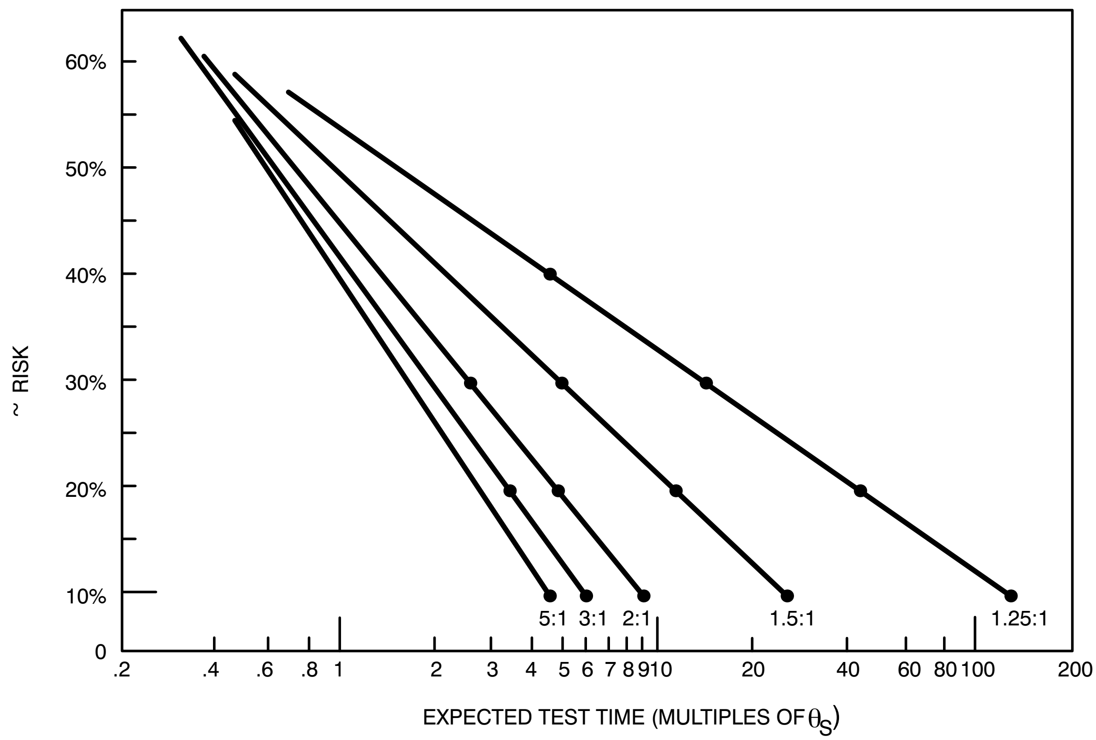
1.	Ease of replacement factor	plugged in	60
		screwed down	48
		soldered (to terminals)	40
		soldered (to PC board)	32
		wire wrap/crimp/wire weld	16
		potted or coated	2
2.	Level of repair	Organization	4
		Intermediate	8
		Depot	20
3.	Technician experience level	unskilled/E-3 or below	2
		semiskilled/E-4 or E-5	8
		skilled/E-6 or above	16

Maintenance life factor (MLF) = sum of values from 2, 3) above —30

Supply support factor (SSF) = ratio of preferred standard parts (per MIL-STD-242) to total number of parts

$$RF = 1 + (1n\ C)(1.82)^{1.1C}\ (MLF)\ (SSF)$$

C = complexity (per chapter VI) (derived empirically)



EXPECTED COST = (EXPECTED TEST TIME (HOURS) ÷ NUMBER OF UNITS UNDER TEST) (COST/HOUR) + (EXPECTED NUMBER FAILURES X COST/FAILURE)

Figure XI-1. Risk as a function of test time.

XII. SYSTEM/DEVELOPMENT SPECIFICATION

Program-peculiar system, development, and product specifications are required for system/equipment items undergoing engineering or operational development at government expense. The top-level specification — the first to be prepared and the one of concern to this section — is intended to establish the functional configuration identification of the item being developed.

According to MIL-STD-490, there are three types of specifications the contents of which identify the functional configuration of an item — the Type A "system" specification and the Types B1 and B2 "development" specifications. Which to use depends on the complexity of the item. The Type A specification is necessary for a system comprising "subsystems, assemblies (or sets), skills, and techniques capable of performing and/or supporting an operational (or nonoperational) role to the degree it can be considered a self-sufficient item in its intended . . . environment" (MIL-STD-490). In addition to requirements common to the functional identification of all hardware developments, this specification would require definition of the extent to which the missions of the system affect design requirements, current and potential enemy threats to the system, operational and organizational concepts which constrain design and operation, nuclear control requirements, and coverage of system effectiveness models.

A Type B1 specification is applicable to a "prime" item. This item does not have the complexity of a system, but in order to define it properly in the specification it generally would be complex enough to have to include (1) functional flow diagrams to the level required to identify its several essential functions; (2) functional and physical interfaces between it and other items and between the major components within itself; (3) a major component list; and (4) lists of government-furnished and -loaned property incorporated by the item. In addition, this item will require provisioning actions, operation and maintenance manuals, and quality conformance inspection of each unit of the item.

The functional configuration of a "critical" item one below the complexity of a prime item — can be described adequately by a Type B2 specification.

When a system is covered by a Type A specification and additional specification of its major functional areas is necessary to completely identify system functional configuration, Types B1 and B2 specifications also are used as second-level development specifications to describe the "allocated" functions of subsystems and other major items of the system. The criteria of complexity described above apply to which Type B specifications to use for allocated functional-configuration identification.

Content and format of Types A, B1, and B2 specifications are indicated in appendices I, II, and III, respectively, of MIL-STD-490.

Besides the "type" of specification, which "form" to use must be considered. MIL-S-83490 specifies the use of four different forms which differ in the degree of control they provide over format and content. They are identified as "Form 1a, Form 1b, Form 2, and Form 3." The degree of control required depends on how refined the specification must be to satisfy government needs for the particular development.

Form 1a specifications are prepared to rigid military standards where extensive control of paragraph content and format is necessary. They must conform to MIL-STD-490 in all respects, including paragraph numbering and titling and subject coverage as specified in the appendices of MIL-STD-490.

Form 1b specifications also are prepared to military standards, but where limited format control is allowable along with maximum content control. They can be prepared according to the requirements of MIL-STD-461 or MIL-STD-490. If MIL-STD-490 is followed, the strict paragraph sequencing, numbering, and titling of its appendices are not obligatory, although the six-section format is mandatory.

Form 2 specifications are prepared to commercial standards with supplemental military requirements when such specifications will be acceptable for the government's intended use (possibly with minor change) and offer a price or delivery advantage over Form 1 specifications. The supplemental military requirements are (1) characteristics must be specified to the degree necessary to allow eventual procurement and delivery of an item that meets all government requirements; (2) quality assurance provisions must be included to assure the meeting of these requirements; (3) symbols, reference designations, codes, abbreviations, etc., must be to military standards or be fully explained; and (4) the commercial standard to which the specification is prepared must be furnished or be referenced and available.

Form 3 specifications are prepared merely in accordance with the contractor's/agency's normal practices, but must satisfy the intended use of the document.

Although strict adherence to the appendices of MIL-STD-490 is not mandatory for Forms 1b, 2, and 3 specifications, use of the appendices as a guide is encouraged to assure adequate coverage of all requirements that may be necessary for the particular development.

Types A, B1, and B2 specifications establish a functional configuration baseline against which changes are evaluated and made as design development progresses. When design changes are approved and incorporated, the documented baseline is updated accordingly to ensure continual correspondence between the item's actual configuration and the documentation which describes it. This baseline identification serves throughout the life cycle of the item as a description of required functional characteristics.

Functional baselines should be specified flexibly to avoid undesired, premature commitments to detailed requirements that would be difficult and/or expensive to change. In the case especially of major system developments, the initial baseline identification could well be a preliminary system description of a range of proposed broad performance parameters or characteristics which then could be used to facilitate the evaluation of alternative design approaches as performance-cost tradeoffs are made.

A flexible functional baseline is a good start toward later establishment of product specifications which are performance oriented rather than design oriented — "product function" specifications rather than "product fabrication" specifications. Various studies and current directives emphasize the preference of the former over the latter except for developments where materials, individual parts, add/or internal configuration must be controlled because of particular military needs. Performance-type specifications (i.e., form, fit, function specifications) which include environmental and interface requirements, as opposed to detailed design specifications requiring particular parts, processes, materials, and internal configuration, assure multiple-source procurement. Also, by including standardized mechanical, electrical, and environmental interface requirements in performance-type specifications for items applicable to common operational functions, the interchangeability of similar equipments can be ensured. This results in ready replacement of old designs by new-generation equipment as well as enhancing design and price competition among contractors. However, the other side of the coin — proliferation of detailed designs — must be considered, too, for optimum end results. To minimize variety and to control design features which pertain to interchangeability, compatibility, reliability, and maintainability, it may be necessary to include some detailed design requirements in performance-type specifications.

In exploring and establishing system/equipment requirements for specification, cost, quantity, and schedule constraints should be given equal status to performance and physical characteristics. Cost factors should be introduced as early in the conceptual design and planning phases as possible, and formal requirements in final form should be specified and issued only after several iterations of cost-performance estimates. Not only should first cost (design to cost) be weighed carefully, the costs of maintenance, supply, and training — along with the tradeoff values of cost, reliability, performance, maintainability, and efficiency — should be carefully considered.

The following features can increase cost:

Needless refinement
Expensive finishes
Unreasonable tolerances
Critical materials
Restrictive processes
Overemphasis on appearance
Overlong life expectancy as related to intended use
Overprotection against failure
Unreasonable and excessive inspection
Unrealistic reliability

A special case exists when establishing requirements to be specified for items which are to be supported initially by contractor long-term warranties. Here, reliability, maintainability, and initial provisioning are not the major concerns they otherwise would be. These requirements may be relaxed along with their quality assurance provisions when there are adequate contractual warranty provisions which make it profitable for the contractor to design and build highly reliable and maintainable equipment.

Regardless of the scope of requirements in a specification, each requirement should be stated to present exactly what the government wants. Requirements should be so worded as to provide a definite basis for rejection when testing and inspection reveal unsuitability. Also, care should be exercised to avoid unrealistic requirements and those which conflict with referenced documents. If requirements are not absolutely clear and definite, bidders will not know exactly what they are to furnish in order to make a responsible bid.

The contents of a specification pertain directly and only to the item to be developed. Thus, the following activities of a development program are not covered by a specification, but rather by the statement of work of the contract:

Configuration management
Integrated logistics support
Safety program
Human factors program
Training program
Level of repair
Acquisition management
Supply support
Contractor services
Quality program
Reliability program
Maintainability program
Planned maintenance subsystem
Test point program
Calibration and instrumentation
Electromagnetic compatibility program
Special test programs

In addition, the specification must not contain requirements for the delivery of data. Data to be delivered under the contract can only be ordered by the Contract Data Requirements List, DD Form 1423. The form and content of each line item of data on the DD Form 1423 are required to be specified by a Data Item Description, DD Form 1664, which is attached to and becomes a part of the DD Form 1423. When data requirements are contained in a DD Form 1664, such requirements must not appear in the specification except that deliverable data can be identified in Section 6, Notes, of the specification. This identification should include the corresponding DD Form 1664 numbers. An exception allowing data requirements to be described directly in a specification occurs when it is impractical to separate such description from its context. An example of this would be data requirements covering quality assurance provisions.

XIII. DECISION TO BUILD, BUY, OR MODIFY

Commercial enterprises base their make-or-buy decisions on economics. The military frequently bases the decision on expediency. The design and procurement approach should result in the provision of the required equipment characteristics to the Navy at lowest system life costs. This is done through the use of life-cycle cost (LCC) analyses, as follows.

SELECTION OF THE BEST CANDIDATE EQUIPMENT/DESIGN

Identify all candidate equipments — existing and to be developed — and their requirements for operation and maintenance during the deployment phase of the system life cycle. Eliminate those that cannot meet minimum requirements for the new mission. On the basis of total life cost analyses, the equipment having the lowest total life cost design which provides the minimum essential performance should be selected for procurement. In addition to total life costs, quality, delivery, acquisition costs, and political factors must be considered (although total life cost should pre-dominate) so that the greatest project effectiveness is achieved.

MILITARY OFF-THE-SHELF EQUIPMENT

Determine whether there are any off-the-shelf military (other service as well as Navy) equipments that could provide the require characteristics without modification or after being modified. Obtain the existing procurement specifications of these equipments and one of the units of each to review their characteristics. Remember that even existing military equipment may require new interfaces for the new mission. Check with the cognizant acquisition agency to find out what deviations and waivers have been granted against the specifications.

FEASIBILITY OF MODIFYING MILITARY EQUIPMENT

The criteria for deciding whether or not modifications to military off-the-shelf equipments are feasible are:

- Will meet new requirements
- Performance will not be degraded
- Service life will not be decreased
- Availability (reliability and maintainability) will not be decreased
- Will be cost-effective

COMMERCIAL OFF-THE-SHELF EQUIPMENT

Determine if there are any off-the-shelf commercial equipments that could provide the required characteristics, without modifications or after modification. See chapter XI, Screening Techniques, for details. Even without modification, new interfaces may be required for the military mission.

NEW DESIGNS

Since the costs during the deployment phase (assumes a quantity greater than 10) always exceed development and procurement costs, consider new design concepts that, compared to the candidate off-the-shelf equipments, are aimed at less expensive operation, maintenance, and support. Develop or expand the new design(s) to the extent necessary to provide the input data required by comparative LCC analysis (see chapter IX, Life-Cycle Costing). Be sure new design and utilization concepts include a well planned maintenance concept (see MAINTAINABILITY PROGRAM in Chapter X) and the use of proved technology (no forcing the state of the art) and of components commonly used in industry.

New designs are often preferred in order to obtain the advantage of in-house control which allows the program manager to influence the design. Such control and influence are not present for existing equipments, though modifications permit some opportunity for reconfiguring an equipment to the latest desires as well as requirements.

The problems associated with new designs involve unknown cost, unknown development time, and the risk that the new development will not perform as specified. Any two of these three factors may be defined and controlled, but the third one will <u>always</u> be an unknown. Some of the elements that comprise the development costs are labor, management, documentation (administrative, procurement, engineering, and support), inventory (procurement, storage, and control), fabrication, quality assurance, and testing (performance, environmental, reliability, maintainability, safety, etc.). There is also a learning curve, wherein the first units <u>always</u> cost more than following identical units on the same production line.

DEVELOPMENT OF MODIFICATIONS

For military or commercial off-the-shelf equipment requiring modification, the modification(s) will require developmental effort. The selected equipment should be developed to the extent that a development specification (Type B, MIL-STD-490) could be prepared in sufficient detail to effectively describe the characteristics which must be finalized through engineering development into a production model. That is, the equipment must be developed sufficiently at this point so that the requirements for its engineering development can be specified well enough to get this phase of the effort off to a good start and end in a cost-effective production design and specification. Check chapter XVI, Types of Contracts; and chapter XV, Warranty Applications. Development of modifications should include considerations similar to those discussed for new designs in the next paragraph.

DEVELOPMENT OF NEW DESIGNS

In new designs, all equipment characteristics have to be addressed in a development effort. Refer to chapter III, Program Planning. The extent and detail of design delineation required at this point for a new design can be inferred by reference to MIL-STD-490, Appendixes II and III, which define the content requirements of Type B development specifications.

LIFE-CYCLE COST ANALYSIS FOR DETAIL DESIGN

For modification or new designs, urgent consideration should be given to the use of LCC analysis, commensurate in scope and expense to the overall project, for helping to establish the design details that must be delineated. The LCC model of the selected design which was used for the comparative analysis can be amplified to be of value at this point. It then can be updated and revised as it is used to help determine design refinements and approved engineering changes which occur during engineering development. The LCC analyst must be provided the necessary additional input variables relating to equipment characteristics (see chapter IX, Life-Cycle Costing, for use in this LCC modeling).

Table XIII-1. Summary of the Buy, Build, Modify Decision.

The Buy Alternative ("Procure," "Nondevelopmental Item NDI)"	The Modify Alternative	The Build Alternative ("Develop")
ADVANTAGES	ADVANTAGES	ADVANTAGES
• Provides item quickly • Avoids development $ • Shares broader production base with other applications	• Can achieve the advantages of both "build" and "buy" when suitable modifiable item exists • Can address unique MIL requirements	• Provides suitable items for unique requirements • Design can be tailored for the lowest support costs • Can usually achieve more capability in smaller, lighter, package
DISADVANTAGES	DISADVANTAGES	DISADVANTAGES
• Item design may not be for similar usage environment • If commercial item — may preclude low levels of design ownership, standardization or repair • If previously qualified for MIL environment — check waivers granted	• Can suffer all disadvantages of both "build" and "buy" if - improperly designed - or poorly managed - or suitable item to modify does not really exist - or information for modification design cannot be obtained	• Item usually small quantity procurement • Development $ & time • More likely to generate peculiar support requirements
USAGE	USAGE	USAGE
• Almost always best for nonvital applications • Consider first	• Consider modification of ideal system partitioning to minimize new design and to keep new design in "one place" • Consider second	• Most often suitable for vital requirements • Consider as last resort

XIV. CONSIDERATION OF STANDARDIZATION

Standardization is a highly controversial subject. The essence of this section is that DoD requires standardization because of its many benefits. Standardization also has many disadvantages. Fortunately, there are various degrees of standardization, and it is wise to select the appropriate degree of standardization for the particular program.

The Navy has committed itself strongly to a standardization program as evidenced by the various directives, instructions, standards, and specifications on the subject. J.S. Gansler, Assistant Director in the office of Defense Research and Engineering, stated that standardization "is a major step in our cost-reliability attack" and that "standardization can and must be achieved" (June 1975). In essence what the proponents of standardization are saying is that they do not want to repeatedly pay for developing the same equipment. A highly informative review of this subject is to be found in an Electronics "X" project report by ARINC. For instance, "The reliabilities achievable for SHP (Standard Hardware Program) modules are no greater or less than for other modules of similar complexity and technology subjected to the same quality-control provisions." Also, "Among those who contributed information ... it was the consensus that, to date, increased costs are involved in the develop-ment of systems utilizing SHP concepts."

Those within industry who were questioned on this subject for the TELCAM task indicated a dislike of the idea of a requirement to use standard modules. Telling the manufacturer how to design, fabricate, and install essentially relieves him of responsibility for the result. This in turn destroys incentive. Actually, industry has standardized many components, procedures, and designs through their joint efforts in technical organizations. Acceptance of these standards is voluntary, but, as the Electronics "X" report states, ". . . good standards do not have to be 'enforced.' They are accepted because they make economical and technical sense to all concerned." Further standardization by industry is accomplished by its acceptance of circuit designs, modules, components, etc., due to their usage history within the industry. This standardization may not always be formalized by the term "standard," but the results are the same. These items are repeatedly used because their history of reliability, cost-effectiveness, replaceability, and safety contributes to a desirable and competitive product.

Many of those interviewed from within industry felt that the required use of SHP modules stifled their engineers' creativity and meant the expenditure of time and money to "design in" the standardized modules. Industry does make use of prevailing commercial standard components and parts where suitable for their product; but where and when to use them is the individual decision for each firm. For instance, some firms such as Motorola, Scottsdale; stock nothing but high-reliability parts such as JAN-TX. Because of the volume of parts purchased they can do this at a price equivalent to lower-reliability parts purchased on fragmented buys. These parts are used for design work as well as production.

The military achieves a form of standardization by repeatedly procuring identical equipments over a period of years. This results in technological obsolescence and mediocre reliability.

At the same time, other similar equipment is procured for slight variations in mission requirements or improved equipment capabilities for the original requirements, or because new technology surpasses some facet of original equipment technology. This results in an excessive proliferation of alternative equipments and defeats any benefits of repeatedly procuring identical equipments.

Where only minimal organizational maintenance is required, a better approach might be interface standardization at the level of the black box, line replaceable unit, or weapons replaceable (repairable) assembly. This concept is widely used in the Navy, especially in missiles and avionics.

The airline industry has been using interface standardization for years. Combined with functional specifications, they call it "form, fit, function" standardization. The internal configuration is free to evolve as technology changes, taking advantage of new techniques, devices, and materials. Organizational maintenance consists mainly of replacing black boxes for repair under warranty or at repair depots.

The military can adopt this plan and standardize the functions, interfaces, components, and workmanship. Since internal circuits and configuration are not specified or standardized, the manufacturer is free to give his best effort in the internal design. Competition breeds innovation and reduced prices. The military will end up with the functional capability specified, the optimum technology at the time of purchase, and the lowest price. Later models of the same functional item will be different internally, but will be fully interchangeable with the initial equipment. The need for modifications to an installation to accommodate the new equipment is eliminated.

Organizational maintenance will not extend below the modular level or perhaps the black box level, depending on mission requirements and the logistics program involved. The maintenance concept will include a suitable combination of throwaway modules, warranties, and depot maintenance. See chapter X, Integrated Logistics Support, for more details.

General worst-case standards have been developed for various military environments. Equipment developed to withstand such environments is expensive. Where it is known that the actual environment for an equipment will be less severe than "standard," it will mean savings to modify the requirements to the actual environment. This is encouraged by MIL-STD-2036 and various environmental standards including MIL-STD-810, MIL-STD-167, MIL-STD-108, and MIL-STD-469.

A well-organized standardization program takes advantage of standardization's benefits and avoids its pitfalls. To accomplish this, the project manager must be aware of the advantages and disadvantages.

POTENTIAL ADVANTAGES OF STANDARDIZATION

1. Standardization reduces life-cycle cost.
2. It makes practical a larger design budget due to the larger number of units for amortization of design cost.
3. The number of types of parts to be purchased and stocked is reduced.
4. Standardization reduces the unit cost of necessary repair parts by requiring larger quantities of relatively fewer types.
5. It increases the quantity of the same item, which reduces its unit cost through economies of scale, mechanized processes, and longer production runs of fewer designs.
6. Larger-quantity productions make practical the use of LSI integrated circuits.
7. The number of odd or unusual items is reduced.
8. Production cost is reduced in terms of tooling due to higher usage of fewer setups.
9. Fewer types of test equipment are required.
10. Simplified test procedures and fault isolation become possible. Automated test equipment becomes more practical to design and produce.
11. Training requirements and skill levels required for maintenance are reduced.
12. Standardization increases maintainability and minimizes equipment downtime due to common spares and off-line repair or throwaway.
13. The number of different documents is reduced.
14. Predictability is increased for reliability, maintainability, safety, costs, etc.
15. Reliability is increased through evolutionary redesign.
16. Availability is increased due to increased reliability and maintainability.
17. Universal packaging becomes possible through standardization.
18. Uniformity in size, shape, and/or connectors simplifies storage and testing requirements.
19. Standardization permits parts or modules to be interchanged between or within systems and equipments.
20. It provides modular "building blocks" for electronic and mechanical design (which speeds design and reduces development time).

21. Time and expense are saved in determining optimum enclosure size, module size, circuit board size, etc.

22. Standardization reduces redundant design efforts, reinventing the wheel, or redeveloping existing equipment.

23. It permits universal use of carefully designed solutions to problems such as cooling, electromagnetic interference, shock, and vibration, thus reducing design time and documentation requirements while improving the design integrity.

24. The number of similar equipments is reduced along with their development time, costs, and documentation.

25. Multiple use or broader application of an item becomes possible.

26. The cost of adding a nonstandard item to the stock system is eliminated.

27. Instructive guidelines are provided to the uninitiated, which allows "novices" to compete for the development and production of military electronic equipment.

28. Standardization program quality procedures allow higher quality, high-reliability items at a lower cost of implementation. The end products are more uniform and predictable.

There are always some things we would like to see done, but the question is how much we are willing to pay for it versus how much we will actually benefit from it. Military standards and specifications tend to be excessively long and complex, slow to follow the rapid advances in technology, and difficult and expensive to implement. They often fail to produce the intended results. Numerous military standardization programs have been tried. Most have died through lack of use. The causes for such lack of use are among the following disadvantages of standardization.

TYPICAL DISADVANTAGES OF STANDARDIZATION

1. Standardization "benefits" are often ideals that cannot be realized.

2. Standards are usually prepared by designers of standards rather than designers of equipment.

3. High initial costs are inherent in standardization programs.

4. Components which are larger, more expensive, or unnecessary except for standardization purposes add to equipment and repair costs.

5. Repair by replacement of expensive subassemblies is not cost-effective in cases where it is obvious that an individual component has failed. Standardization at the modular level can lead to difficulty in locating what would otherwise be a simple, low-cost repair of an obvious failure.

6. Standardization limits design flexibility and alternatives (which increases cost).
7. Standardization cannot satisfy all requirements (can't please everyone).
8. Standardization tends to have a narrow view and does not always consider all parameters as variables, but rather fixes certain ones as constants. This results in unreasonable constraints to the designer and possibly unreliable equipment in service.
9. It usually involves less than optimum electrical and mechanical design parameters. "Optimum" for one circuit system, etc., is not optimum for the next.
10. Generally inefficient systems result from standardization. Problems include excessive weight, excessive volume, excessive heat, and excessive complexity. Standards designed for expected worst-case conditions produce inherently inefficient results, and cost more than optimum items.
11. Equipment standardized internally has low volumetric efficiency due to additional required connectors and hardware, and larger than optimum (but standard) connectors, hardware, and components, all assembled in a larger than optimum (but standard) module, subassembly, case, cabinet, etc.
12. Standardization generally conflicts with "best commercial practices."
13. Equipment designed to a multitude of standards to fit a variety of needs generally suits none of the needs well. Due to extensive tradeoffs and compromises, the result may be unsuitable for any of the intended applications.
14. Standard modules, circuits, etc., are frequently peculiar to the one system for which they were originally designed, and cannot be designed into another system without causing deficiencies, inefficiency, or unnecessary complexity.
15. Items designed and built to general standards have trouble adapting to special requirements.
16. There can be otherwise unnecessary and cumbersome interface restrictions required for the sake of standardization; e.g., connectors, voltage levels, and module sizes.
17. An increase in the number of connections leads to reduced reliability.
18. Increased conductor lengths may cause cross talk or noise, or other EMI problems.
19. Long lead times (often due to low usage) are common for standard items.
20. Commercial managers may be unwilling to change to military standards from their in-house standards for psychological, economic, or sound technical reasons.

21. Standardization can add to the complexity of fault isolation.

22. When a defective subassembly is isolated, a modular replacement philosophy may preclude module repair due to lack of detailed internal information or lack of repair parts.

23. Standardization requires that adequate documentation regarding the standard be made available to users.

24. It tends to be arbitrary for the sake of documentation.

25. Sometimes “the tail wags the dog”; standardization controls and directs the program rather than being a tool of the project manager.

26. Standardization is sometimes more politically than economically or technically motivated.

27. Standards become obsolete even if valid when written (often obsolete before published). This limits improvements in performance, cost, size, weight, or reliability. A good (rather than arbitrary) standardization program requires time to develop. Unfortunately, this sometimes leads to a “new standard” which becomes obsolete before it is finalized.

28. Standardization programs generally do not last. Needs, missions, and state of the art are all constantly changing. Standardization is an attempt to hold on to the present and assumes that the particular standard will remain useful for an indefinite period of time.

In theory, the advantages of standardization clearly outweigh the disadvantages. In the real world, however, “standardization” is often no more than a management technique to maintain control over an otherwise constant stream of changes. The changes may be improvements, but if designers continue to improve, nothing ever gets built.

Excessive or mismanaged standardization can be bad and can become very expensive and yield obsolete systems with excessive size, weight, etc.

There is always some natural standardization in any project. The questions are how much and whether it should be enforced. If enforced, how much enforcement and by what means. Allow flexibility in the application of specifications and standards to increase cost-effectiveness. Encourage standardization as a means of lifecycle cost reduction, but remember that excessive standardization can lead to excessive complexity and excessive cost.

In order to develop standards, many variables that are extreme for one purpose must be made extreme for all uses (which drives up the cost of the system), or else must be made less extreme to reach a compromise between the various requirements (which may make the system unsuitable for any purpose). There is a third alternative: to develop a standard with specified options or defined classes of use to meet the independent needs of different users.

Another use of standards is to put on paper constantly changing interface requirements. This ensures that two or more groups designing portions of a system will have a common meeting ground. Only interface standards (form, fit, and function) are required for this.

DEFENSE STANDARDIZATION PROGRAM (DSP)

The Navy's role in the Defense Standardization Program is outlined in SECNAVINST 4120.3E. An enclosure to the instruction in DoD Directive 4120.3, which defines standardization as the adoption and use (by consensus or decision) of engineering criteria to achieve the following objectives:

1. To improve the operational readiness of the military services by increasing efficiency of design, development, material acquisition, and logistics support.
2. To conserve money, manpower, time, facilities, and natural resources.
3. To minimize the variety of items, processes, and practices which are associated with design, development, production, and logistics support of equipments and supplies.
4. To enhance interchangeability, reliability, and maintainability of military equipments and supplies.

DSP PLANS FOR ACHIEVEMENT

The Defense Standardization Program seeks to achieve these objectives through:

1. Management and engineering actions required to establish and effectively implement standardization agreements and decisions.
2. Establishing and maintaining uniform and technically adequate records of the engineering definition of equipments and supplies.
3. Promoting, in support of procurement, maintenance, supply, and future design, the reuse of records of engineering definitions, the engineering criteria therein, and previously developed or acquire material represented by these records.
4. Prescribing, for specifications, standards, drawings, and other standardization association documentation, (a) format, (b) procedure for effective coordination, (c) quality of documentation, and (d) procedures for collating and disseminating this information.

POLICIES OF THE DSP

1. <u>Military Operational Requirements</u>. Wherever feasible, military operational requirements for material shall be satisfied through the use of existing military designs or commercial products. If military need can be

satisfied only through new development, the new development authorized shall encompass, to the greatest extent practicable, all equivalent needs of the Military Departments and Defense Agencies.

2. Exploratory Development and Advanced Development. The categories of Exploratory Development and Advanced Development represent scientific, experimental, and early development efforts aimed at innovation and evaluation of feasibility. The use of existing standard items and engineer-ing practices is advocated in the interests of economy, where these satisfy the needs of such program efforts. However, use of standards shall be secondary to the prime objective of these development categories; e.g., proof of a concept.

3. Engineering Development and Operational System Development. In the categories of Engineering Development and Operational System Development where the systems and equipment are engineered for eventual Service use, a maximum degree of standardization shall be achieved without causing unacceptable compromise of performance, reliability, timely availability, or cost of systems and without preventing the applications of the most advanced proved techniques or hardware.

4. Procurement. Techniques that provide opportunities to achieve standardization objectives during procurement include (a) the specification of complete design requirements, (b) multiyear procurement, and (c) negotiation authorized by Paragraph 3-213 of Armed Services Procurement Regulation to achieve standardization of technical equipment.

5. Supply. The variety of types, kinds, and sizes of items of supply shall be reduced to the minimum consistent with effective support of military operations.

6. Standardization Planning. Standardization efforts will be planned and managed with a view to establishing (a) timely design standards that reflect current technology, and (b) standards, specifications, and other documentation that offer the greatest advantages for cost reduction, for item reduction, for competitive procurement, for simplification of maintenance and logistics support, for increased reliability, or for increased design efficiency.

7. Management of Engineering Information.

   a. Organization of Engineering Information. Engineering information, obtained from design and development and of the type reasonably expected to be necessary for future reuse, shall be organized in standard format to promote repetitive use in support of procurement, production, maintenance, supply, and new design.

   b. Specifications. When required for design support, configuration identification, or procurement, an adequate engineering definition shall be established for material and practices resulting from new development (engineering and operational systems development), and for items authorized for production or supply support. The preferred format is the Federal or Military specification.

c. Industry Documents. Specifications and standards of nationally recognized industry organizations and technical societies shall be used in the development and design of material, and in the preparation of Military or Federal specifications or standards to the maximum extent practicable. Duplication in the Military series of industry standards is to be avoided.

8. Industry Coordination. The procedures for Department of Defense Standardization will provide for industry participation to an appropriate degree and will avoid duplication of effort. Consideration will be given to the contractual responsibilities of contractors in the design-development-production cycle to prepare required documentation and also to the needs of contractors in the use of documentation produced under this program.

RESPONSIBILITIES ASSIGNED BY THE DSP

The Defense Standardization Program assigns responsibilities as follows.

1. Engineering Determinations. Design, development, and engineering activities are responsible for the engineering determinations recorded in specifications, standards, drawings, and criteria for interchangeability and substitutability (when the criteria are not contained in military design standards).

2. Record Preparation. Design development, and engineering activities are responsible for the timely preparation records of new development in authorized format for the support of configuration management, production, procurement, and follow-on logistics support. These activities also are responsible for recording and approving any justified use of nonstandard parts, components, and materials.

3. Use in New Design. The design and development activities have responsibility for the use in new design of (a) applicable standards, (b) suitable items available in supply, and (c) suitable commercial items, before any new development is authorized to meet equipment or systems objectives.

4. Users. Users of engineering information are responsible for the formulation of programs (e.g., item reduction, item entry control, configuration management, and design selection discipline) to achieve maximum benefit from use of standards and other standardization documents.

5. Logistics Support. Inventory Managers are responsible for programs (a) to screen items seeking entry into supply through provisioning, (b) to prevent identical items from entering with differing identifications, and (c) to substitute, for the new item, an interchangeable or substitutable item already in the supply system, or an available item covered by a military standard or specification. Supply management is responsible for limiting the number of different makes and models of equivalent equipment in any geographical area.

STANDARDIZATION OF COMPONENTS/ EQUIPMENTS (C/E)

One of the Navy's standardization efforts is outlined in NAVMATINST 4120.97B. In this instruction, Components/Equipments (C/E) is defined as repairable items which require repair part support.

The Navy Component/Equipment Program was established to curb the proliferation of components/equipments being introduced into the Fleet. Several logistics studies had reported the existence of many nonstandard and low-population equipments requiring differing repair parts which were difficult to support. Also, such nonstandardization has contributed directly to proliferation of allowance parts lists, technical manuals, configuration management, training, and other logistic requirements.

POLICIES OF THE C/E PROGRAM

The policy of the C/E Program applies to all elements of the Navy in all phases of system development, acquisition, and maintenance. It includes all systems, subsystems, components, and equipments. Stated in the broadest terms, the policy is to:

1. Include hardware standardization requirements in concept formulation, contract definition, procurement, production, maintenance, conversion, modernization, and alteration.
2. Standardize designs — with intersystem and intrasystem standardization of C/E and parts.
3. Reuse (in new design) existing, suitable C/E already supported in depth by the military system.
4. Preclude use of limited-application and poor-performance C/E.
5. Exercise configuration control to maintain standardization.
6. Use procurement techniques to restrain proliferation.
7. Effect item entry control in design selection and provisioning phases of material acquisition.

C/E PLAN OF OPERATION

1. The plan for increasing C/E standardization is to:
   a. Promulgate and implement the policy set forth above.
   b. Give visibility to ongoing standardization effort by indexing it.

   c. Promote the use of standardized and/or existing C/E.

   d. Backfit standardization into existing systems.

2. The attainment of an optimum degree of standardization by curbing C/E make and model multiplication and resultant spare parts proliferation must be within the bounds of the Armed Services Procurement Regulation (ASPR) and any governing requirements of the Defense Standardization Program. Standardization cannot be mandated arbitrarily but must result from thoroughly considered tradeoffs, generally on the basis of cost versus effectiveness.

   Each Project Manager shall maintain his own internal plan for standardization of C/E under his technical cognizance (NOTE: Project Managers will not be required to develop separate standardization plans if their PMPs (Project Master Plans) specifically address requirements for standardization of C/E.) Each plan shall stipulate the development of indices to reflect the current situation of standardization in major commodity areas (e.g., Hull/Mechanical/ Electrical, Electronics Communications Equipment, Electrical/Electronics Test Equipment, Aviation Ground Support Equipment, Avionics, Aviation Ordnance, Conventional Ordnance, Guided Missiles) against which to plan and measure future accomplishment. The plan will provide for:

   a. Implementing the standardization policy in:

      (1) Concept formulation, contract definition, and other phases of material acquisition planning, including Project Master Plans (PMPs), Research and Development Planning, and Advanced Procurement Plans (APPs).

      (2) Procurement of C/E with use of standardization requirements clauses, where warranted; life-cycle costing; and central procurement of GFE/CFE to effect consolidated buys of standardized (identical in make and model) C/E. The Standardization Exception (FAR 6.302-1), covering technical equipment requiring standardization and interchangeability of parts, will be utilized wherever the stipulations contained therein can be met (for the purposes of application of the exception a "standard item" is any item already in use in the Navy (e.g., an item identified by a Federal Stock Number (FSN) and/or an Allowance Parts List/Component Identification (APL/CID) number; excluded are items designated nonstandard in the Federal cataloging records). It will be specified that all systems/subsystems/components/equipments/instrumentation requiring repair part support are to be of identical make and model (having identical internal parts) within the block of hardware being bought under any individual contract.

   b. Developing, whenever practicable standardized design for C/E.

   c. Selecting C/E for new systems from those equipments which are presently supported (operationally and logistically) in depth.

d. Utilizing subsystems of one system in other systems requiring similar design and performance.

e. Assuring that a minimum variety of C/E is used in system design by incorporating standard C/E with better performance, or other values, wherever significant logistics benefits will accrue and can be measured on a life-cycle cost savings basis.

STANDARD ELECTRONIC MODULE (SEM) PROGRAM

MIL-STD-2036, via MIL-STD-454 REQUIREMENT 73, requires the consideration of the SEM packaging techniques conforming to MIL-STD-1378.

NAVMATINST 4120.102D states that the requirements of the Standard Electronic Module Program apply to the initial development or redesign of ship and shore electronic equipment and systems. The program is optional for other types of equipment such as avionic equipment, satellites, and portable equipment.

All PMs will participate in the SEM to the extent that SEM modules will be used in new systems where technically and economically feasible. The features of the SEM that concern maintaining and controlling the use of the standards will also be observed. The instruction requires that PMs analyze and assess the feasibility of using SEM modules; and that, where the analysis indicates the SEM modules to be technically and economically suitable, use of the modules shall be specified in the development of the system. Once this decision has been made, the SEM procedural rules established by SPAWAR to maintain integrity of the standards shall be observed. The requirements do not, however, relieve responsibility, nor abrogate the authority, of PMs as the technical and management agents over their programs in accordance with established directives. As previously stated, the project manager has the option of using, not using, or discontinuing use of SEM modules on the basis of legitimate and demonstrable technical or economic factors. Increased participation in the SEM is desired, and will be of mutual benefit to all concerned, but established authority of PMs will continue to be recognized.

PMs who require testing services for modules under a specific project at the SEM Quality Assurance Activity (NAD, Crane) will be responsible for the cost of the testing and related overhead.

PMs will deal directly with the Quality Assurance Activity through normal channels. Services performed by the Design Review Activity (NAC, Indianapolis) that are related to the overall SEM standardization program, will be funded by SPAWAR and made available to other SYSCOMs and PMs. SPAWAR will provide assistance to other SYSCOMs and PMs in applying SEM.

The SEM program generally achieves Standardization Advantages 1, 4-6, 10-14, 16-18, 20, 21, 23, and 28 while suffering Standardization Disadvantages 3 and 11.

RESPONSIBILITIES UNDER SEM

All PMs will:

1. Review all planned projects within the scope outlined above for technical and economic applicability of the SEM.

2. Where review indicates feasibility for application of the SEM, require its use in contract specifications by citation of MIL-STD-1378.

3. For those programs whose combined total estimated cost for R&D and initial production exceeds $10 million, provide notification to SPAWAR, in format of RCS NAVMAT 4120-10, at the use of SEM has been considered; if not used, give the details thereof.

4. Provide for the production sampling tests at the SEM Quality Assurance Activity on existing standard modules at will be used in the project.

5. Provide for qualification tests at the SEM Quality Assurance Activity on new standard modules that will be needed in this project.

6. Provide for contractor development and delivery of SEM documentation for new standard modules resulting from the project.

7. Recommend to SPAWAR any techniques found effective in specific projects which could or should be applied Navy-wide.

8. Provide points-of-contact, technical panel representation, and supporting information, upon request, to assist SPAWAR in SEM management.

STANDARDIZATION REFERENCES

1. Naval Electronic Systems Command
MIL-M-2878C, *Modules Electronic Standard Hardware Program, General Specification for* 16 MAY 80

2. Naval Electronic Systems Command
MIL-STD-l378D, *Requirements for Employing Standard Electronic Modules,* 16 May 86

3. Naval Electronic Systems Command MIL-STD-l389C, *Design Requirements for Standard Electronic Modules,* 16 May 86

4. Department of Defense DoD Directive 4120.3M

5. Secretary of the Navy SECNAVINST 4120.3B,
"Defense Standardization Program," 25 Jan 68

6. Naval Material Command NAVMATINST 4120.97B, “Standardization of Components/Equipments (C/E) Required for Fleet or Ashore Support,” 7 May 84

7. Naval Material Command NAVMATINST 4120.102D, “Standard Electronic Modules (SEM) Program,” 20 Oct 82

XV. WARRANTY APPLICATIONS

GENERAL

The use of warranties in contracts is intended to assure the buyer of — and make the seller liable for — a specified performance of the system/equipment being procured. For government-purchased electronic equipment such assurance has become a matter of great concern because supporting the unreliable performance of many of these items has become increasingly more costly. There is an urgent need to reduce support costs to levels that are consistent with today's stringent funding limitations, and DoD is taking a new look at acquisition strategy as one way to solve this cost problem. The new look is being directed in part at the use of types of warranties that are more extensive than the standard warranties for which FAR has clauses and that attack the support-cost problem directly.

A significant portion of the increasing cost of maintenance and support is due to poor reliability. It is axiomatic that the greater the time between failures (or the fewer failures), the less the support cost will be both for per-unit cost of repair and for cost of spares. Thus, effective effort to improve reliability of an equipment will yield reduced support costs, not to mention the significant benefit of improved availability.

The "new" warranty concept the government is considering is aimed at this reliability and maintainability improvement. It adopts a warranty practice the airline industry has been successfully using for some time to improve reliability and lessen maintenance.

Conventional government procurements have the contractor's liability ending with delivery and government acceptance, with reliability and maintainability (R&M) accomplished by specifying numerical requirements and applicable military-standard programs during design, development, and production. The efforts have been partly successful, but have not produced the desired and needed results. Too often the government has been unable to exactly define reliability requirements and measure reliability attainments. This has made it difficult to levy stiff penalties on contractors for failure to achieve required full reliability, and has resulted in deviations and waivers often being allowed by the government and in very little use of available reliability-incentive clauses in procurement contracts.

Working to aggravate this problem is the contractor's inclination to maximize his profits. As he tries to improve profits, reliability suffers because high reliability costs him more to produce. Regardless of the intent of reliability specification, demonstration, and test requirements, the contractor has the final say about the reliability level of the item being produced simply because he is the one actually doing the job. And if he is motivated more by profit than by product excellence, the delivered product more often than not will be barely acceptable — and then on the basis of deviations and waivers.

Enter the "Reliability Improvement Warranty" (RIW). The RIW is one of the several types of warranties intended for improving R&M which are discussed in this section, and one to which DoD is giving particular attention at the time of this writing. The RIW works to take advantage of contractor profit motivation rather than working at cross purposes like the conventional procurement contract. If the contractor is made responsible for long-term reliability after delivery and during operation, and for a fixed fee that allows him to increase profits in proportion to the level of reliability and the ease of maintenance that are achieved, the contractor is inclined to burn the midnight oil on his R&M programs. The RIW becomes a contracting technique by which the government derives the benefits of improved reliability and maintainability for each individual dollar the contractor earns. Other warranties of this nature approach the R&M problem a little differently, as will be noted.

Before discussing the individual warranties designed to lessen the cost of R&M, a few words are in order about the general requirements of FAR for all warranties — including the R&M ones.

Two basic types of warranties exist based on the Uniform Commercial Code (UCC) to provide buyer protection. No federal law conflicts with the UCC, and the government has adopted it for government contracting. The first type of warranty is an implied one. In government procurements the existence of an implied warranty depends on the type of contract; it does not apply to cost reimbursement contracts. The second type of warranty is an expressed one, a clause being included in the contract to define the conditions and provisions of the warranty. Reliability improvement and other maintenance and repair-oriented warranties are expressed warranties.

Defense Procurement Circular 74-2, issued 4 October 1974, revised the Warranty Section of ASPR and added new clauses for conventional-type warranties; these were carried into the FAR. The new clauses do not differ significantly from the former except for a major change which states, "All implied warranties of merchantability and fitness for a particular purpose are hereby excluded from any obligation contained in this contract."

Two purposes are given for warranties: to delineate rights and obligations regarding defective items, and to foster quality performance. FAR policy is that a warranty clause shall be used when it is found to be in the best interest of the government.

New provisions involve the pricing aspects for fixed-price incentive warranty provisions and differ from the previous FAR. The new section says the estimated costs of warranty coverage should not normally be considered in the incentive target price, and all costs should be considered in establishing a ceiling price. All warranty costs incurred are to be considered then in the total final price. And after establishment of the total final price, the contractor is to bear all warranty costs.

RELIABILITY IMPROVEMENT WARRANTY (RIW)

DoD has requested the Armed Services to initiate RIWs on a trial basis, to help determine the scope and benefits that these warranties may have. In a memorandum signed by both the Assistant Secretary of Defense (I&L) and the Director of

Defense Research and Engineering, guidelines for a test program have been provided for trial-basis use. These guidelines are similar to those published by the Air Force in July 1974 in *Interim Guidelines Reliability Improvement Warranty (RIW).*

An equipment acquisition contract having an RIW provision specifies equipment characteristics for form, fit, and function only, and allows the contractor freedom of design as well as freedom to change design without intervention of all the usual government configuration-management constraints, but within government requirements for preserving configuration control. The RIW provision stipulates that the contractor will, for a certain length of time or number of operating hours, repair and/or replace the units in service upon occasion of certain defined failures.

A firm fixed-price contract is used, one price including both acquisition and follow-on servicing. Once a fixed price is established for the contract, the actual profit realized by the contractor depends on the equipment's reliability and maintainability in service use, plus any improvements that he can make in R&M during the warranty period to keep the number and cost of repairs as low as possible. In this connection, the terms and commitments required of the contractor by the RIW provision must result in a reasonable balance between his risks and the degree of incentive (profits) needed to achieve the primary goal of system/equipment availability. Such consideration must include the uncertainties of future support costs and the resultant risks to both contractor and government.

The RIW is not the same as a maintenance contract and does not require the contractor to provide routine periodic upkeep, regulation, adjustment, cleaning, or other normal upkeep. Government personnel accomplish these jobs. The RIW also does not cover components of the warranted item which usually need replacement under normal use; such items may be covered by separate provisions in the contract, but cannot be included in the RIW provision.

ADVANTAGES

When a new-procurement item meets criteria for RIW application (to be discussed), the use of the RIW offers the following advantages to the government:

1. Contractor has responsibility and incentive for improving field reliability.
2. Financial commitment for logistic support is known and constant during a 3-5 year period of possible economic inflation.
3. Life-cycle cost approach can receive greater emphasis.
4. Contractor has responsibility for configuration management of field units and for keeping all units to same configuration.
5. Contractor has an incentive to introduce design and production changes that will increase MTBF and result in reliability growth.
6. Contractor has an incentive to introduce design and production changes that will reduce labor hours and materials needed for field repairs.
7. Minimal initial support investment is required.

8. Requirements for skilled military maintenance and support manpower are reduced.

Use of the RIW offers the following advantages to the contractor:

1. Increased profit potential when field MTBF is increased above contractual MTBF.

2. Guaranteed multiyear business.

3. More familiarity with operational reliability and maintainability characteristics, which is advantageous in obtaining additional government contracts.

Benefits obtained from the RIW concept can be maximized only if prospective contractors are notified early in the development period that the government intends to consider including such warranty provision in the production contract. Otherwise, the contractor will not have the incentive intended by the RIW to give necessary attention to R&M at the time of initial design, the outcome of which has significant effect on eventual MTBF and repair costs.

USING THE RIW

The use of RIWs is limited to certain acquisitions of equipment that satisfy (1) stipulations by ASPR for warranty use in general, (2) specific criteria for RIW use, (3) certain funding requirements, and (4) conditions relating to elements that must be contained in the RIW clause of a contract. These sets of conditions are presented in the following paragraphs.

FAR/DFAR Requirements for General Warranty Use

FAR 52.246 lists the following factors that must be considered in deciding whether a warranty clause of any kind is to be used in a contract.

1. Nature of the item and its end use

2. Cost of the warranty and degree of price competition as it may affect this cost

3. Criticality of meeting specifications

4. Damages to the government that might be expected to arise in the event of defective performance

5. Cost of correction or replacement, either by the contractor or another source, in the absence of a warranty

6. Administration cost and difficulty of enforcing the warranty

7. Ability to take advantage of the warranty, as conditioned by storage, time, distance of the using agency from the source, or other factors

8. Operation of the warranty as a deterrent against deficiencies

9. The extent to which government acceptance is to be based upon contractor inspection or quality control

10. Whether because of the nature of the item the government inspection system would not be likely to provide adequate protection without a warranty

11. Whether the contractor's present quality program is reliable enough to provide adequate protection without a warranty

12. Reliance on "brand name" integrity

13. Whether a warranty is regularly given for a commercial component of a more complex end item

14. Criticality of item for protection of personnel or property; e.g., for safety in flight

15. The stage of development of the item and the state of the art

16. Customary trade practices

FAR 52.246-16, 17, 18, and 19 cover the warranty clauses most generally of interest in system acquisitions.

Specific Criteria for RIW Use

Currently there are three sources for criteria which establish the practicability or advisability of using the RIW. They are the joint memorandum of ASD(I&L)/DDR&E; the Air Force interim guidelines document for RIWs; and a tabulation of criteria developed by ARINC Research Corporation for the Rome Air Development Center. All three cover essentially the same points. The ARINC tabulation, however, is more precise and definitive and is presented here as table XV-1.

Three broad areas of consideration are to be found in the tabulated criteria: procurement factors, equipment characteristics, and application factors. Each is equally important in accepting or rejecting RIW use. The individual factors within each area, however, do vary in importance, and have been ranked as follows:

"1" factors are of major importance. Failure to meet the stated criterion could be grounds for not using the RIW.

"2" factors are of secondary importance. Failure to meet the criterion of one of these factors will generally not be sufficient in itself for rejecting the RIW, but a combination of "2" factors could be.

"3" factors are of minor importance. Failure to meet these criteria is generally not considered serious, but may require special consideration in structuring the warranty or the administrative procedures.

Table XV-1. Criteria for use of RIWs in hardware acquisition contracts.

Criterion	Rationale	Importance*
Procurement Factors		
P.1 — The procurement is to be on a fixed-price basis.	The provisions of FAR provide that contractor warranty expenses are admissible under a cost-type contract.	1
P.2 — Multiyear funding for warranty services are available.	To realize the full potential of warranty, the warranty period must be of sufficient duration to provide the contractor strong incentive to achieve and maintain high reliability. Sufficient funds to cover such multiyear services must be budgeted.	1
P.3 — The procurement is competitive.	In a sense, a warranty maintenance concept is always competing with organic maintenance. However, competition among contractors will tend to provide more realistic warranty pricing which, for large procurements, can involve large sums of money.	2
P.4 — Potential contractors have a co-operative attitude toward acceptance of a warranty.	Successful warranty application heavily depends on contractor motivation and performance. Reluctance to accept a warranty provision may be due to lack of understanding of warranty terms and conditions.	2
P.5 — Potential contractors have proved capability and experience in providing warranty-type services.	Experience and capability in maintaining military equipment will provide contractors a good basis for pricing warranty realistically and for successfully performing warranty tasks.	2
P.6 — The procurement quantity is large enough to make warranty economically attractive.	A significant portion of warranty costs may be essentially fixed; e.g., facilities and test equipment. Unless the procurement size is large, such costs may tend to drive the warranty price per delivered unit to an unacceptably high level.	2
P.7 — Analysis of warranty price versus organic repair costs is possible.	If warranty is an option, the final decision will be made when contractor warranty price bids are received. Evaluation of such bids is best made when compared to equivalent costs under organic maintenance.	3

*1 = Major; 2 = Secondary; 3 = Minor

Table XV-1. Criteria for use of RIWs in hardware acquisition contracts (continued).

Criterion	Rationale	Importance*
P.8 — An escalation clause is included in the contract which is applicable to warranty costs.	Unless such a clause is included, contractors may tend to price-in an abnormally high price-risk factor to account for price-level uncertainties.	3
P.9 — The contract can be structured to provide for incremental payments for warranty services.	From a financial as well as control viewpoint, such a payment procedure appears to be a logical approach.	3
Equipment Factors		
E.1 — Equipment maturity is at an appropriate level.	Warranty should not be used for items which are considered to be developmental. Conversely, for very mature items, warranty may not offer proper incentive. Warranty is intended for proved designs (nonexperimental) which are entering full-scale production. Through warranty, feedback is provided to the contractor to achieve stated reliability levels through an improvement or growth process. A very mature design, which has undergone such growth, may not be a candidate for cost-effective warranty application.	1
E.2 — Control of unauthorized maintenance can be exercised.	Unauthorized maintenance of a warranted item is a normal exclusion to a reliability improvement warranty. Items whose construction precludes the installation of seals or other control mechanism are considered to be poor candidates for warranty unless careful maintenance technician discipline can be exercised.	1
E.3 — Unit is field testable.	Since compliance with most warranties will require the failed unit to be returned to the vendor, it is important that the unit be field testable to determine whether it is in a go or no-go state. Lack of field testability can greatly increase cost of support due to added pipeline spares required plus the added expense of testing the good item by the contractor.	1

*1 = Major; 2 = Secondary; 3 = Minor

Table XV-1. Criteria for use of RIWs in hardware acquisition contracts (continued).

Criterion	Rationale	Importance*
E.4 — Unit can be properly marked or labeled to signify existance or warranty coverage.	The most effective manner in which to communicate the existence of warranty coverage is by suitable marking of the item itself. Items which due to their physical size or the nature of their external surface preclude such marking are thus not considered good candidates for warranty coverage.	1
E.5 — Unit should be susceptible to Class I and II changes for R&M improvement	A primary objective of warranty is reliability and maintainability growth. The contractor should be permitted to implement no-cost ECPs subject to timely government review.	2
E.6 — Unit is reasonably self-contained.	If the performance of an item is highly dependent upon the performance of auxiliary equipment, it may be difficult to determine which equipment is at fault during a system failure and frequent disputes may arise. Ideally, warranties should be supplied by the system integrator or at least flowed down in a consistent manner to the item suppliers.	2
E.7 — Unit can be readily transported to the contractor's facilities.	The contractor's most cost-effective method of providing warranty service is to make use of his centralized facilities. It may, however, in the case of large ground installations, be cost-effective for the contractor to establish on-site warranty service.	2
E.8 — Unit should have level of ruggedization.	Delicate units highly subject to failure from handling and shipping may lead to unacceptably high rate of occurrence of warranty exclusions for mistreatment or abuse. In such cases, special shipping containers may be required.	2

*1 = Major; 2 = Secondary; 3 = Minor

Table XV-1. Criteria for use of RIWs in hardware acquisition contracts (continued).

Criterion	Rationale	Importance*
E.9 — Unit maintenance is highly complex.	If the unit's maintenance requirements involve highly trained personnel and/or test equipment which the government cannot be certain of acquiring initially, warranty may be a better contracting form than a time and materials maintenance contract.	3
E.10 — An elapsed time indicator can be installed on the equipment.	ETIs permit accurate measurement of operating time thereby permitting more complete assessment of usage, failure rates, and trends.	3
Application Factors		
A.1 — Use environment and operating exposure are known or predictable.	In order for the contractor to effectively evaluate and price his warranty liability, information on the expected use environment and equipment operating time must be available to him. Such information is also required by the contracting agency in order to independently evaluate the warranty price. However, there is a method by which warranty price can be adjusted for variance in operating time from a "pricing standard."	1
A.2 — Equipment operational reliability and maintainability are predictable.	Estimating reliability is important for determining the expected number of failures and estimating maintainability is important for determining expected repair costs. Too much uncertainty in such estimation proceedings may expose the contractor to undue risks.	1
A.3 — Equipment wartime criticality is not of the highest level.	Any reduced self-sufficiency arising from warranty maintenance must be tolerable in a wartime situation. Even though the government has the authority to request expanded services, timely planning for implementing wartime provisions and/or organic maintenance takeover must be made.	1

*1 = Major; 2 = Secondary; 3 = Minor

Table XV-1. Criteria for use of RIWs in hardware acquisition contracts (continued).

Criterion	Rationale	Importance*
A.4 — Equipment has high operational utilization rate.	High utilization will permit early surfacing of deficiencies, economic diffusion of fixed warranty costs, and more precise estimates of R&M parameters. Equipments which remain dormant for long periods and have limited shelf life may not receive sufficient exposure to make warranty worthwhile.	2
A.5 — Warranty administration can be efficiently accomplished.	The success of a warranty program requires that careful attention be given to the plan for warranty administration. The administration plan must include identification of material flow paths, and cognizant agency responsibilies and procedures, along with generation of requisite data to implement warranty terms and conditions. Since DCAS will ordinarily have heavy responsibilities for in-plant contractor performance, such involvement must be considered.	2
A.6 — Warranty may not be appropriate when the replication of an existing or desired government repair facility would not be cost-effective.	If the provision of a contractor warranty repair operation entails the establishment of costly maintenance facilities which are duplicative of current military facilities, the use of warranty would nto be cost-effective. Additionally, in the case where such facilities do not exist, the government may determine that it is in their best interest to acquire this capability rather than have the contractor provide it under a warranty arrangement.	2
A.7 — Unit reliability and usage levels are amendable to warranty maintenance.	Units which are highly reliable may not fail often enough to justify a warranty procurement, especially if the government already has repair capability. Similarly, if the unit reliability/operational usage level leads to a large number of failures, warranty support may be uneconomical due to the large number of spares required to maintain the pipeline to the contractor's plant as compared to the cost of an on-site field repair.	2

*1 = Major; 2 = Secondary; 3 = Minor

Table XV-1. Criteria for use of RIWs in hardware acquisition contracts (continued).

Criterion	Rationale	Importance*
A.8 — Detailed operational failure and usage information can be supplied to the contractor.	To achieve reliability growth as expeditiously as possible, pertinent failure and usage information should be supplied to the contractor to the extent possible.	3
A.9 — Backup warranty repair facilities are available.	In order to minimize the disrupting effects of strikes or natural disasters, it is advantageous to have a contractor who can maintain a backup facility remotely located from the main facility.	3

*1 = Major; 2 = Secondary; 3 = Minor

It should be emphasized that the criteria in table XV-1 are to be used qualitatively with an awareness of the extra effort and cost required of both the government in requesting and the contractor in proposing the RIW provision. That is, there should be, before requesting contractors' proposals, a reasonable certainty, based on cost analysis as well as the criteria factors, that the RIW will be employed, even though a thorough economic analysis of the use cannot be made until RIW price and implementation proposals are received from the bidding contractors. To decide on the basis of cost whether or not the RIW may be a good course of action, there must be a MTBF figure on which to base a probable price for contractor development/production and support (acquisition with RIW), and then this price must be compared with the price of a development/production-only contract plus the probable cost of support by the government without the RIW. This may be undertaken, as indicated in figure XV-1, by plotting costs versus a range of MTBF levels for development/production (curve A) and operation/maintenance (curve B), which curves when added provide rough figures for a life-cycle cost (curve C). The vertical width of the curves in figure XV-1 represents the uncertainty of the costs associated with achieving and supporting the various levels of reliability. The use of life-cycle cost (LCC) models can assist in this evaluation process when sufficient data are available.

When judgment has been made for the use of the RIW provision in the RFP/ contract, the RFP is worded to indicate that the RIW provision may or may not be included in the contract, depending on responding proposals and what they have to say about proposed MTBF and cost.

Upon receipt of bidders' proposals, further cost analysis is made to determine whether the use of the RIW would be cost-effective. The life-cycle cost curve developed prior to RFP release — such as the one shown in figure XV-1C — can be compared with the total fixed-price bids in the proposals and their respective proposed MTBFs. If a cost proposal is below the lower bound of the cost curve, the price is right and use of the RIW is definitely indicated. If the proposal is above the upper bound, the RIW should not be considered. In between, further evaluation must be made. The fair-price question here is helped considerably, as is achievable reliability, by the fact of competition among bidders for a fixed-price contract. Overestimation of expected reliability by a bidder will tend to increase his total price and reduce his chance of being accepted, whereas underestimation for the purpose of improving profit may lose him the contract as well.

A bidder may be inclined to lump the costs associated with the RIW into his unit price. But, in order to make an accept/reject decision on the use of the RIW, the actual price proposed for the RIW must be known. Bidders therefore must be required to separately price the RIW provision so that a clear comparison may be made with the government's cost estimate. The accept/reject decision is based in no small part on the difference between the RIW support costs and the support costs the government would incur if the equipment were purchased without an RIW. The warranty should normally cost 4-6% of the operational unit acquisition cost per year.

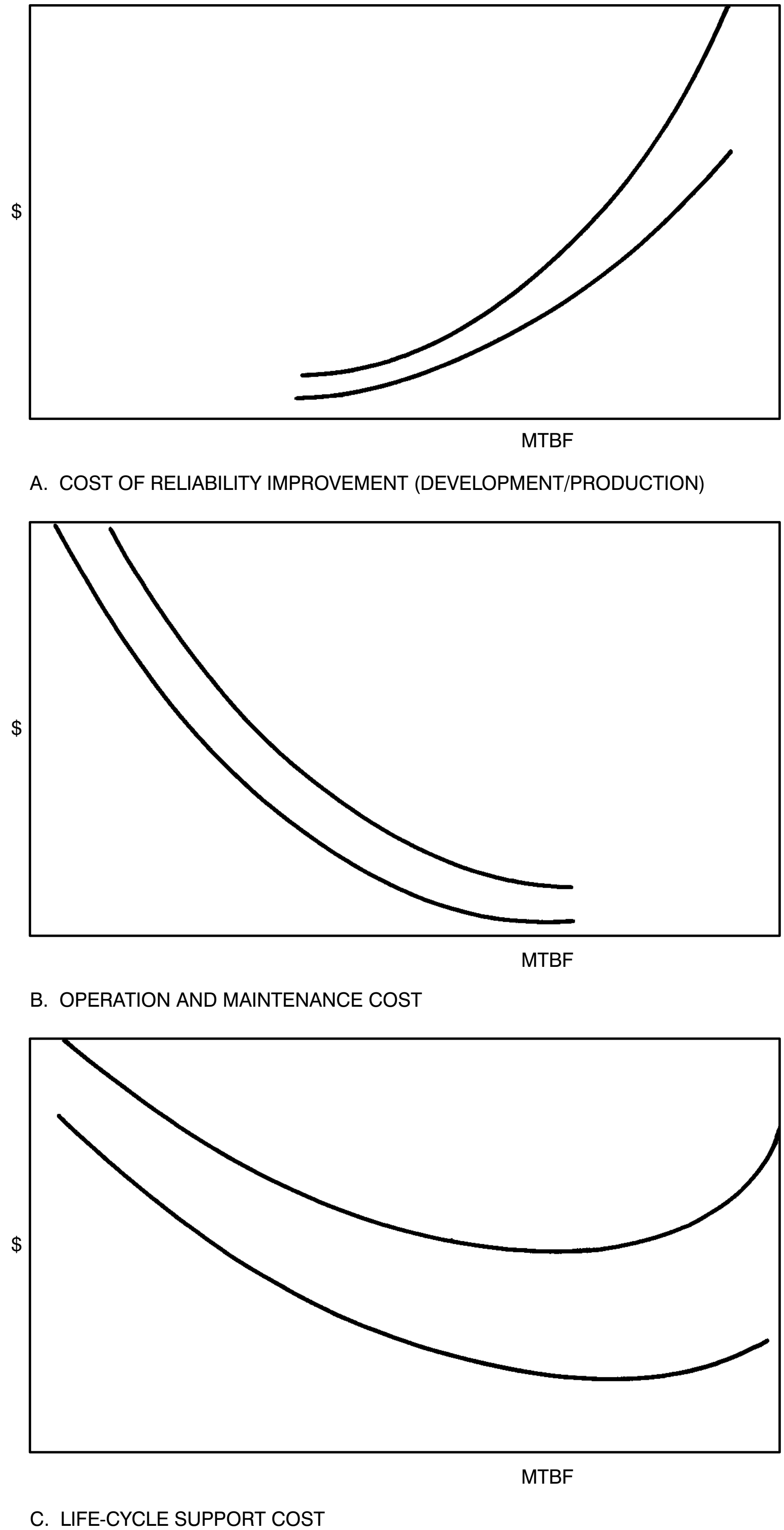


Figure XV-1. Development of life-cycle support cost.

Funding Requirements

To clarify the types of funds to be used for procurements having the RIW provision, the following funding policy guidelines have been authorized for use by OASD(C) and OAGC(FM):

1. RIWs shall be funded from the same appropriation as the acquisition. That is, the RIW shall be paid from the procurement or RDT&E appropriation of the service or agency concerned, depending on from which of the appropriations the acquisition is funded.

2. The RIW price shall be part of the fixed-price contract, and payment to the warrantor for RIW portion shall not be made differently from payment under the remaining portion of the contract except that payment for the RIW may be delayed until delivery or relinquishment of production control of the item by the warrantor.

In addition, to maintain the distinction between an RIW and a service contract covering normal, periodic maintenance, the following requirements must be satisfied:

3. The warranty period on the item(s) shall begin after manufacture and upon delivery or relinquishment of production control by the warrantor.

4. The RIW shall require the warrantor to repair or replace the warranted item upon failure.

5. The RIW shall not include requirements for the warrantor to provide normal upkeep, cleaning, adjusting, regulating, or other periodic maintenance accomplished whether or not failure occurs.

6. The RIW shall exclude components of the warranted item(s) which normally require replacement during the period of the warranty (such as filters and light bulbs). These components may be accounted for by separate provisions in the contract consistent with current laws and regulations.

Essential Elements in the RIW Clause

Because RIW provisions must be tailored to the particular item being warranted, a standard RIW clause is not contained in the FAR. However, certain elements should be considered for inclusion in an RIW clause. These elements, which are discussed below, concern (1) the statement of contractor warranty, (2) contractor obligations, (3) government obligations, (4) miscellaneous requirements, and (5) data requirements. RIW provisions are constructed by implementing tailored provisions under "Warranty of Supplies of a Complex Nature" (FAR 52.246-18).

Statement of Contractor Warranty

1. <u>Term</u>. State the length of time the warranty will be in effect. Usually this should cover usage (operating hours) and calendar time (generally 3 to 5 years), whichever occurs first.

2. Objective/scope. State the primary objective of the warranty; that is, to motivate the contractor to design and produce equipment that is more reliable and less costly to repair. If there is a specified reliability requirement, it should be clearly set forth.

3. Failure. Define the failure(s) which ill require the contractor to repair or replace a failed item at no change in the contract price, when the item is returned to him.

4. Exclusions. State the conditions and actions associated with repair/ replacement which are specifically excluded under the warranty — such as items lost or damaged due to fire, explosion, packing, and shipping.

5. Shipping costs. State who pays the costs of shipping the failed units to the contractor, the government or the contractor.

6. Price. State that a price breakout of the warranty should be included (along with the total price) to allow the government to determine the cost of the RIW.

Contractor Obligations

1. Warranty markings. State that the contractor shall be required to prominently display the following information on the face of the unit: that the item is warranted; the warranty period; and actions to take if the unit fails during the warranty period.

2. Turnaround time. State the turnaround time, and the appropriate adjustments or other considerations to be exacted if the contractor exceeds the number of days so specified. A contract turnaround time should be defined as the period between the date the unit is received by the contractor for repair/replacement and the date when the repaired/replacing unit is shipped by the contractor to the government.

3. Records. State that the contractor shall maintain records, by serial number, for each unit under warranty, and shall make such records available to the government upon request.

Government Obligations

1. Containers. State whether or not the government will supply special containers for transporting units to and from their destinations for the life of the warranty.

2. No-cost modifications. State the procedures for submittal of contractor initiated no-cost Engineering Change Proposals (ECPs) (designed to improve the item's reliability/maintainability). The contractor should be advised that such ECPs will be subject to government approval.

Miscellaneous

1. Inspection. State the extent of both government and contractor inspection to be required.

2. Disposition. State that each unit returned to the contractor which is considered to be nonrepairable shall be imposed of by the contractor as directed by the government. Also, state the banner of disposition of the unused portion of the warranty for such nonrepairable unit as well as for other similar instances such as when the government has certified that a unit has been lost.

3. Notification. State the requirements including time limits, for both the government and contractor to notify each other of deficiencies in a unit.

4. Unverified failures. State whether or not the contractor will be compensated for the cost of testing units returned to him under the warranty when the tests reveal no discrepancies.

5. Adjustments. State the circumstances, if any, under which the government is authorized to make adjustments to units under the warranty.

Data Requirements

1. Contractor warranty data. State that the contractor shall establish and maintain a data system that will provide formation on the repair record of each unit, analysis of unit failure, number of units returned, turnaround and pipeline times of units returned, remaining warranty coverage, etc.

2. Government-developed data. State that the government will be required to provide, in a timely manner, available government-generated operation and maintenance data pertaining to the warranted units.

Summary of RIW Use

Even to consider the use of the RIW in a procurement contract depends on whether the item is expected to have moderate to high support costs. If so, then the item must be amenable to being specified only in terms of form, fit, and function, without the need for detail design constraints. When these conditions prevail, then the four measures of suitability discussed above can be applied. And the item measures up, the project manager has the green light to go ahead with the RIW.

OTHER R&M COST-REDUCTION WARRANTIES

Three other types of R&M cost-reduction warranties are presented. They are referred to as Mean Time Between Failure, Equipment Turnaround Time, and Maintenance Cost — names that indicate the nature of the guarantee being purchased. They are warranties with which the airline industry has had some success, but with which the government has had little experience. Consequently, their use as allowed by FAR must be carefully considered, just as the use of the Reliability Improvement Warranty must be carefully considered, and their clauses must be tailored to the particular procurement requirements. Clauses that have been used by the airline industry are presented for each of these warranties as examples only of the elements to be considered for inclusion in government clauses.

MEAN TIME BETWEEN FAILURES (MTBF) WARRANTIES

Under this type of warranty the contractor guarantees that the equipment will achieve a stated MTBF. If the equipment fails to do so, the contractor must provide labor and materials to modify the equipment to meet the MTBF requirements. In essence, this is another way to obtain a required level of reliability.

An MTBF warranty can reduce infant mortality because it gives the contractor an incentive to test the equipment before delivering it to the government. On the other hand, historical information on the equipment must be made available to determine an equitable and realistic price. The contract also must contain definitions for various classes of failures which must be mutually satisfactory to both parties. Also, conditional MTBF warranties can lead to disputes; an unconditional warranty under which all agreed-upon failure conditions are rectified is more desirable, but also more expensive.

Examples of Clauses

1. Each manufacturer guarantees that the Equipment covered under this agreement shall achieve the Mean Time Between Failure (MTBF) guarantees as set forth in Attachment XXX, a copy of which is attached hereto and made a part hereof.

2. Buyer shall provide Equipment failure data from the date the Equipment enters the Buyer's service. The data shall be sufficient to determine MTBF and any additional equipment required.

3. Equipment provisioning shall be determined by Buyer and shall be based upon the MTBF guarantee set forth in Attachment XXX as modified by other program factors determined by Buyer. MTBF guarantees, set forth in Attachment XXX, for the purpose of this program, shall be divided into three periods: (a) Initial — first 24 months; (b) Interim — 25th to 42nd months; and (c) Final — 43rd and subsequent months.

4. Support is to be based upon the data provided by Buyer in accordance with paragraph 2 above, and such data shall be used to compute any additional equipment required. Such equipment hall be made available on a no-charge consignment basis.

5. MTBF measurements shall be based upon a monthly measurement corresponding to a 3-month moving average. The Manufacturer's obligation under the MTBF Guarantee Program shall commence on the date the Equipment enters Buyer's service and shall terminate when the respective MTBF guarantees set forth in Attachment XXX are achieved over 18 consecutive monthly measurements commencing no earlier than the 43rd month after introduction of the Equipment into Buyer's service.

6. The specific provision for measuring the MTBF is as hereinafter set forth:

   a. Calculation of MTBF: The MTBF shall be calculated by the application of the following formula:

$$\text{MTBF} = \frac{\text{Cumulative Number of Hours of Equipment Operation} \times \text{The Number of Equipments}}{\text{Total Cumulative Number of Chargeable Failures}}$$

   b. Definition of Failure: The following failure definitions and conditions shall apply:

      (1) Confirmed Failure: Any Equipment removed from a platform for suspected failure shall be deemed a confirmed failure when, upon being subjected to test in the condition removed, it is unable to pass the test for the Equipment specified by Manufacturer's Overhaul Manual supplied to Buyer or other mutually agreeable test procedure. The specified test must be comparable in scope to Manufacturer's acceptance test for production equipment. Tests may be performed in Buyer's facilities or those of its approved designee.

      (2) Irrelevant Failures: Irrelevant failures shall not be counted in the MTBF determination. Irrelevant failures are defined as follows:

         (a) A failure caused by a condition external to the Equipment, such as improperly supplied power, improper interconnecting wiring, or improper operation of the Equipment.

         (b) The failure is a dependent (secondary) failure resulting from an independent (primary) failure within the same Equipment, provided that the independent (primary) failure is specified. A dependent failure occurring in a separate piece of equipment from the Equipment which the primary confirmed failure occurred shall be considered as a confirmed failure.

      (3) Additional Requirements: At all times while in Buyer's possession, the Equipment shall be subjected to an environment within Specification requirements. Failures which occur as a result of an exposure to an environment in excess of that specified shall not count in the MTBF determination. Failures resulting from accident or improper maintenance shall not count in the MTBF determination. Operation and maintenance procedures shall be in accordance with the applicable operating and maintenance manuals.

7. a. In the event the MTBF calculated for any Equipment in operation in a calculation period is less than the guaranteed MTBF, Manufacturer shall re-engineer and modify such Equipment as required to meet the guaranteed MTBF, at no charge to Buyer, and consign additional Equipment at no charge based on the following formula:

$$n = KN\frac{(M - m)}{Mm}$$

where

n	=	Maximum number of additional Equipment to be consigned to Buyer under MTBF Guarantee Program. This number shall be rounded to the nearest whole number, but not less than 1, and shall not exceed 100% of Equipment installed in Buyer's platforms as of the date of MTBF calculation.
K	=	5000
N	=	Total number of Equipment installed in Buyer's platforms as of the date of MTBF calculation.
M	=	Guaranteed MTBF for the Equipment.
m	=	Calculated average MTBF of the Equipment.

b. Failure classification shall be mutually agreeable to Manufacturer and Buyer. If no agreement can be reached, the failed Equipment shall be subject to failure analysis prior classification.

c. If additional consignment Equipment is required to be furnished by Manufacturer to Buyer hereunder, Manufacturer shall ship such Equipment to Buyer not later than 1 week after completion of the MTBF calculation by Buyer. Buyer shall notify Manufacturer if the indicated number of consignment Equipment exceeds Buyer's requirements, in which case, Manufacturer shall be obligated to supply only that quantity required by Buyer. Manufacturer agrees to furnish each additional Equipment notwithstanding the possible existence of any disagreement as to failure classification.

8. Return of Consigned Equipment: Any Equipment consigned under the provisions of paragraph 7 above shall be returned to Manufacturer by Buyer not later than 90 days after an MTBF calculation. Buyer shall have the flexibility of replacing any consigned Equipment with similar Equipment.

EQUIPMENT TURNAROUND TIME WARRANTIES

Under the terms of this warranty the manufacturer guarantees to repair his delivered equipment within a stipulated average turnaround time. Normally, it is assumed that the same unit will be returned to the government after repair, but allowances can be made to replace the unit with another like unit to expedite turnaround time.

This type of warranty is especially suited to depot-level or manufacturer repair situations. Only a limited area of concern is covered, however. Other guarantees would have to be used to cover reliability as well as the costs of maintenance and repair. This warranty would have to be tailored if it was to be used for shipboard equipment, which should not be too difficult.

Examples of Clauses

1. Manufacturer guarantees the average repair turnaround time as listed in Attachment XXX, a copy of which is attached hereto and made a part hereof, for the Equipment covered under this Agreement requiring repair or correction. These turnaround times include round-trip shipping time between Buyer's maintenance facilities and Manufacturer's repair facility. The average turnaround time shall be calculated on a 3-month moving average. In the event Manufacturer fails to meet the average turnaround times as listed in Attachment XXX, Manufacturer shall consign additional Equipment, at no charge, in accordance with the following formula:

$$N = R(t - T)$$

where

N	=	Number of additional Equipment to be consigned to Turnaround Time Guarantee. This number shall be rounded to the nearest whole number, but shall not be less than 1.
R	=	Quantity of Equipment returned to Manufacturer for repair, in units per week, calculated on a 3-month moving average.
T	=	Guaranteed repair turnaround time in weeks.
t	=	Calculated average repair turnaround time in weeks.

2. The above assumes that the same serial numbered Equipment shall be returned to Buyer as received. However, Manufacturer shall have flexibility to replace the failed Equipment with other similar equipment, if this will expedite repair, provided that the number of hours on such other equipment shall not exceed the number on such failed equipment.

MAINTENANCE COST WARRANTIES

Under this warranty the contractor guarantees that the labor and material costs for the government to maintain the equipment will not exceed a specified amount. If this amount is exceeded, the contractor will reimburse the government for the excess.

Use of this type of warranty allows the government to use its own maintenance personnel. The warranty could be practicable for use with shipboard equipment. However, a maintenance history of the equipment is required to determine an equitable and realistic contract price and, during application, thorough maintenance-cost records must be kept.

Examples of Clauses

1. Manufacturer guarantees that the maintenance labor and material cost for Buyer to maintain the Equipment covered under this Agreement shall not exceed the respective guaranteed maintenance labor man-hour costs and maintenance material costs set forth on Attachment XXX, a copy of which is attached hereto and made a part hereof. The Maintenance Cost Guarantees set forth in Attachment XXX all commence with delivery of the first unit to Buyer and shall terminate 8 years thereafter.

2. At periodic intervals, but not less than once each year, after delivery of the first unit to Buyer, Buyer shall report its recorded maintenance labor man-hour costs and maintenance materials costs for Manufacturer's Equipment. In the event such periodic maintenance labor man-hour costs or maintenance materials costs are in excess of those set forth in Attachment XXX hereto, Manufacturer agrees that it shall provide at no additional cost to Buyer and at the request of buyer, the following:

   a. Technical service support by qualified personnel

   b. Corrective engineering design changes

   c. Modification of all applicable Equipment covered by this Agreement

   d. Reimbursement to Buyer for all costs incurred, above those set forth herein, on an annual basis

   Such service as outlined above shall be performed by Manufacturer at Buyer's request in order to bring the direct maintenance labor man-hours and maintenance material costs within the Maintenance Cost Guarantees set forth in Attachment XXX.

3. This program pertains only to maintenance labor and material costs for Manufacturer's Equipment. All labor and material costs shall exclude acts of omission of Buyer, acts of God or a third party, Buyer modifications unrelated to improvements in operating cost of Manufacturer's Equipment, consumable fluids, or outside maintenance burden and profit charges.

GOVERNMENT STUDY RECOMMENDATIONS PERTAINING TO WARRANTY USE

The following recommendations are excerpted from appendix B, and serve to summarize this section.

1. Use long-term contractor maintenance warranties to motivate the contractor to design for minimum life-cycle cost.

2. To overcome the potential problem of spare-parts stocking and field repair of multiple equipment configuration, make use of depot repair or supplier maintenance under warranty. In the field, replace rather than repair failed

replaceable units. Include warranty requirements when initiating development.

3. Institute a cost accounting system that will afford visibility of the maintenance process and make possible realistic cost comparisons between military and industrial maintenance.

4. Establish alternative sources of maintenance, including the maximum feasible amount of contractor maintenance, foster competition and resultant efficiency in the maintenance process and to ensure the proper utilization of scarce military personnel in the present zero-draft environment.

5. Extend the application of long-term contractor maintenance warranties to military electronic procurements.

6. Make known the intention to contract for maintenance warranties on production equipment at the time development is initiated, so that the contractor will design to minimize total costs of production and warranty maintenance.

7. Establish a warranty review group within OSD to monitor results of trial applications, to determine desirable warranty contractual formats, and to refine the categories of equipments which warranties are most applicable and for which warranties are most effective.

8. Initially, apply long-term contractor maintenance warranties to equipments whose failed units can be replaced in the field and conveniently returned to the contractor's plant or base for repair, or to which the contractor can have ready access for field repair, such as airborne communications, navigation, and identification equipment; modular radars; vehicular communication sets; complex manpack equipment such as LORAN C/D; forward-looking infrared (FLIR) systems; and domestic communication, data processing, and radar installations.

9. The government should defer invocation of the final product baseline, as applicable to electronic equipment, until field reliability objectives have been achieved, or, in the case of equipment under contract maintenance warranty, until the warranty period is about to end and the government is about to take over maintenance from the warrantor.

10. Use contractor warranties and maintenance to reduce the need for technical and maintenance manuals and provisioning data.

FINAL CONSIDERATIONS

The use of long-term warranties is subject to the same tradeoff considerations that apply to other forms of nonorganic maintenance. Only in rare circumstances can organic maintenance be performed without compromising the warranty. Furthermore, the use of the equipment must lend itself to the collection of valid field failure data and to a reasonable description of the mission and use environments. In short, the mission must be of a character that allows nonorganic maintenance with reasonable turnaround time. It should be noted that nonorganic maintenance will generally require higher procurement quantities to fill supply pipelines and equipment pools; for mission-essential equipments, these pools should include an inventory hedge against possible disruptions such as strikes.

XVI. TYPES OF CONTRACTS

TWO PRINCIPAL TYPES OF CONTRACTS

Basically, there are two types of contracts — fixed price and cost. The major distinction between the two is in the nature of the seller's obligation. Under a fixed-price contract, the contractor must produce the required items or perform the services for the firm fixed price or within the ceiling price of an incentive contract or he is subject to the penalties provided in a Default clause. There are various types of fixed-price contracts — firm fixed price (FFP), fixed price with escalation (FPE), and fixed-price incentive (FPI).

The second general category of contracts is cost reimbursement. Under a cost-type contract, the product is not paid for on the basis of an invoice price; rather the government pays the contractor's cost of material and labor and a portion of his overhead costs as provided in Cost Principles cited in the contract. Cost-type contracts include cost, cost plus fixed fee, cost plus incentive fee, and cost plus award fee.

Under a cost-type contract, the contractor agrees to use his best efforts to complete the contract within the estimated amount provided in the contract but has no obligation for further performance when, despite his best efforts, the contract is not fully performed at the time he expends the funds in the contract, unless the Contracting Officer increases the funds.

A time and material type contract is a hybrid form under which the contractor is paid a fixed price for each labor hour, which includes the labor costs, indirect expenses, and profit, plus material at cost. See table XVI-1 for a summary of contract types.

Appendix A of this chapter is a glossary of procurement terms.

BASIS OF SELECTION OF THE TYPE OF CONTRACT

The major consideration in the selection of the type of contract should be whether or not the item can be made or the services can be performed. From the contractor's viewpoint, if he is sure that he can make the item and can secure a price which will adequately cover contingencies and risks in the contract, then a firm fixed-price contract is best. On the other hand, after determining that the contractor can reasonably be expected to perform the contract, the Contracting Officer must determine whether the price asked is a reasonable one considering the risks in the procurement. If the Contracting Officer finds that there are unusual contingencies present which the contractor has taken into consideration in establishing his price, then the Contracting Officer must negotiate a price which equitably shares the risk between the contractor and the government, or he should include provisions for escalation, with or without incentive provision, which will allow him to recapture the contingencies included in the contractor's price if they do not occur.

Table XVI-1. Contract types.

COST REIMBURSEMENT (Greatest Risk on Government				FIXED PRICE (Greatest Risk on Contractor)			OTHER CONTRACTUAL DEVICES (Special Uses)	
COST AND COST SHARING	COST PLUS INCEN-TIVE FEE	COST PLUS AWARD FEE	COST PLUS FIXED FEE	FIRM FIXED PRICE	FIXED PRICE WITH ESCALA-TION	FIXED PRICE INCENTIVE	TIME AND MATERIAL (LABOR HOUR)	LETTER CONTRACT
← Uncertainties in Peformance — Impossible to Firmly Estimate Costs →								
Cost: R&D with non-profit organization or educational institutions; facilities contracts Cost Sharing: production or research projects jointly sponsored by government and contractor where contractor gets commercial benefit	Development and test when incentive formula can provide positive incentive for effective management. Where feasible use performance incentives together with price incentives	Level of effort contract for services; absence of performance objectives	Research preliminary exploration or study when level of effort is initially unknown (or development and test when a CPIF is impractical).	Fair - Reasonable price can be established at inception, e.g., • Reasonably definite specifications • Standard items • Realistic estimates • Adequate competition	• Market or Labor conditions unstable over extended production period • Contingencies are identifiable and can be excluded from basic price	Possibility of cost reduction by giving contractor (1) a degree of cost responsibility and (2) a positive profit incentive Firm Target Type: firm target and final price - profit formula can be negotiated initially Successive Target Type: initial target can be negotiated, but firm final targets cannot; sufficient information will be available early enough in performance to set final goals providing an incentive.	Not possible initially to estimate extent or deviation of work (L-H used where materials not involved) e.g., engineering or design services; repair, maintenance, or overhaul	National defense requires immediate binding commitment so work can begin but time does not permit negotiation of a definitive contract
Cost: government pays FAR 16 costs, but no fee Cost Sharing: government pays agreed portion of FAR 16 costs; no fee	Target cost: target fee; minimum and maximum fee; fee adjustment formula (formula applied at end of performance)	Special fee provisions: two-part fee (1) fixed (2) award. Amount of award based on subjective evaluation of performance in terms of predetermined criteria Base fee maximum is 3% of estimated cost of contract	Negotiated estimate of costs; fee fixed initially except for changes in the work or services required.	Initial fixed price places 100% responsibility and risk on contractor	FAR 16 CLAUSES • Price • Labor/Material: ceiling on adjustment ADJUSTMENT Upward or downward on the occurrence of defined contingencies	Firm Target: target cost; target profit; price ceiling; firm target profit formula and production point for application to get either a firm target and final profit formula, or a fixed-price contract	Direct labor hours specified at fixed hourly rates; direct materials at "cost" ("cost" as defined by FAR and departmental instructions). Ceiling if appropriate	Maximum government liability type of definitive contract; as many definitive contract provisions as possible; other provisions required by FAR; price ceiling if applicable

Table XVI-1. Contract types (continued).

COST REIMBURSEMENT (Greatest Risk on Government				FIXED PRICE (Greatest Risk on Contractor)			OTHER CONTRACTUAL DEVICES (Special Uses)	
COST AND COST SHARING	COST PLUS INCENTIVE FEE	COST PLUS AWARD FEE	COST PLUS FIXED FEE	FIRM FIXED PRICE	FIXED PRICE WITH ESCALATION	FIXED PRICE INCENTIVE	TIME AND MATERIAL (LABOR HOUR)	LETTER CONTRACT
← ADEQUATE CONTRACTOR ACCOUNTING SYSTEM REQUIRED →	Statutory Fee Limitations Production — 10% estimated cost R&D — 15% estimated cost Architectural and Engineering Services — 6% estimated cost Formula must provide incentive effective on variations of 25% or more from target		Not for development of major weapons once exploration indicates development is feasible	Government and contractor must agree on fixed price at inception	Contingencies are industry-wide and beyond contractor control	Adequate Contractor Accounting System Required. Must determine (1) that this is least costly contract type and (2) that any other contract type is impractical	Determination that no other type of contract is suitable	No other contract type suitable; definitive contract prior to (1) 180 days or (2) 40% of production of performance; maximum liability no more than 50% estimated cost
← DETERMINATION AND FINDINGS BY CONTRACTING OFFICER →				None	None	D&F by Head of Procuring Activity	D&F by Contracting Officer	
				Advertised or Negotiated Procurements		Negotiated procurements only	Negotiated Procurements only	
			Least contractor responsibility for costs	• Preferred over all types Minimum administration	Reduces fixed price risk for contractor	May also use performance incentives	Constant government surveillance necessary	Greatly restricted see departmental implementations of FAR

Where the contractor is not certain that he can perform the contract due to uncertainties in the contract requirements which prevent him from developing a reasonable estimate of the cost of performance, or where the contract calls for advances in the state of the art which the contractor is not sure he can achieve, then he should endeavor to secure a cost-type contract. On the other hand, under a cost-type contract, the Contracting Officer has no assurance of the success of work being performed and no idea of how much it will eventually cost. This type of contract can only be used where the Contracting Officer determines that it is likely to be less costly than other methods, or that it is impracticable to secure supplies or services of the kind or quality required without the use of such types of contracts.

If he has the option, the contractor should base selection of the type of contract on the knowledge acquired during the preparation of the cost estimate associated with the proposal. The government makes its decision on the basis of competitive prices or the cost or price analysis of the contractor's proposal. In addition, a major factor in determining the type of contract and its terms is the relative bargaining strength and negotiating ability of both sides. With reference to this, FAR 16, Types of Contracts, provides as follows:

> To provide the flexibility needed in the purchase of the large variety and volume of military supplies and services, a wide selection of types of contracts is available to the contracting parties. The respective contract types vary as to (i) the degree and timing of responsibility assumed by the contractor for the costs of performance, and (ii) the amount and type of profit incentive offered the contractor to achieve or exceed specified standards or goals. With regard to degree of cost responsibility, the various types of contracts may be arranged in order of decreasing contractor responsibility for the costs of performance. At one end is the firm fixed-price contract under which the parties agree that the contractor assumes full cost responsibility. At the other end of this range is the cost-plus-a-fixed-fee contract where profit, rather than price, is fixed and the contractor's cost responsibility is therefore minimal. In between are the various incentive contracts which provide for varying degrees of contractor cost responsibility, depending upon the degree of uncertainty involved in contract performance.

The purpose of the contractor's estimating process and the government's price and cost analysis is to develop some idea of the possible range of costs within which the contract work may be performed. The size of this range from minimum to maximum factored by the bargaining position will determine the type of contract used and therefore the relative cost risk of the contract to both parties. For example:

$100,000
"Probable" Cost

Low	High	Contract type
$95,000	$105,000	Firm fixed price Confidence range ±5%
$95,000	$120,000	Fixed price incentive Confidence range ±5% to 20%
$80,000	$140,000	Cost plus incentive fee development Confidence range ±20% or more
? ? ? ? ? ? ?	? ? ? ? ? ?	Cost plus fixed fee R & D Minimum confidence in cost and term

Establishing the range of possible cost is not easy. Since the estimate is just that, an estimate, conclusions regarding its accuracy can be no more than similar estimates. Consideration of the following factors will provide guidelines as to the nature of the type of contract.

1. Nature of the work. In general, a high ratio of development to fabrication will tend to create a high degree of uncertainty.

2. Past experience. In situations where both the contractor and the government have had little experience in estimating costs on similar work, confidence in the estimate will be low.

3. Time available. The degree of confidence in the estimate increases substantially if adequate time is available for careful estimation.

Usually, the request for proposal will specify the type of contract which the customer wishes. In the majority of cases, however, proposals on alternative types of contracts will be considered. Where the alternate proposal decreases the contractor's share of the risk — for example, proposing on a cost-type basis when the customer has requested a fixed-price proposal — it may seriously affect the contractor's chances of winning. Following is a brief description of types of contracts.

FIRM FIXED-PRICE CONTRACT

This is the basic type of contract. In formally advertised procurements, the firm fixed-price contract, with or without provision for escalation, is the only type that may be used. In negotiated procurements, FAR directs that it be used unless, under the attendant circumstances, use of another type is more appropriate.

The firm fixed-price contract, as the name implies, is an agreement by the contractor to furnish designated supplies or services at a specified price which is not subject to adjustment in the light of performance costs. In its basic form, the firm fixed-price contract carries the greatest risk and offers the greatest possibility of profit or loss of any type of contract. The contractor cannot collect more than the agreed fixed price but is entitled to receive the full amount of the fixed price, regardless of his actual performance costs. This type of contract is best suited for procurements where reasonably definite specifications are available, price competition exists, production experience is present, and costs can be predicted with reasonable certainty. Examples of items for which this contract is used are standard commercial items, modified commercial items, or military items for which adequate information on production and cost is available.

Since this type of contract provides fundamentally for a simple exchange of a specified sum of money for a specified item, it is the easiest and least costly of all contract types to administer.

Firm fixed-price contracts can be used for research or development work when (1) there is a proper scope of work, (2) the contractor assumes the risk on a cost sharing basis, or (3) the contractor recognizes the risk and is willing and financially able to take it.

FIXED PRICE WITH ESCALATION

The fixed-price contract with escalation provides for the upward and downward revision of the proposed price upon the occurrence of certain contingencies which are specifically defined in the contract.

Price escalation provides for an adjustment of the contract price on the basis of increases or decreases from an agreed-upon level in published or established prices of specific items or in price levels of the contract end item.

The use of this type of contract is appropriate where serious doubt exists as to the stability of the market and labor condition which will exist during an extended period of production, and where contingencies which would otherwise be included in a firm fixed-price contract are identifiable and can be covered separately by escalation. This type of contract is difficult to administer.

Escalation will usually be restricted to industry-wide contingencies and labor and material escalation will be limited to contingencies beyond the normal control of the contractor. This type of contract is limited to long-term production contracts for standard items.

Labor and material escalation provides for the adjustment of the contract price on the basis of increases or decreases from agreed standards or indices in wage rates, specific material costs, or both.

FIXED-PRICE INCENTIVE CONTRACTS

The fixed-price cost incentive contract is a fixed-price-type contract with provision for adjustment of profit and establishment of the final contract price by a formula based on a relationship which final negotiated total costs bear to total target costs. An incentive contract includes a target cost, a target profit, a price ceiling (but not a profit ceiling or floor), and a formula for establishing final profit and price. After performance of the contract, the final price is negotiated and the final contract price is then established in accordance with the formula.

Fixed-price incentive contracts are appropriate when, due to the nature of the work required, neither the contractor nor the government has the confidence to negotiate a firm fixed price, but the contractor is willing to take the risk at the ceiling price established.

COST-TYPE CONTRACTS

The cost-reimbursement-type contract provides for payment to the contractor of allowable costs incurred in the performance of the contract to the extent prescribed in the contract. This type of contract establishes an estimate of total cost (1) for the purpose of obligation of funds, and (2) to establish a ceiling which the contractor may not exceed except at his own risk without prior approval or subsequent rectification by the Contracting Officer. A cost-reimbursement-type contract is considered suitable for use only when the uncertainties involved in contract performance are of such a magnitude that cost of performance cannot be estimated with sufficient reasonableness to permit use of any type of fixed-price type contract. In addition, it is essential that the contractor's cost accounting system be adequate for the determination of costs applicable to the contract. The contract normally provides for surveillance by the buyer to ensure that inefficient and wasteful methods are not used. There are various types of cost-type contracts — cost, cost sharing, cost plus fixed fee, cost plus incentive fee, and cost plus award fee.

COST CONTRACT

The cost contract is a cost reimbursement type contract under which the contractor receives no fee. Under this type of contract, the government agrees to reimburse the contractor for allowable costs of performance as governed by FAR 16, and specific terms of the contract. It is used for research and development work with educational institutions and other nonprofit institutions, and for facilities contracts.

COST SHARING CONTRACT

The cost-sharing contract is one under which the contractor received no fee and is reimbursed only for an agreed portion of his allowable costs, as governed by FAR 16. The cost-sharing type of contract recognizes that the contractor sometimes benefits substantially (apart from profit) by the performance of a government contract. This is particularly true in the field of development work, where the results of the work performed under a government contract may have profitable commercial application. Where the prospect of commercial application can be foreseen at the time of entering into the contract, contracts are negotiated which provide that the government will reimburse the contractor for only a specified percentage of its costs. The unreimbursed portion of the cost of performance represents the contractor's contribution to what is, in effect, a joint enterprise.

COST-PLUS-A-FIXED-FEE (CPFF) CONTRACT

The cost-plus-a-fixed-fee (CPFF) contract is a cost-reimbursement-type contract which provides for the payment of a fixed fee to the contractor. In addition, the contractor is reimbursed for the allowable cost of performing the contract as governed by FAR 16, and the terms of the contract.

Present procurement law (10 U.S.C. 2306(d)) limits the fee for performing a CPFF for experimental, developmental, or research work to not more than 15% of the estimated cost of the contract, not including the fee. For architectural or engineering services for a public work or utility, the fee is limited to not more than 6% of the estimated cost of that work or project, not including the fee. The fee for performing any other CPFF may not be more than 10% of the estimated cost of the contract, not including the fee. Because the CPFF contract obligates the government to reimburse the contractor for the allowable cost of performing the contract without regard to the estimated cost, it specifies a maximum amount beyond which the government will not be obligated to reimburse the contractor. The maximum may be more or less than, or equal to, the estimated cost. The contractor agrees to use his best efforts to complete the contract within the maximum limitation, but has no obligation for further performance when, despite his best efforts, the contract is not fully performed at the time the maximum has been reached, unless the Contracting Officer increases the maximum.

Irrespective of whether his actual costs are greater or less than the estimated cost, the contractor receives the predetermined fixed fee. If the scope of the contract work is increased or decreased, appropriate increases or decreases both in the estimated cost and the fixed fee are negotiated.

There are two forms of CPFF contracts:

1. The Completion form is one that describes the scope of work to be done as a clearly defined task or job with a definite goal or target expressed and with a specific end product required. This type is used for the development of hardware or where a final report of research accomplishing the goal or target is required.
2. The Term form is one which prescribes the scope of work to be done in general terms and which obligates the contractor to devote a specified level of effort for a stated period of time for the conduct of research and development. This type of contract is primarily used for basic research and the furnishing of level-of-effort-type services.

The CPFF contract is used (1) for the performance of research, preliminary exploration, or study where the level of effort required is unknown; or (2) where the contract is for development and test and the use of cost plus incentive fee is not practical.

COST-PLUS-INCENTIVE-FEE (CPIF) CONTRACT

Under this type of contract, the government and the contractor agree at the time of negotiation of the contract upon the target cost of performance. The target fee is then determined in relation to the target cost. Also established are minimum and maximum fees and, finally, a fee adjustment formula.

After performance of a contract, the fee payable to the contractor is determined in accordance with the formula. The formula provides, within limits, for an increase in fee above target fee when the total allowable costs are less than target costs. Conversely, it provides for decreases in the fee below the target fee when the total allowable costs exceed the target costs.

The incentive-fee contract is used where a cost-reimbursement-type contract is necessary and where there is a probability that its use will result in lower costs to the government than other forms of cost-reimbursement-type contracts through cost-reduction incentive to the contractor. Maximum fees are subject to the same percentage limitations previously mentioned under CPFF contracts.

The CPIF contract is suitable for use primarily for development and test. Where it is highly probable that the development is feasible and the government generally has determined its desired performance objectives, the CPIF contract should be used in conjunction with performance incentives in the development of major systems, and in other development programs where use of the cost and performance approach is considered both desirable and administratively practical.

COST-PLUS-AWARD-FEE (CPAF) CONTRACT

The cost-plus-award-fee (CPAF) contract is a cost-reimbursement-type contract which provides that the contractor's variable fee will be determined subjectively by designated, high-level government personnel on the basis of periodic after-the-fact evaluation of the contractor's performance. The CPAF contract has a base (in some cases, the base fee may be "zero") and provision for the fee to be adjusted upward on the basis of the contractor's performance evaluated in accordance with broad criteria set forth in the contract. The award fee determination is the subject of special checks and balances which provide procedural safeguards protecting the contractor from arbitrary or capricious evaluations, but it is not subject to the Disputes clause procedure. The broad criteria against which the contractor's ultimate performance is evaluated include performance of operations, technical management, business management, and utilization of resources.

CPAF contracts are considered appropriate for support services generally associated base maintenance and operations and mission support contracts. In addition, they are used for contracts for the operation and maintenance of computer centers.

TIME AND MATERIALS CONTRACT

The time and materials type of contract provides for the procurement of supplies or services on the basis of payment for direct labor hours at specified fixed hourly rates (which rates include direct and indirect labor, overhead, and profit) and materials at cost. Material handling costs may be included in the charge for "material at cost," provided they are clearly excluded from any factor of the charge computed against direct labor hours. Under this type of contract, a price ceiling is established which the contractor may not exceed, except at his own risk.

The time and materials contract is used only in those situations where it is not possible at the time of placing the contract to estimate the extent or duration of the work or to anticipate costs with any substantial accuracy. Its use is restricted, as its disadvantage is obvious; since it provides for payment of a fixed price per applicable unit of time, it is evident that, unless the rate is insufficient to cover the contractor's costs, the total amount of profit under the contract is increased proportionately as the number of hours are increased. For this reason, the time and materials contract is not preferred and is used only after the Contracting Officer has determined that it most suitably serves the requirement.

This type of contract is usually used for (1) repair, maintenance, or overhaul work, and work to be performed in emergency situations; (2) engineering design and preparation and revision of drawings; and (3) manufacture of dies, jigs, and fixtures.

LETTER CONTRACTS

A letter contract is a written preliminary contractual instrument which authorizes immediate commencement of manufacture of supplies or performance of services, including, but not limited to, preproduction planning and the procurement of necessary materials. It is used when negotiation of a definitive contract in sufficient time to meet the procurement need is not possible, as, for example, when the nature of the work involved prevents the preparation of definitive requirements, specifications, or cost data.

PROCUREMENT PLANNING

Large contracts require an Acquisition Plan (AP), which must be approved through NAVSUP prior to soliciting proposals. Smaller contracts should be carefully planned, too, to determine how the contract should be constructed to fit into the overall system acquisition strategy. The PM/SE should start coordinating early with the contracting officer to assure that all the required elements are included. Coordinate the CDRL through the Data Management Office so that the data requirements are consistent with the contractual requirements and the acquisition strategy.

APPENDIX A: GLOSSARY OF PROCUREMENT TERMS

Term	Procurement Usage
Administrative Contracting Officer (ACO)	A government contracting officer, often at an installation other than the one which made the contract, who handles the business administration of the contract. For the larger primes, the ACO is commonly resident at the prime's facility.
Bid	A prospective contractor's (bidder's) reply to a formally advertised solicitation document (IFB). Needs only government acceptance to constitute a binding contract.
Bidders Conference	In formally advertised procurements, a meeting of prospective bidders arranged by the contracting officer during the solicitation period to help solicited firms fully understand the government's requirement and to give them an opportunity to ask questions. (For research and development procurements, see Presolicitation Conference.)
Bidders (Mailing) List (Master Bidders List)	List of sources maintained by the procuring office from which bids (formal advertising) or proposals or quotations (negotiation) can be solicited.
Blanket Purchase Agreement	A negotiated contractor agreement between a contractor and the government under which individual purchase orders not exceeding $2500 may be placed for a specified period of time and within a stipulated aggregate amount.
"Boiler Plate"	See General Provisions.
Buy American Act	Federal statute imposing restrictions on placing contracts with manufacturers who would deliver items not substantially produced in the United States.
CDRL	Contract Data Requirements List (DD 1423)
Change Order	Unilateral direction to a contractor to modify a contractual requirement within the scope of the contract, pursuant to the Changes clause contained in the contract. See also Modification and Supplemental Agreement.
Commerce Business Daily	See Department of Commerce, *Commerce Business Daily.*
Contract Type	Normally, a reference to the pricing terms of the agreement between a buyer and a seller, but may refer to the special nature of other important terms in the agreement. Thus, a contract may be a "fixed price" type. Further, a "letter contract" may be either a fixed-price type or a cost-reimbursement type.
— Basic Agreement	A written instrument of understanding (not a legally enforceable contract per se) between a contractor(s) and the government. Sets forth the contract clauses applicable to future procurements entered into between the parties during the term of the basic agreement. Used to eliminate extensive and costly negotiation when a substantial number of separate contracts may be entered into with a contractor over a definite period of time.

Term	Procurement Usage
— Cost-Reimbursement Contracts	In general, a category of contracts whose use is based on payment by the government to a contractor of allowable costs as prescribed by the contract. Normally only “best efforts” of the contractor are involved. Includes (i) cost, (ii) cost sharing, (iii) cost-plus-fixed-fee, and (iv) cost-plus-incentive-fee contracts.
— Fixed-Price Contracts	In general, a category of contracts whose use is based on the establishment of a firm price to complete the required work. Includes (i) firm fixed price, (ii) fixed-price with escalation, (iii) fixed price redeterminable, and (iv) fixed-price with incentive provisions contracts.
— Indefinite Delivery	Used when the precise quantity of items or specific time of delivery desired is not known. Usually will specify a maximum and/or minimum quantity. Such procurement is effected via (i) a definite quantity contract, (ii) a requirements contract, or (iii) an indefinite quantity contract. May be either negotiated or formally advertised.
— Letter	An interim type of contractual agreement, sometimes called a “Letter of Intent,” authorizing the commencement of manufacture of supplies or performance of services. Used in negotiated procurements only when a definitized fixed-price or cost-reimbursement contract cannot be written until a later date.
— Special-Purpose Contracts	In general, a category of contracts designed to facilitate a procurement for which one of the fixed-price or cost-reimbursement-type contracts is considered inappropriate. Includes (i) basic agreements, (ii) indefinite delivery type contracts, (iii) letter contracts, and (iv) time and materials/labor hour contracts.
— Time and Materials/Labor Hour Contracts	Negotiated contracts based on specified fixed hourly rates to complete a given task. Used only in situations where it is not possible at the outset to estimate the extent or duration of the work involved or to anticipate cost with any substantial accuracy.
— Cost Overrun	The amount by which a contractor exceeds (i) the estimated cost and/or (ii) the final limitation (ceiling) of his contract.
Data	All recorded information to be delivered under a contract. “Technical data” excludes management and financial data.
DAR	Defense Acquisition Regulations. The implementation of FAR for DoD.
Defense Contract Administration Service (DCAS)	An agency, under direction of Director of DSA, created as result of Project 60 to provide unified contract administration services to DoD components and NASA, for all contracts except those specifically extempted.
Determination and Findings (D&F)	Written justification by a contracting officer or higher authority for (i) entering into contracts by negotiation, (ii) making advance payments in negotiated procurements, and (iii) determining the type of contract to use.
Extras	Additions to items being procured, or any quantity above that called for by the contract (besides allowable variation in quantity), or any combination of these two.

Term	Procurement Usage
Federal Acquisition Regulations (FAR)	(Replaces ASPR). The basic federal procurement regulations.
Formal Advertising	The preferred method for government procurement of supplies and services. After public opening of sealed competitive bids, award is made to the lowest responsive and responsible bidder, price and other factors considered, in accordance with FAR 16.
— Bid	A prospective contractor's (bidder's) reply to the solicitation form used for formally advertised procurements (IFB). Needs only the government's acceptance for award to be made.
— Bidders Conference	A conference—held after solicitation, but before bid opening—of all those suppliers who were invited to bid on the procurement to discuss details of the Invitation for Bids.
— Invitation for Bids (IFB)	The solicitation form used in formally advertised procurements and in step two of two-step advertising (see below).
— Request for Technical Proposal (RTP)	The solicitation form used to request proposals in the first step of two-step advertising.
— Responsive and Responsible Bidder	A bidder is responsive if his bid conforms to the requirements of the IFB, and is responsible if he has the capacity and facilities to produce the supplies or render the services being procured.
— Two-Step Advertising	A method of procurement authorized by FAR 14.5. Step one consists of requesting technical proposals from prospective contractors. Step two consists of inviting bids under regular formal advertising procedures from those firms that submit acceptable proposals under step one.
General Accounting Office (GAO)	An agency of the legislative branch, responsible solely to the Congress, which functions to audit all negotiated government contracts and investigate all matters relating to the receipt, disbursement, and application of public funds. Determines whether public funds are expended in accordance with appropriations.
General Provisions	The mandatory (by law or regulation) clauses for all DoD contracts for the type of procurement involved—sometimes called "boiler plate." The clauses devised particularly for the procurement are called the Special Provisions.
Government-Furnished Property (GFP)	Government-owned property furnished to a contractor for the performance of a contract. Defined as (i) industrial facilities, (ii) material, (iii) special tooling, (iv) special test equipment, and (v) military property. Also designated GFM, Government-Furnished Material, and GFE, Government-Furnished Equipment.
Master (Task Order) Contract	A type of agreement describing the total desired area of contractor performance and breaking this down into a number of broadly defined tasks. The contractor is obligated to perform Task Orders subsequently issued by the government under the terms and conditions in the Master Contract.
Modification	Any formal revision of the terms of a contract, either within or outside the scope of the agreement. Includes Change Orders. See also Supplemental Agreement.

Term	Procurement Usage
Negotiation	The method of procurement used when one or more of the basic conditions incident to formal advertising is absent and/or when there is justification under one or more of the many exceptions provided by Title 10, U.S.C. 2304(a). See FAR 15, and Negotiation Authority, below.
— Offer/Proposal/Quotation	A prospective contractor's response to the solicitation form (RFP/RFQ) used for a negotiated procurement.
— Presolicitation Conference	A conference between government and industry concerning technical problems or other areas of importance relating to the procurement. Precedes the solicitation of prospective contractors for the procurement.
— Request for Proposal (RFP)	The solicitation form used for negotiated procurements when the government reserves the right to award without further oral or written negotation. Only the acceptance of the government is required for award.
— Request for Quotation (RFQ)	The solicitation form used in negotiation to obtain price, cost, delivery, and other information from prospective suppliers. Used when award will be made following extensive negotiation with the offeror. Award requires bilateral agreement of both the contractor and the government.
Negotiation Authority	Authority to negotiate a contract under one of the 17 statutory exceptions granted by Congress, rather than to formally advertise the procurement. FAR 15 describes circumstances in which this authority may be used and the requirements for its approval.
Offer	A prospective contractor's response to a solicitation document in a negotiated procurement. The contractor can be termed the "offeror." See also RFP and RFQ.
Option	A contractual clause permitting an increase in the quantity of supplies beyond that originally stipulated or an extension in the time for which services on a time basis may be required.
Preaward Survey (Facility Capability Review—FCR)	Study of a prospective contractor's financial, organizational, and operational status made prior to contract award to determine his responsibility and eligibility for government procurement.
Preproposal Conference	In negotiated procurements, a meeting held with potential contractors a few days after requests for proposals have been sent, to promote uniform interpretation of work statements and specifications by all prospective contractors. See also Bidders Conference.
Presolicitation Conference	A meeting held with potential contractors prior to a formal solicitation, to discuss technical and other problems connected with a proposed procurement. The conference is also used to elicit the interest of prospective contractors in pursuing the task.
Price and Fee	
— Ceiling Price	The negotiated monetary limit—in a fixed-price-type contract—to the amount that the government is obligated to pay. Cost incurred beyond this point must be absorbed by the contractor.

Term	Procurement Usage
— Fee	An amount, in addition to allowable costs, paid to contractors having CPFF or CPIF contracts. In CPFF contracts, the fee is fixed as a percentage (stated in a dollar amount) of the initially estimated cost of the procurement. In CPIF contracts, the fee is expressed in maximum and minimum amounts, along with a fee-adjustment formula that provides the incentive for a reduction in cost to the government. Statutory limitations are prescribed for the maximum setting of fees.
— Target Price	The negotiated estimate of price—in a fixed-price redeterminable or incentive contract—that the government expects to pay for supplies procured under the contract.
Procurement Contracting Officer (PCO)	The government contracting officer directing and administering the procurement through the award of the contract and the signing of the actual contractual documents. Administration of the contract after award may be delegated to an ACO, as described above.
Procurement Request (PR)	Document which describes the required supplies or services so that a procurement can be initiated. Some procuring activities actually refer to the document by this title, others use different titles, such as Procurement Directive, and so forth.
Purchase Order	A contractual procurement document used primarily to procure supplies and nonpersonal services when aggregate amount involved in any one transaction is relatively small (for example, not exceeding $25,000).
Qualified Products List (QPL)	A list of products which are pretested in advance of actual procurement to determine which suppliers can comply properly with specification requirements. This is most usually done because of the length of time required for test and evaluation.
Supplemental Agreement	Bilateral written amendment to a contract by which the government and the contractor settle price and/or performance adjustments to the basic contract. See also Change Order and Modification.
Termination	The canceling of all or a part of a prime or subcontract prior to its completion through performance.

APPENDIX B: STATEMENT OF WORK REQUIREMENTS

Statement of work (SOW) writers should ensure that objectives and performance requirements in the SOW are complete and clearly written in conventional language to the extent practical. Complete elimination of technical language is not required, but it should be reduced to essentials required to describe the task. The person responsible for preparing the SOW must keep in mind that excess technical language or technical constraints can affect the procurement beyond simply stating or directing the contract effort. It may also affect the number of good sources willing and able to respond.

BRAND NAME OR EQUAL

Occasionally, a requirement will be of such nature that it can be met by one of several commercial products. When this situation exists, it is frequently possible to make the procurement on a "Brand Name or Equal" basis. Brand name does not require a full statement of work, but does oblige the requiring activity to specify all the technical characteristics which are necessary to fulfill the requirement. These characteristics become the specification against which "equal products can be measured. A sample SOW for a Brand Name or Equal procurement appears at the end of this appendix.

SOW CHECKLIST

The following checklist for work statements provides some of the considerations which the writer must bear in mind:

- Is the SOW sufficiently specific to permit the writer and the contractor to make a list of manpower and resources needed to accomplish it?
- Are specific duties of the contractor stated in such a way that he knows what is required and the technical representative who signs the acceptance report can tell whether the contractor complied?
- Are sentences written so that there is no question as to whether the contractor is to be obligated (that is, "the contractor shall do this work," not "this work will be required")?
- Is the proper reference document shown? Is it really pertinent to the task? Fully or partially? Is it properly cited?
- Have the elements of quality assurance been fully considered for the total life of the procurement requirement?
- Are any military specifications or exhibits applicable? In whole or in part? If so, are they properly cited? (Use the latest available revision or issue of each document.)
- Is general information separated from direction so that background information, suggested procedures, and the like are clearly distinguishable from contractor responsibilities?

- Is there a date for each thing the contractor is to do or deliver? If elapsed time is used, does it specify calendar days or work days?
- Have the headings been checked for format and grammatical usage? Are subheadings comparable? Is the text compatible with the title? Is a multi-decimal numbering system used?
- Have extraneous material and cross references to contract clauses and general provisions been expunged?
- Are task/line item and end item procurement provisions mutually discrete with regard to development and test versus production activities?
- Have all requirements been reviewed to ensure compatibility with the data requirements specified on DD Form 1423?
- Have all extraneous data requirements been eliminated?
- Are all obligations of the government carefully delineated? (If government furnished equipment is to be provided, the nature, condition, and availability of the equipment should be stated. If approval actions are to be made by the government, provide for a time limit. Remember that any provision which takes control of the work away from the contractor, even temporarily, must be covered by a contingency reserve if the contractor is to protect himself.)
- Have all loopholes been closed? (Contractors and inspectors go by the letter of the SOW. The contractor may refuse to do something that is only referred to, desired, or described as a goal.)
- Is the requirement completely described? (To be legal and binding, an agreement must be complete. Not only for reasons of legality, but for every practical application, it is necessary that the details be complete. Specify when and where as well as what.)
- Since they generally result either in an expensive disagreement or in a windfall to the contractor, have all "catchall" statements been eliminated?
- Does the SOW sole source the work? (The SOW specifies a requirement of the government and is supposedly impartial concerning who can do it. In keeping with this philosophy, the work statement itself should contain no reference to sources or proprietary talent.)
- Is the requirement overspecified? (The ideal situation is to specify results required and let the winning contractor find the best method of getting there.)
- Has the work been organized into tasks? (These are helpful in evaluating and during performance may be used for control.)
- Have all points of control, where needed, been included (for example, submission of designs for approval)?
- Does the SOW include only such reports and documentation as are really needed for control; documentation of technical results; and follow-on procurements?

FORMAT OF THE STATEMENT OF WORK

The importance of work statements is such that consistency of format will make them much easier to review and understand. A general format and headings for SOWs are as follows:

1.0 Introduction (Objective)

2.0 Scope

3.0 General background (information, constraints, and reference documents)

4.0 Task/Technical Requirements

5.0 Reports, Data, and other Deliverables

6.0 Special Considerations

Other formats can be used or may be directed by specific contract requirements. For statements of work prepared in support of SYSCOMS, use MIL-HDBK-245.

STATEMENT OF WORK CONTENT

The content of the SOW is described by paragraph below.

1.0 Introduction (Objective). The introduction is intended to give a brief overview of the specialty area and leads up to why this particular new program is being pursued. The overall requirement which needs fulfillment, the present difficulties or deficiencies which do not permit the requirement to be met, and the determinations which must be made to solve the problems should be outlined briefly, in fully understandable terms. Quite often an understanding of the value of the technical objective can be reinforced by inclusion of an explanation of the payoff that this technical objective will have to future naval systems capability. In framing the objective, think clearly on how the results will be used. The stated objective should be consistent with the funds planned and/or with the minimum requirements.

2.0 Scope. This section provides an overall picture of the desired work program in concise form. The scope will outline the various phases of the program and tie down the overall limits of the program in terms of specific technical objectives, time, and any special provisions or limitations. It must be consistent with the detailed requirements. This section should also describe in a clean-cut statement the end result desired or what the "product" of the effort should be. Don't overextend the magnitude expected, or an overrun may be the result.

3.0 General Background. Include any background information, explanations, or constraints which are necessary in order to understand the requirements. Discuss how the procurement arose; indicate its relationship to previous, concurrent, and future operations, including the threat analysis; and relate details which reveal its purpose and significance. Statements on the importance of the new work may also be included. Techniques which have previously been tried and found ineffective should be included. Frequently it is best to leave the writing of the background to the last. The listing of applicable technical reports resulting from the Defense Technical Information Center (DTIC) bibliography search should be entered here. Any such listing in this paragraph is for information only and is not contractually obligatory. All contractually applicable documents must be cited either in the text of the appropriate task or in a separate paragraph entitled "Applicable Documents List." If there are no applicable reports, a comment to this effect should be made on the supplemental sheet to the purchase request but not included in the SOW.

4.0 Technical Requirements/Tasks:

4.1 Areas of Consideration. This paragraph should define the work to be accomplished and indicate the main steps and actions which are required of the contractor to conduct the program properly. These main steps constitute the work phases (recommended approach). The technical leadership provided by the government in planning and establishing the contractual program appears here. It should not reflect an attitude that this is the only approach to the problem. It should state that this is a suggested method but new or unique ideas supported by available data are acceptable and encouraged. This paragraph also gives known specific phenomena methods which could contribute to a solution, possible correlation with existing knowledge, operational and installation environments anticipated for the ultimate operational equipment, and other factors, including all available foreign technology information, such as would tend to assure that the bidder/contractor would conduct a fully effective program.

4.2 If the work encompasses several areas or lends itself to division into tasks, this should be indicated. The essential procedures (that is, theoretical analyses, design, fabrication, checkout, tests, verification, formulation of final recommendations, etc.), with limits on each, constitute the bulk of this paragraph. In some cases, the engineer may wish to indicate the percent of the total effort each phase is to receive. If there are existing specifications with paragraphs that define what you want to have the contractor do in terms of tests, etc., use them or incorporate by reference, as appropriate, rather than compose original paragraphs. Specify those considerations which may guide the contractor in his analysis, design, or experimentation on the designated problem. These should include operational characteristics (if any) or other factors the contractor is expected to consider in performing under the contract. Definitions may also be included or can be identified in a separate section.

4.3 Be sure that limits of environment, test durations, combustion pressures, data recording, expansion ratio, mixture ratio, range of particle size, etc., are specified. Criteria governing the number of designs, types of propellants, performance, hardware size, number of tests, etc., and constraints such as budget, environmental, producibility, and risk levels should be included in the definitization of the work to be done by the contractor. This may be better set forth in a detail specification.

4.4 Commit yourself. When the burden of definition must be placed on the offeror, clearly impose the requirement in such a manner that he understands that he must provide this definition in the bid (if this is what is wanted) or later on in the contractual program (if this is the intent). Any specific limitation such as "not desired" or "previously tried" techniques should be stated. If there is a primary area with a secondary contributing or limiting area, these should be defined. Experimental or installation environments (known or anticipated), scientific or technical personnel, or other resources should be indicated. When the bidder provides definition or plans, it should be stipulated that these are subject to Navy approval.

4.5 A description should be given of any end item that is the subject of development. It will firmly and clearly define the required work for such tasks as those listed below.

a. Review of current literature to establish a basis for further research, analysis, investigation, or experimentation.

b. Search for new ideas through investigation of various phenomena.

c. Paper or theoretical analysis of ideas in relation to requirements, ultimate use, and trade-off capabilities.

d. Computational analysis and formulation of mathematical model. Experimentation to evolve methods of instrumentation.

f. Derivation of a basic equipment design or experimental assemblies.

g. Test and evaluation.

4.6 If the state of the art is such that one or more specific methods of approach to the solution are to be followed, this section should indicate the desired approach. If no specific approach is primarily warranted and one will be determined on the basis of the selected contractor's technical proposal, this need not be mentioned, and this section should include a statement of criteria on which a choice of alternative approaches will be based.

4.7 Scientific and Technical Information. Insert the following, if applicable: "The contractor shall search the existing sources of scientific and technical information to determine the current state of the art to avoid duplication of effort and conserve scientific and technical resources." Ensure that all generated scientific and technical information that has significant value to the pertinent scientific and technical communities is furnished to the DTIC.

5.0 Reports, Data, and Other Deliverables. Contract data or reporting requirements should not be duplicated in the SOW. DD Form 1423 is the medium for establishing the requirements. The SOW may refer to the DD Form 1423 incorporated in the contract by reference or even to any particular data item for clarifying a requirement. If deliverable hardware is required, it should also be listed in this section as a separate paragraph.

6.0 Special Considerations. A paragraph outlining any special interrelationships between the contractors for use of government-furnished or loaned property, for example, may be devised and added to the SOW as paragraph 6.0. Any other specific directions relative to technical work (not administrative matters) for the contractor to follow should be included here. This paragraph might also provide instructions to the contractor relative to the possible utilization of government expertise.

WORK PACKAGES

An integral aspect of both understanding and developing a statement of work is the ability to separate the complete effort into smaller, concise work packages. The reasons for doing this are several:

The job is much easier to estimate by segment than as a total.

The work packages essentially become the task breakouts in the final SOW.

The prospective contractors will segment the work in their responses, giving another dimension for evaluation.

In many instances, work packages can be used to indicate a desired approach to a problem.

The action of generating work packages will indicate to the technical code areas in which it is not sure of the specifics of its requirements.

The breakout of work packages cannot be formalized into a procedure, since each one will be different from all others — just as each SOW is different. The effort can only be defined as a realistic separation of a total effort into its reasonable parts. In general, the work packages should conform to the project work breakdown structure (WBS) (see chapter III, Program Planning — Organization).

SOW TASK AREAS

The content of specifications is limited to technical requirements in terms of design, performance, and test. The exactness of design details may be specified to the extent necessary to ensure the interchangeability of certain components, modules, or parts. In view of these limitations, it becomes necessary to establish other contract tasks in the SOW to supplement the specification. The following task areas are typical in support of a specification:

1. Integrated Logistic Support Program Requirements

2. Configuration Management Program

3. Technical Manual and Publications

4. Training Requirements

5. Acquisition Management System Requirements

6. Supply Support Tasks

7. Engineering Drawings and Associated Lists, Tasks and Ordering Data (paragraph 6.2 of MIL-D-1000)

8. Contractor Services Requirements

9. Quality Program Requirements
10. Level-of-Repair Program Requirements
11. Test Point, Nodes, Calibration, and Instrumentation Information Requirements
12. Reliability Program Requirements
13. Maintainability Program Requirements
14. Human Factors Program Requirements
15. Safety Program Requirements
16. PMS (Planned Maintenance Subsystems) Requirements
17. Electromagnetic Compatibility Program Requirements
18. TEMPEST Control Program Requirements

In addition, there are project tasks which go beyond the scope of the technical effort and its management which also must be included in the SOW. The following task areas suggest some of these “other” tasks:

1. The development of specifications and data for future project phases
2. Tasks in support of a design-to-cost effort or life-cycle cost procurement
3. Standardization program
4. Value engineering program
5. Special research, investigation, or study tasks independent of, but supporting, the equipment specified
6. Special data/information requirements (which will be ordered in the CDRL) not derived from a specification requirement or SOW program requirement

Date______________

SAMPLE
Statement of Work
Brand Name or Equal

Electric Motor-Generator Set, 60 Hz to 400 Hz
XYZ Company, Model 1234, or Equal

1.0 Introduction

1.1 This statement of work specifies a NRaD requirement for fabrication and delivery of a commercial electric motor-generator set, 60 Hz to 400 Hz. The XYZ Company Model 1234 motor-generator, or an equal, will meet this requirement.

2.0 Technical Requirements

2.1 The contractor shall provide all necessary materials and services to fabricate an electric motor-generator to meet the specified characteristics and limits in the attached NRaD Specification 0004780.

/s/________________________________

APPENDIX C: EVALUATING PROPOSALS

The purpose of the evaluation is to select the source(s) whose proposal has the highest degree of realism and credibility and whose performance is expected to best meet the government objectives at an affordable cost. This is to be done in a manner which assures an impartial, equitable, and comprehensive evaluation of each competitor's proposals and related capabilities and which minimizes the complexity of the solicitation while maximizing the efficiency of the evaluation/selection decision. This process is directed by DoD Directive 4105.62 of 6 January 1976.

The evaluation process includes an evaluation plan, a solicitation, the actual evaluation, negotiations to clarify details, and source selection. The evaluation plan is formulated prior to the solicitation and serves the following purposes:

To ensure that all efforts are directed toward a common goal

To collect, organize, and display the performance, schedule, and cost requirements by emphasizing pertinent evaluation criteria

To provide a structure for organizing the evaluation group and scheduling its activities

To provide a structure for the preparation of the RFP

To establish a format for discussion at preproposal conferences, if held, and later offeror or contractor discussions

To serve as a guide for the contracting authority in source selection

To provide procedures and methodology for evaluation purposes

To provide guidelines for making tradeoffs among and within the various factors to the performance of the equipment and to the management of the project in relationship to the development, production, operating and support costs, the delivery schedule and quantity, and the qualitative requirements of the procurement

The solicitation should request proposals in two parts, the first containing the technical and management responses and the second addressing costs. Page limitations on the solicitation and on the proposals are encouraged, provided that completeness is not sacrificed. The solicitation should state technical goals, tolerances, and acceptable values within which tradeoffs can be made. The solicitation also must request the types of detailed information which will allow an evaluation of the technical approach, the respondee's understanding of the complexity of effort and risks, the proposer's experience and capabilities to perform the required tasks, and the realism of schedules and costs. The solicitation also states the criteria, methods, and procedures used to conduct the evaluation, but not the weighting and scoring.

The evaluation plan should include the following:

- Evaluation elements incorporating all specification and SOW requirements (each element may address a general area covering many individual specifications and SOW requirements)

- Element weighting based on system-critical requirements and the acquisition strategy (as a minimum, a qualitative weighting of critical, important, noncritical, and desirable should be used); a numeric weighting is preferred, especially when it is derived from a system-effectiveness model).
- Scoring plan (a method of combining raw scores from each evaluator for each element into a single proposal score)
- Procedures for resolving inconsistent scores
- Acceptance criteria

In general, the scoring plan should assign a zero for unacceptable proposals for any critical elements. The acceptance criteria should identify the conditions under which a proposal will be accepted without modifications, may be modified through negotiations, or rejected. The project manager, system engineer, and contracting officer should mutually agree to the plan prior to the release of the RFP.

The actual evaluation is based upon the scoring of each proposal against the preestablished evaluation criteria ranked in order of importance and weighted accordingly. Specific factors and rankings will vary with each procurement, but the cost proposal will always be evaluated separately from the other part. In general, the scoring should follow these guidelines:

Raw Score	Description
9–10 (90–100)	Excellent—comprehensive and complete; meets or exceeds all proposal requirements; exemplifies complete understanding of the requirements; and demonstrates in detail how to accomplish the task.
7–8 (70–80)	Good—generally meets or exceeds proposal requirements; omissions are of minor consequence or small; would be likely to produce an acceptable end item.
5–6 (50–60)	Adequate—omissions are of significance, but are correctable; substantiation of points is weak or lacking; probability of successful effort is marginal.
0 (0–49)	Unacceptable—gross omissions; failure to understand problem areas; failure to respond to requirements; little or no chance of success in completing the end item.

Each evaluator will formulate questions on each proposal, and the consolidated questions can be submitted to the offeror for clarification. In each case, the government evaluates each proposal against its own previous estimates to assess the realism of cost, schedule, risk assessment, and technical approach; and against established standards for management, accounting practices, and the like. Proposals which are unrealistic in terms of technical and schedule commitments or unrealistically low in cost or price can be rejected on the grounds that the offeror fails to comprehend the complexities and risks of the contract requirements or else has made an improvident proposal. Only proposals which are evaluated as acceptable (by preestablished criteria) will be passed for final source selection.

The final source selection is an integrated decision based on a consideration of technical approach, capability, management, design-to-cost, historical performance, price/cost, and other pertinent factors. The selected source(s) should be the one(s) who is expected to do the best overall job for the government at the best price. The selected offeror's proposal (technical, management, and cost) must satisfy the government's minimum requirement.

XVII. DEVELOPMENT ALTERNATIVES

It is desirable to avoid development — with its associated risks, tests, and time requirements — whenever possible. Nevertheless, some development may be necessary to support the various phases of the acquisition cycle.

DEVELOPMENT IN THE CONCEPTUAL PHASE

The purpose of exploratory development is to investigate or evaluate the feasibility or practicality of a concept, device, circuit, or equipment in rough experimental breadboard/brassboard form without regard to the eventual overall fit or final form. A concept can frequently be proved in theory through paper analysis, simulation techniques, or the mere existence of similar commercial products; however, these techniques may have an unacceptable degree of uncertainty attached to them or may restrict program options unnecessarily. Exploratory development as a method of proving feasibility is relatively inexpensive compared to later development efforts and may be pursued to excellent advantage if certain guidelines are followed to avoid pitfalls. In combination with some degree of operations/threat/technology/force objec-tives analysis, exploratory development can also serve to validate the operational requirements statement.

The major problem to be solved in setting up an exploratory development program is to maintain options in the follow-on phases; all too often, a course of action picked in pursuing exploratory development will dictate the future of the entire acquisition program. The primary alternatives in conceptual phase development are the following:

In-house development
In-house development with industry support
Industry development of technology
Industry development of the technical approach

The in-house alternatives are flexible; when industry support is required, small, well-defined work packages should be formulated. The primary difficulty with in-house approaches is in creating and maintaining a diversity of possible technical approaches because of the natural biases of any single organization; nevertheless, a number of different approaches can be generated quite efficiently if that requirement is stated in the development tasking. When industry is utilized to develop the technical approach, a number of contractors should be utilized to engender competition between approaches. The contracts should procure all rights and documentation to the developed approaches; otherwise, the government may later find itself in a sole-source position with the contractor dictating the prices. Multisource contracting should also be employed when industry is used to develop technology; again, the procurement of rights and documentation is important because the high exploratory development risks may yield only a single successful technology which the government may wish to exploit with multiple sources in the future.

In any of the alternatives, it is important to document and maintain some configuration control on the developed item so that the knowledge gained is not lost to future phases. Another important consideration is the decision for in-house or industry development in any future phase of the acquisition cycle. If industry plays a major role in the conceptual phase, it is difficult to pursue any in-house development later regardless of the program decision factors because of the political forces which are activated by industry participation.

When it is necessary to sole-source industry participation in exploratory development, the participation should be on only one of several possible alternative approaches. Because of the potent political forces accompanying industry involvement, the industry tasks should be divorced from the program in name and funding — that is, totally.

The system concepts and overall system design are the responsibility of the Government. The use of industry during the conceptual phase does not and should not abrogate this responsibility.

DEVELOPMENT IN THE VALIDATION PHASE

Advanced development is intended to demonstrate the technical feasibility of a design, to determine its ability to meet existing performance requirements, to secure engineering data for use in further development, and, where appropriate, to establish the technical requirements for contract definition. Dependent on the complexity of the equipment, technical risks, and other technological factors involved, advanced development may necessarily be an iterative process in order to achieve the development objectives. The final development iteration should closely approximate the required form factor including the appropriate levels of repair, standardization, reliability, maintainability, safety, human engineering, and environmental qualifications. The development model produced may be nothing more than an assembly of existing equipments or it may consist of extensively developed equipments.

The purposes of the validation phase may be served by the proof of feasibility of a key concept, device, circuit, or equipment in combination with technical analysis if the other portions of the envisioned system are well defined, the system integration has a low risk associated with it, and sufficient engineering data are available for further development and any contract definition requirements. However, the confidence achieved through advanced development can greatly reduce the technical risk associated with follow-on development. Except that the assembled system and its performance to existing requirements are at issue rather than the feasibility of a piece of the system, the considerations, issues, and alternatives in advanced development are almost identical to those in exploratory development. The provision of documentation and preservation of options in the succeeding acquisition phases are important. To this end, compatibility with possible procurement alternatives and the major issues in the transition to production must be maintained. Since advanced development frequently defines values for parameters in the technical requirements, it is important also to define acceptable tolerances in order not to exclude possible existing equipments.

When industry development is pursued, competition should be maintained between at least as many sources as will be solicited in the follow-on phase.

It is the Government's responsibility to ensure that a development baseline is clearly defined and low-risk for follow-on engineering development.

ENGINEERING DEVELOPMENT

Engineering development is the most expensive development phase; however, the technical risks encountered should be less than in either advanced or exploratory development. Engineering development includes the product design and production engineering tasks required to make the item reproducible while maintaining the performance, reliability, maintainability, environmental, human engineering, etc., characteristics which were determined to be required in the validation phase. The technical risks are greatly increased, however, when an advanced development phase has not been completed or when the technical requirements parameters have not been sufficiently validated to have established acceptable tolerances. Tight tolerances are more difficult to engineer into production processes, and the lack of solid engineering data increases the "fudge factors" an engineer utilizes to ensure the product will perform as intended. In practice, some increased risk must be assumed in order to move ahead in the acquisition process. Engineering development costs are higher because of (1) the scope of the engineering effort, (2) the detailed configuration control which must be maintained on production processes and tooling as well as on the design of the equipment, and (3) the multitude of documentation and support efforts normally associated with this phase—ILS tasks, technical manuals, provisioning lists, etc. (see chapter VI, Transition to Production).

The selection of an engineering development alternative will depend on the resolution of the major issues in the transition to production and the procurement mode alternatives. The first issue will be in-house versus industry development; the factors in this decision include the extent of industry involvement in prior phases, the appropriateness of in-house involvement, the capabilities of available in-house resources versus industry sources, the government needs for precise control of the technical effort in conjunction with other program factors, and the percent of the system requiring development. If industry has played only a support role in prior phases, in-house involvement is appropriate (necessary), and capable in-house resources are available, the in-house execution should be selected. The necessity of in-house involvement may arise from the factors under which in-house development is appropriate (see chapter VI), from government need for control, or from the primacy of the system integration responsibilities when only a small portion of the system requires development. Normally, an industry alternative will be selected; this will require resolution of the major issues prior to the development contract solicitation. In addition, the following issues must be considered: (1) requirements for competition, (2) program cost constraints, and (3) prior industry involvement.

If industry has been involved in prior phases, will those contractors be capable of meeting the remaining program requirements for production and support, and will they be adequate in number to support any needed competition dictated by the procurement mode? A competitive base must be maintained up to the point that all follow-on costs for procurement, reprocurement, and contractor support can be fixed within contractually binding limits. If new contractors are to be brought in, provisions must be made to educate/indoctrinate the contractors to the program requirements, key program elements, acceptable tradeoffs which may not have been specified, etc. If a sufficient number of contractors have participated in advanced development, competitive selection may be considered for engineering development. If an insufficient number of contractors are available to support the procurement mode needs, provisions should be made to execute the preproduction phase in-house, or at least to make the successful validation of the design data package part of the acceptance procedure for the engineering development contract in a leader-follower program.

Further requirements for competition may arise from the risks associated with the technical approaches identified in the prior phases. If the technical risk is low — i.e., the major system equipments have been previously developed and used together on a prior program and require only adaptational development for this program — a single technical approach may be pursued. If a moderate risk exists — e.g., the major system equipments have been previously developed but never before integrated in this way — a primary technical approach should suffice, but alternative approaches should be identified which can provide an acceptable product with minimal transitional costs should the preferred approach bog down. If a high risk exists — e.g., one or more major system equipments requires development — parallel technical approaches should be pursued.

Program cost constraints can be major determining factors, especially for low priority programs. Funds may not be available to support competitive development or an adequate preproduction (design validation) phase, and conditions may not lend themselves to functional specification procurement. Assuming in-house development cannot be followed even though it may be the best alternative under these conditions, and assuming no additional funds can be identified for design validation, the procurement must be converted to a combined design-to-cost and life-cycle-cost procurement. Design-to-cost procurements attempt to control acquisition costs and contractor-supplied support costs; life-cycle-cost procurements attempt to control operations and support costs. Both types of procurement are discussed below. This type of combined procurement is risky; the contractor must be contractually obligated to absorb loss due to his failure. If such a contract is not feasible (because of the extent of development uncertainty), and if contractor default cannot be allowed for any reason, the government is better off canceling the acquisition altogether.

DESIGN-TO-COST (DTC) PROCUREMENT

Program cost constraints in the procurement phase give rise to design-to-cost (DTC) procurement modes. In DTC, acquisition costs are fixed prior to engineering development and provisions for proving the cost targets have been achieved and are incorporated into the acceptance procedures; contractual incentives are often employed. Very wide and notably achievable performance tolerances are normally required because cost is the prime design factor and performance is traded off to achieve that cost within acceptable limits. The advanced development phase is usually required to identify reasonable-cost targets and acceptable performance parameters. Procurement quantities to support multiyear, multisource buys are required.

The *Joint Design-to-Cost Guide* (AMCP 700-6/NAVMAT P5242/AFLCP-AFSCP 800-19) contains guidelines in the formulation and execution of a DTC procurement.

LIFE-CYCLE-COST (LCC) PROCUREMENT

Life-cycle-cost (LCC) procurements are useful when the equipment service life is long enough that support costs become significant; generally, only a few years is required, as these costs can accumulate rapidly. A reasonably accurate LCC model for the system is required, and the award of the contract is made to the lowest bid which results in the least overall costs to the government. A number of procurement modes are available along this theme. The *Life-Cycle Costing Procurement Guide* (DoD LCC-1) is useful in constructing the model, and the *Life-Cycle Costing Guide for System Acquisitions* (DoD LCC-3) discusses the procedural aspects, including some suggested procurement modes. LCC procurement can be particularly effective when long-term warranty provisions are integrated into the procurement. LCC procurement effectiveness is greatly enhanced when large reprocurements can be made over many years to multiple sources.

TECHNICAL ACQUISITION STRATEGIES

ADVANTAGES AND DISADVANTAGES

Sequential or Waterfall

Structure: This model proceeds from logical phase to logical phase. The model reduces risks by enforcing well-defined entrance/exit criteria for each phase. It is the procedure recommended for major (ACAT I/II) programs by DoD directives. It is the baseline against which all other methods and models are compared.

Advantages: Close correlation between design thought processes and planning processes when appropriately applied; therefore, is well coordinated with management strategies. Can be highly cost-efficient. Well understood by most supervisors of the acquisition process. Usually provides good breakpoints for contract efforts and, therefore, meshes well with procurement strategies. Usually works well when funding is influx because efforts can be shut down and started up in an orderly manner without major replanning (as long as design documentation and testing are in sync with design efforts).

Disadvantages: Usually results in longer schedules. Does not handle rapidly changing or poorly defined requirements well. Very complex problems (which usually result in poorly defined requirements) require extensive studies and investigations in this model which may delay the development of product.

Example: AN/SRC-47 Flight Deck Communication System.

Integrated Cross-Disciplinary

Structure: All designs are undertaken by interdisciplinary teams which cover all disciplines which are to be needed in the product development (or portion thereof). Although designs are approached in distinct phases, design considerations in each phase take into account the requirements of future phases.

Advantages: Overall product development time is generally both shorter and less expensive than sequential methods. Overall product quality is generally increased. The method works well in a TQM environment and can be combined with other methods to gain efficiency.

Disadvantages: Some wheel-spinning and start-up inefficiencies are almost always incurred (project morale can be adversely affected). Well-understood requirements are needed, although some changes can be accommodated if the change environment is understood.

Example: AN/GSC-40 SCIACT.

Parallel Path

Structure: Multiple technical approaches are pursued in parallel until the required performance can be demonstrated. Applicable to technical projects with extremely high technical risk. Requirements must be reasonably stable. Funding must be stable.

Advantages: High technical risk can be effectively handled while delivering a product within a reasonable length of time.

Disadvantages: Sufficient resources, especially funding, must be available (and justified) to support all paths. The paths must be independent of each other in their technical risk (not risk-dependent on the same laws of physics).

Example: Initial Navy Nuclear Power Program (development of NAUTILUS and SEA WOLF).

Parallel Competition

Structure: Multiple contractors are funded to address the requirements. Parallel paths are pursued until a solution is definable and risk is reduced. Requirements should be reasonably well defined. Funding should be reasonably stable.

Advantages: Can handle moderately high technical risk. The varying skills of the contractor organizations each contribute to the problem solution in different ways. Another organization (such as in-house resources) may be required to integrate partial solutions into a whole product, but solutions may result which could not have been developed by any of the design agents independently. Competition is often encouraged when there is a sufficient production run.

Disadvantages: Sufficient funding must be available and justified to support all efforts. Progress toward a solution must be measured to ensure that a solution is being developed. Unstable funding or poorly defined requirements can lead to large losses and gross inefficiencies.

Example: LVT7.

Prototyping

Structure: Prototype is used to define ill-defined requirements. The prototype is used for user evaluations, laboratory tests, or other technical investigations to gather the needed information. The prototype is constructed to be easily changed so that a wide range of parameters can be evaluated across the problem domain.

Advantages: Can promote development of solutions to very poorly defined problems.

Disadvantages: Prototypes are inherently difficult to support for long periods of time and are notoriously difficult to convert into a supportable product. Some other strategy is needed to get to the final system configuration.

Example: TFCC.

Incremental

Structure: Incremental approaches separate requirements which are well known or well understood and requirements which are stable from the “poorly behaved” (high-risk) requirements and form a system product around the well-behaved (low-risk) requirements. This base system product is developed and fielded as a first increment. Studies and exploratory development tests are used to harness the poorly behaved requirements, which are incremented into the system product as they are matured to a point that they can be handled. The system architecture and the baseline increment design anticipate the future increments and include interfaces which simplify their inclusion.

Advantages: The base capability can be fielded early and with relatively low risk. Future increments can be prioritized and fielded in an affordable manner. The method works well when funding is variable or from different sources.

Disadvantages: Substantial up-front system engineering is needed to establish a system architecture which can accommodate the future changes easily. Extensive configuration management is needed from the beginning. A failure to either the system architecture well or the configuration management increases costs very substantially over sequential methods.

Example: ASWTDA and Advanced Prophet (FF-1052 is an example of a poorly executed incremental strategy).

Preplanned Product Improvement (P^3I)

Structure: Preplanned product improvements are used when a usable base capability can be defined and fielded short of the ultimate desired (and justified) capability when technology needs to be developed to support the desired capability. Characteristics of this approach are very similar to the incremental approach except the architecture and subsequent development is technology-driven rather than requirements-driven.

Advantages: Same as incremental.

Disadvantages: Same as incremental.

Example: F-14D.

Evolutionary (Spiral)

Structure: This approach fields a core capability, obtains user input from field use, and adds/expands the capabilities based on those inputs. In this method, development and maintenance are somewhat smeared together. The method is most useful when the requirements are not fully known initially and/or when they are heavily user-driven.

Advantages: User satisfaction and utility tend to be very high as a result of this strategy, assuming that there is sufficient quality in the core capability to engender user acceptance. Costs of documentation and change control (which are extensive) are balanced by the building of a high-quality product that has few requirements defects.

Disadvantages: The methodology is such a radical departure from sequential methods that very heavy tailoring must be accomplished and approved by the program milestone decision authority for virtually all elements of the program plan. Support contracts become difficult to write because there are not clearly defined decision points unless the evolution is spread out over a long time. The measurement of user satisfaction and the gathering of user inputs can be difficult to do, but it is essential to the success of this approach. Documentation costs tend to be higher in this method than with sequential strategies because baseline documentation is continually being changed. Configuration management is essential to control costs of changes.

Example: NTDS, many command control systems, most commercial software products, many software projects.

Chunking

Structure: This method works well when requirements are rapidly changing. Small capable "chunks" are identified and developed and fielded very rapidly—more rapidly than the requirements are changing. A system architecture is needed that allows additional chunks to be added in as building blocks. This architecture must allow previously fielded chunks to be replaced easily. Typical programs using this method rely heavily on NDI elements to provide core capabilities. The method can be used effectively for one-of-a-kind systems as well as large production run systems.

Advantages: Can handle rapidly changing requirements and funding instabilities well because work increments occur in shorter intervals than the external changes. This method is amenable to multiple sponsorship situations.

Disadvantages: Interface documentation is much more extensive in the associated architecture and more essential to program success. A modular system architecture is required. Change costs on large production run systems can be large if there is a need to change out hardware.

Example: Many small fleet support systems.

Leader-Follower

Structure: A prime developer (leader) accomplishes the design and initial production, then turns the design over to another contractor (follower), who becomes a second production source. The follower is often used to validate the system documentation. The method allows competition to be maintained through the production phase. This method is most applicable when requirements and technology issues are not drivers and when a large, lengthy production run (high-volume production) is anticipated.

Advantages: Builds competition through production. Helps ensure that system documentation is validated. Helps to ensure an enduring production base.

Disadvantages: Transition to the follower is often expensive and difficult to achieve. If the design is performance-based rather than fabrication-based, multiple products with slightly different support characteristics must be supported in the field (at a cost). If the design is fabrication-based, the production risk is almost wholly on the Government.

Example: MK 50 torpedo, SINCGARS, most in-house developed systems which are mass produced.

Competitive Fly-Off

Structure: This strategy employs multiple developers of system designs and selects down to the production system based on DT/OT2 testing. This method is encouraged by OMB Circular A−109. Stable requirements are needed for successful employment of the competition. The design competition encourages innovation and cost control (when the contracts are properly written). Because the fly-off is a select-down which limits future competition, this method is usually combined with the Leader-Follower strategy for systems which have a significant production run. On small production runs, reliability improvement warranties and other procurement techniques which fix future costs are usually employed.

Advantages: Benefits of competition are brought to bear against difficult technical problems. Useful for high technical risk programs.

Disadvantages: Costs of multiple developers. Difficulties in writing contracts and specifications which are not biased toward a solution.

Example: F-16/17.

Recursive

Structure: This strategy is used when top-level requirements are well defined but detailed design requirements are poorly defined. System is designed from the top down, evolving greater and greater requirements detail.

Advantages: Good requirements traceability is maintained for changes when requirements change. If object-oriented architecture is used, detailed levels can be isolated from high-level changes.

Disadvantages: This is a relatively new strategy that is poorly understood by those who have not tried it. Also, heavy tailoring is required at all levels of program planning (as with evolutionary strategies).

Example: NATO Interoperable Submarine Broadcast System (NISBS), Object-oriented software development.

XVIII. INSTALLATION PLANNING

This section provides information to assist the project manager in planning for system and equipment installations on Navy platforms − temporary, for tests and evaluations; and permanent, for service use.

TEMPORARY INSTALLATIONS

The primary purpose of temporary installations (under 1 year) is to subject equipments to the operational environment for a realistic test and evaluation (see chapter XIX). However, short-term operational requirements may also dictate the temporary installation of equipment in service platforms, and occasionally it will be necessary to install instruments to measure operational environments. Whatever the circumstance, the proper management of a temporary installation is important to the success of the project and to the operation of targeted platform.

The project is responsible for supplying all the resources necessary to accomplish and to disestablish a temporary installation. The funding is in excess of any special operating and observer costs for operational tests and evaluation. The installation personnel are under project tasking. It is incumbent on the project manager to plan for these requirements well ahead to ensure that the budget is adequate to support the installation tasks.

The most difficult task in the temporary installation is obtaining Fleet services and coordinating them with the availability of the equipment to be installed. Fleet services are requested through CNO in accordance with OPNAVINST 3960.10. (However, minor services are sometimes available informally through special laboratory-type commander relationships such as the Navy Science Assistance Program (NSAP) and other Fleet assistance functions.) These formal procedures are designed to coordinate the burden on Fleet operations and should be followed for all formal test programs.

The other tasks are as follows:

1. Preliminary planning — establishes the scope of the installation; the number of equipments involved; the interfaces to platform systems such as power, air conditioning, navigation systems, and sensors; the types of materials needed; the skills needed to execute the installation; the types of support required for the equipment while it is installed; and the travel and transportation requirements for the installation personnel and the equipment.

2. Installation survey — accomplished well ahead of the planned installation date, the survey identifies precise equipment installation sites, mounting requirements, relationships with platform interfaces, cable routings and distances, and man-hour estimates for the different installation skills.

3. Detailed planning — tasking of the installation team (project personnel, contractor field representatives, shipyard, etc.), procurement of required

materials, documenting the installation procedures, establishing checkout procedures, and determining ripout procedures.

(Plans for temporary submarine installations must be submitted to the cognizant NAVSEA Ship Logistics Manager (SLM) for approval.)

4. Installation and checkout

5. Ripout — it was, after all a temporary installation.

It is wise to use the installation survey to establish good relations with platform personnel and to keep them informed of your intentions. They can be a valuable source of information regarding unsuspected problems or unusual platform characteristics and can also provide limited assistance in the installation, operation, and maintenance of the equipment beyond the well-defined scope of operational testing.

No matter which type of platform — ship, aircraft, vehicle, or whatever — is involved, the thorough advanced planning and detailed execution of a temporary installation are essential. The failure to plan adequately will result in badly slipped schedules or poor equipment operation. The installation plan should include steps to ensure that the installed equipment does not interfere with (or, conversely, is not susceptible to interference by) equipments already on the platform; many problems can be created by mounting equipments too close or overloading interfacing systems and the like which a sensible approach can avoid. Also, the installation plan should show contingency plans covering changes in schedule, in either equipment or platform availability. As with any other project task, plan ahead, anticipate and minimize risks and execute the plan to maintain the pattern of success.

PERMANENT INSTALLATIONS

Navy operational requirements tend to grow ever more complex. New systems and equipments and improvements to existing equipments are constantly demanded. Thus, Navy platforms are constantly undergoing change. Without change control, installation of new equipment and alternation of old would eventually become impossible. Table XVIII-1 summarizes the types of alterations and changes affecting Navy platforms.

Table XVIII-1. Alterations and changes.

Type of Change	Cognizant SYSCOM	Initiating Document	Funding Source	Reference
SHIPALT Military Improvement	Sponsoring SYSCOM	PMI	FMP	OPNAVINST 4720.2D, NAVSEAINST 4720.3
Technical Improvement		ECP	FMP	MIL–STD–480, NAVSEAINST 4720.3
QRC SHIPALT			PMI or ECP as appropriate and Ltr of Justification	
ORDALT	NAVSEA	ECP	project (until normal budgeting occurs) FMP	(see SHIPALTS)
SPALT	NAVSEA08	ECP	OMN/FMP	SSPIP4720.1C
AIRALT	NAVAIR	ECP	OMN/ PAMN	(NAVAIRINST 4720.1B) for modifications
SPECOMALT	NAVELEX	ECP	OMN	NAVELEXINST 4720.1, NAVELEXINST 11000.1B
Shore site	NAVELEX	ECP	OMN	NAVELEXINST 11000.1B
Electronic field change	NAVELEX	ECP	(see MIL–F–17655)	MIL–F–17655C

SHIP ALTERATIONS (SHIPALTS)

All proposed alterations classified as military improvements and technical improvements to the ship, to hull equipments, or affecting space layout or configuration are handled by SHIPALT. Alterations to ordnance equipment (ORDALTs) are handled as SHIPALTs.

Ship alterations are controlled through the Fleet Modernization Program (FMP). The Naval Sea Systems Command (NAVSEA) is the designated executive agent for the FMP. For alterations of minor impact, CNO delegates responsibility for configuration control to the cognizant systems command.

These programs are structured so that they may be properly planned, documented, scheduled, funded, and executed. Review of engineering effort and cost-performance tradeoff are built in. The project manager is well advised to allow adequate time for all these essential steps in what by its nature must be a lengthy and serial procedure.

FLEET MODERNIZATION PROGRAM

Ship alteration programs requiring depot-level capability or budget action for the procurement of special material are scheduled through the Fleet Modernization Program (FMP). The FMP is promulgated by CNO and managed by NAVSEA (see fig. XVIII-1). It is implemented via the semiannual FLTMOD conference. Inputs to the conference are consolidated in the Military Improvement Plan (MIP), the Technical Improvement Plan (TIP), and the Amalgamated MIP/TIP (AMT) — one AMT for each ship class.

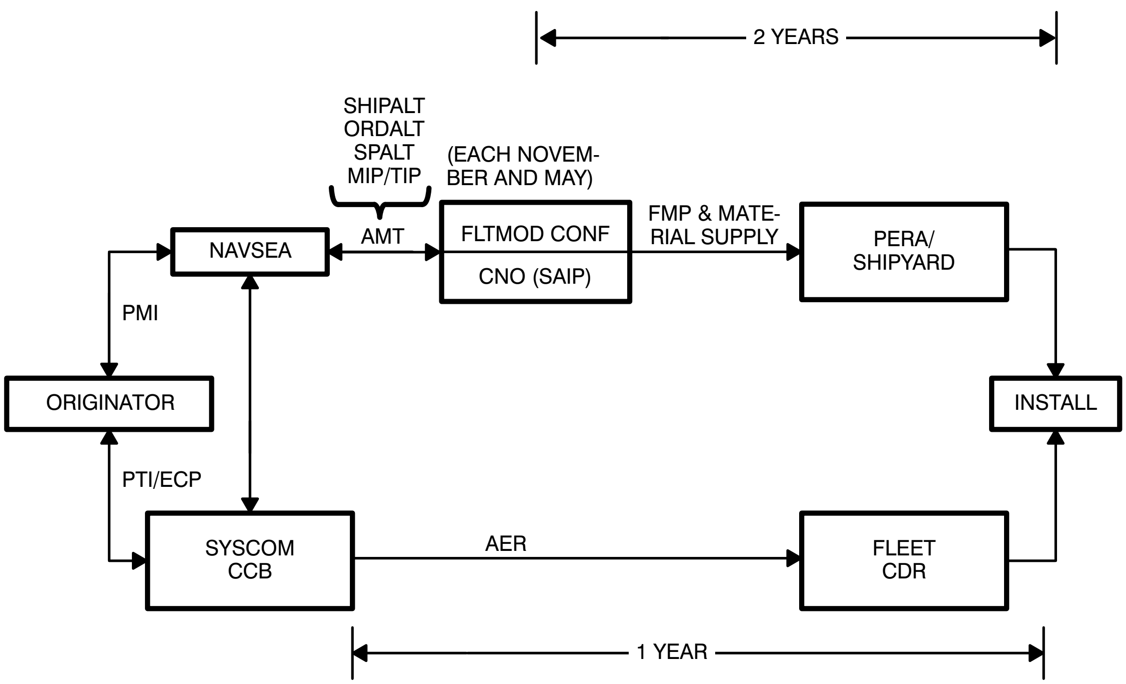


Figure XVIII-1. Fleet modernization program (FMP).

The MIPs and TIPs are working papers used by the SYSCOMs and type commanders in preparing for FLTMOD conferences and by the Ship Acquisition and Improvement Panel (SAIP) as inputs to the AMTs.

The AMTs are developed by the SAIP–Working Group, with the technical support of the SYSCOMs. They are based on consideration of ship and personnel safety, new systems and programs, fleet capability, and CNO policy. They consolidate and prioritize MIP and TIP items and make it possible to establish realistic plans for their accomplishment. They are used to determine alterations to be added when additional funds become available and alterations to be eliminated when programs are reduced. They constitute the basic FMP documentation.

SUBMITTING PROPOSALS FOR ALTERATIONS

The type of initiating document which must be submitted for a proposed alteration depends upon the nature of the alteration (see table XVIII-1). The Pro-posed Military Improvement (PMI) is the initiating document for a SHIPALT which effects a military improvement (one of nature or magnitude such as to increase its operational capabilities). The Engineering Change Proposal (ECP) is the initiating document for a SHIPALT which effects a technical improvement (one which concerns the safety of personnel or the reliability, maintainability, and efficiency of installed equipment). Ordnance alternations (ORDALTs) and Special Project Alterations (SPALTs) (nuclear propulsion plant and tender nuclear support facility alterations) are also initiated by ECP.

It is important that the project manager fully identify critical installation parameters and procedures upon requesting an alteration. The estimated increase in weight and vertical moment should be stated, together with a recommendation for the removal of sufficient weight to compensate for it. If an alteration involves a reduction in space or living facilities normally available, the amount of the reduction and the reason for accepting it should be stated. After a PMI is approved, and upon request of the appropriate SYSCOM, the PMI originator develops information to serve as guidance for the SYSCOM in matters concerning plans, support requirements, equipment/material, test equipment, test and checkout, weight and moment, training, manpower, and personnel.

In the interests of standardization, approved alterations are normally authorized for all ships to which they are applicable.

APPROVAL OF ALTERATIONS

Military Improvements

The decision to incorporate a Proposed Military Improvement (PMI) rests with CNO (SAIP). The SAIP — Working Group reviews and determines acceptance at the FLTMOD conference. Due regard is given to ship situation resulting from alterations already included in the AMT for the particular ship class.

Approved PMIs are entered officially in the MIP and are considered for appropriate priority. If doubt exists as to whether an improvement is military or technical, the matter is referred to CNO (SAIP) for resolution. PMIs not approved are returned to the originator.

Technical Improvements

Requests for approval of proposed technical improvements are forwarded to the cognizant SYSCOMs as ECPs. The SYSCOM reviews the alteration under the command of the SYSCOM Change Control Board (CCB). The alteration is reviewed for concurrence in classification. The CCB approves or disapproves, assigns priorities, and determines whether the improvement will be handled as a SHIPALT. If it is to be handled as a SHIPALT, the approved ECP is forwarded to NAVSEA, where it is officially entered in the Technical Improvement Plan (TIP) upon acceptance and considered for priority at the next FLTMOD conference. The TIP is approved by the cognizant SYSCOM.

Ordnance Alterations (ORDALTs) are handled in much the same manner, by the cognizant ordnance section of NAVSEASYSCOM.

If the technical improvement is an Alteration-Equivalent-to-Repair (AER) (substitution of different but standard materials or parts of later design; strengthening for greater reliability; or other minor modification or replacement), it may be approved and authorized for accomplishment by the fleet commander to the extent that such authority has been delegated by the SYSCOM. A SHIPALT is not necessary.

When a technical improvement is disapproved, the originator is notified.

Execution of the FMP

The FLTMOD conference takes place each year in May and November. The FMP is published in July and January. It contains firm, proposed, revised, and tentative listings. It constitutes the CNO-approved program for modification and improvement of the ships of the Fleet.

Fleet and type commanders, OPNAV, and NAVSEASYSCOM and other commands participate in the formulation and review of this program. NAVSEA collaborates closely with all concerned to achieve efficient execution of changes in requirements, available funding, material delivery schedules, overhaul schedules, and the other factors which bear upon stability. NAVSEA issues a Material Supplement for each semiannual FMP covering the FMP Execution and Budget Year and authorizes advance planning by Planning and Engineering for Repairs and Alterations (PERA) and overhaul yards as required.

At the time of approval and promulgation of the FMP by OPNAV, distribution of the FMP is made under the cover of CNO letter of promulgation. This letter advises the fleets regarding actions to be taken if program adjustments become necessary to meet changing operation conditions.

Requests for changes to the approved FMP from Forces Afloat, Program Managers, or other sources must be directed to CNO, with compensation and justification, via the type and fleet commander where applicable, with information copies to NAVSEA.

QRC/RDC SHIPALTS

Requirements which are identified out of phase with the normal programming and budgeting cycle and which are considered by the SAIP — Working Group to be of higher priority than existing requirements are accommodated on a case basis. Quick Reaction Capability SHIPALTs are initiated by letter of justification. Sponsors of these Quick Reaction Capability and Rapid Development Capability requirements must assure that normal programming and budgeting are commenced immediately.

SHIP LOGISTICS DIVISION APPROVAL

All new shipboard installations and configuration changes that affect the interface between a ship and its systems and equipments are reviewed by the cognizant

NAVSEA Logistics Division (SLD). This includes all long-term (over 1 year) temporary installations such as mission-oriented installations, OP/Tech Installations, and R&D installations.

The installation plan should be submitted through the cognizant type commander well in advance of the required approval date in order to allow adequate time for NAVSEA review. It should include the following information: project title, security classification, sponsoring activity, applicable ship and type commander, installation duration, installation site, installation activity, installation technical support requirements, installation impact data, and installation drawings (see appendix A).

NAVSEA reviews the installation plan for technical adequacy, technical accuracy, and impact on ship safety, personnel safety, military capability, system interface, equipment arrangement, stability, and ship systems, and sends a message or speed letter to cognizant activities on approval.

Aircraft Alterations (AIRALTS)

Aircraft alterations and changes are managed by the Naval Air Systems Command (NAVAIR). Proposed alterations are submitted via ECP to the cognizant airframe type desk in NAVAIR. The NAVAIR CCB acts on each ECP and the originator is notified. Normally, approved alterations are accumulated and incorporated en masse into the airframe as a change of model (e.g., F-4B becomes F-4J). Mass changes are coordinated with new aircraft procurements and aircraft overhaul schedules. Changes which can be accomplished by direct black box substitution are programmed to coincide with overhauls. Alterations which are safety critical are scheduled on a priority basis.

Shore Site Alterations

Shore site alterations include Base Electronic System Engineering Plan (BESEP) and Special Communications System Alterations (SPECOMALTS). Both are administered by the Naval Electronic Systems Command (NAVELEX). Proposed changes are submitted via ECP and acted upon by the NAVELEX CCB. BESEPs are specifically managed by the NAVELEX-assigned Field Technical Authority (FTA). NAVELEX PME-117 manages SPECOMALTs. (All non-SPECOM alteration proposals should be submitted to NAVELEX headquarters; SPECOM alteration proposals should be directed to PME-117.)

FIELD CHANGES

Field changes are developed for the purpose of improving equipment after delivery to the government with respect to performance, operational characteristics, or maintenance features. The change may be a simple wiring or mechanical modification to an existing equipment and consist entirely of instructions for making the change, or it may be more extensive, requiring circuit changes and the removal and/or substitution of parts. Material supplied or required is listed in the field change bulletin, which also provides step-by-step instructions for accomplishing the change.

Field changes bear designations of type, class, and priority which are defined in MIL-F-17655C. Type indicates extent to which parts are supplied; class indicates funding and installation responsibility; and priority indicates urgency of accomplishment.

Changes are initiated by the submission of an Engineering Change Proposal (ECP) (see MIL-STD-973). The originator may be any agency involved in the design, production, maintenance, or operation of a system or subsystem. If the proposed change requires a related change to equipment or material under the cognizance of another command, a Request for Conjunctive Alteration is submitted with the ECP. The originator must ensure that appropriate drawings, sketches, and reference data are submitted to the Cognizant Technical Division, the Coordinating Activity, the Change Control Board (CCB), and other reviewing activities. The originator must also assure that copies of the ECP are distributed simultaneously to all reviewing authorities.

The SYSCOM CCB reviews and evaluates proposed changes and recommends approval or disapproval to the cognizant SYSCOM Project Office. The Project Office makes the final determination.

If an ECP is disapproved, all affected activities are notified.

ECP Approval

The systems command project offices and CCBs base their approval upon the following factors:

1. Need for the change, adequacy of justification
2. Cost-effectiveness
3. Funding availability
4. Effects on training installations
5. Impact on logistic support
6. Proposed installation schedule
7. Adequacy of the design and procurement documentation

The approval or disapproval will be documented by the CCB and forwarded to the originator.

Other Notes on Installations

Installation plans contribute to the equipment technical manuals. Refer to MIL-M-15071 for specific instructions.

In formulating installation plans, remember safety and maintenance. The installation should not create hazards for the operators and maintainers, and it should provide for ample maintenance access.

APPENDIX A: INSTALLATION PLAN

The objective of the installation plan is to provide all the necessary information to perform a cost and feasibility (C&F) study. This ensures that all elements impacting the ship and its various systems are considered and identified. This information is made available to those concerned for decision-making purposes during the process leading to an accomplished ship improvement. It must be recognized that the validity of a C&F study depends upon the accuracy of the technical input; therefore, the originator is responsible for providing technical data of the highest possible validity.

Valid information considering each of the following items is desired with each proposed improvement.

I. PLANS

A. Block Diagrams. Show the function of each basic unit with relation to other units comprising the system. Indicate normal inputs and outputs of each unit in the system. Include block diagrams of all units to be furnished plus all other units required to complete the installation, including racks, junction boxes, motor generators, and antennas.

B. Arrangement. Include arrangement for each electronic space and for all other spaces in which an appreciable amount of electronic equipment is installed. Prepare a plan view, an elevation view, and other views as necessary to show the arrangement clearly. Structural members, ventilation ducts, piping, and equipment other than electronic equipment shall be indicated. Also show large transmission lines. Give details of equipment characteristics that influence the relative locations of units to optimize operation, maintenance, reliability, and safety.

C. Stowage. Give typical stowage requirements, physical dimensions, and environmental requirements for major spare parts. Include stowage area for test equipment, special tools, technical manuals, etc.

D. Ripout

1. Removal instructions. Include all equipment, cables, piping, and foundations to be removed. The following should be provided:

   a. Location of item

   b. Name of item

   c. Disposition

   d. Cable run and length

   e. Weight of item (note change of weight and moment)

2. Compartment and access modification. Include all structural members, bulkheads, etc., to be removed. All drawings should resemble arrangement drawings.

E. Interfaces. All interconnection requirements with other sets, power sources, etc., shall be shown and identified. Include external cables, rf transmission lines, piping for water cooling and heating, piping for air and other services, and any types of interconnections among units and between units and power sources. Identify necessary concurrent or prior completion items such as SHIPALTs, Field Changes, and Mods.

II. SUPPORT REQUIREMENTS

A. Power. Indicate type of power to be used. For electrical power give the requirements for the complete equipment indicating for each power input: power type I, II, or III (as defined by MIL-STD-761), voltage, phase, frequency, current, power factor, and power. Power for starting, operating, standby, and secured conditions, as applicable, shall be specified. Allowable variations in voltage and frequency shall also be specified.

B. Cooling. Indicate type of cooling or heating, whether water or air. Give the amount of heat to be dissipated. A diagram should depict the routing, direction of flow, components with physical location, arrangement, and other characteristics or constraints. All units to be cooled or heated shall be shown.

C. Air conditioning. Give the ambient temperature range and limits of relative humidity for which the equipment is designed. Indicate the location, size, and arrangement of ventilation openings and external ventilation ducts supplied or required, indicating capacity and direction flow. Interface to ship services shall be clearly specified and shall include duct size, material, allowable particle size, allowable moisture environment, allowable velocity, filter characteristics, and pressure required.

D. Special Material. Make a list of special material such as cables, special tools, waveguides, mounting equipment and hardware, connectors, bulk material, parts, loose hardware, test equipment, and other support items needed to complete the installation which are not part of the installation package.

E. Shock. Indicate any special part arrangements, mounting techniques, or joining methods to harden equipment against shock and vibration. Give clearances required for shock and vibration excursions on shock-mounted equipment.

F. Safety. Establish safety requirements to promote maximum safety for personnel and equipment during installation.

1. Identify potential hazards and methods planned to eliminate or control them.

2. Outline undefined areas requiring guidance or decisions.

3. Describe technical risks or problems in design.

G. Stowage. Prepare a list of all installation material such as spares, technical manuals, and tools to be stored in stowage areas.

H. Planned Maintenance System (PMS). Express the planned maintenance requirements of the system, subsystem, or component (see OPNAV 43P2 and OPNAVINST 4790.4). The planned maintenance requirements should include the following: cleaning, inspection, lubrication, replacement, functional test, adjustment and alignment, calibration, and systems check (see MIL-P-28759).

III. EQUIPMENT/MATERIAL

A. Description. Give the weights and space requirements of the new and replaced (if any) installation. Also mention any constraints that may exist.

B. Special Instructions. Mention all special instructions such as handling (location of handling attachments, crating), mounting (shock mounting, special clearances, mounting surface and hardware), cable entrance sway bracing, etc.

C. Standard Stock Items versus New (Contract) Items. Consider cost tradeoffs in logistic requirements for supporting any new material or equipment involved and retrofitting the new material equipment to existing systems already deployed.

D. Indication of Spare Support for New Equipment. List the sources of all spare support materials and equipment whether it be the government Federal Stock System or a contractor.

E. Availability. Make a brief statement of the availability status of the equipment or material. Include when available for installation, confidence of this date, status of tech/op evals or service approval, procurement lead times, and any constraints that could modify this status.

F. Technical Manuals. Technical Manuals shall be available upon installation date and provide information such as instructions for installation, operation, and maintenance.

IV. TEST EQUIPMENT

A. General Purpose. Prepare a list of all general-purpose test equipment to be used. Include the official name or nomenclature, identifying number, and a brief description of the use of the item.

B. Special. Prepare a list of all special tools and special test equipment to be used. Special tools and test equipment are defined as those not listed in the Federal Supply Catalog. An illustration and description of special items required shall be provided for identification.

V. TEST AND CHECKOUT

Prepare installation and checkout test plans and procedures to ensure that all equipment is physically and functionally checked out and to demonstrate the adequacy of each facility installation. Information will be obtained from such sources as specifications, related test documentation used in the development test program, and relevant technical documentation from any agency concerned with the installation testing.

The test plan section shall describe the overall installation test program and should include:

1. Description of the equipment and facility configuration at each site

2. Scope of testing

3. Objectives of each test

4. Roles and of all major participants including the government

5. Support requirements including test instrumentation and facilities

6. Milestones and scheduling

7. Security guidelines

Detailed test procedures shall be provided which shall include the following classes of tests:

a. Preshakedown Tests. This portion shall contain instructions for making physical inspections, turn-on -off procedures, alignment, adjustment, and measurements required to be accomplished prior to the start of shakedown testing of the facility.

b. Shakedown Tests. This portion shall include a tabulation of the equipment and components to be subjected to shakedown tests, the total population of electronic parts in each, and the required duration of the test for each.

c. Operational Tests. This portion shall include instructions for performing the tests required to demonstrate that all equipment programs or facilities covered in the test plan and work specification are properly installed and are capable of performing their operational mission up to the prescribed interfaces with other portions of the subsystem and system.

VI. WEIGHT AND MOMENT

Include the following when determining weight and moment characteristics: total weight, weight reference to baseline, weight reference to midpoint, net moment, and weight reference to centerline (see SUPSHIPINST 9290.1C).

VII. TRAINING

The immediate and long-range training requirements for both civilian and military personnel must be considered. State the following requirements:

1. Training courses required including course length.

2. Training materials and facilities required.

3. A summary of technical data required.

4. Instruction advisory services required.

VIII. MANPOWER

When the accomplishment of an alteration affects any aspect of manning, the Ship Manning Document (SMD) must be updated to reflect the resulting changes. Items such as the addition, removal, or modification of equipment and systems may necessitate increases or decreases in existing manning levels, and must be considered in view of all manning factors.

IX. PERSONNEL

Number and type to install, check out, operate, and maintain.

X. SPARES

Number and type of spares. For permanent installations, required changes to the Coordinated Ships Allowance List (COSAL).

XIX. TEST AND EVALUATION

BACKGROUND

DoD Directive 5000.1 establishes a "fly before buy" philosophy for all major acquisition programs (over $50 million RDT&E and/or over $200 million in production); this policy is extended by SECNAV Instruction 5000.1 to all Navy acquisition programs. This has resulted in revisions to the policies for granting service approval making Approval for Production (AFP) contingent upon a satisfactory completion of a test and evaluation program executed by COMOPTEVFOR who has been assigned responsibilities as the Navy's independent test agency (see chapter VII, Approval for Production). Service approval is a primary milestone in satisfying an operational requirement; however, each of the steps in the acquisition cycle has test and evaluation (T&E) needs to be met even if no mandatory policy exists.

PURPOSES

There are seven basic purposes for executing a T&E program defined as follows:

1. Investigation. Examines natural or special phenomena in an operational environment or gathers data to determine preferred technical alternatives.

2. Diagnosis. Determines the origins and nature of undesirable behavior observed or anticipated in a test item.

3. Evaluation. Appraises the parameters and attributes of a test item.

4. Verification. Confirms the achievement of an established level of operation, the suitability of interfacing facets (space, fixtures, power, etc.), or the adequacy of descriptive item documentation.

5. Qualification. Proves the capability of the test item of meeting established requirements.

6. Acceptance. Determines conformance to specification requirements prior to acceptance.

7. Appraisal. Determines optimum procedures and tactics, confirms corrected discrepancies, and verifies suspected discrepancies.

Each phase of the acquisition cycle may draw on one or more test purposes. Investigations are used to support the Requirements Definition, Concept Formulation, Validation, and Screening phases. In the early phases the investigation serves to better define the operational and technical requirements; in later phases it serves the purpose of selecting technical alternatives. Appraisals may be performed on production equipments to verify the existence or correction of discrepancies noted in operational evaluation (OPEVAL) or discovered in fleet operations. Appraisals are also conducted to determine optimum procedures and tactics for utilizing new capabilities or adapting existing capabilities to new threats; in this latter vein, they may also be conducted to better define and determine requirements for future system acquisitions. Since appraisals are not part of any particular acquisition program because they are conducted directly in support of CNO, they are not discussed further here. The other test purposes serve the program phases shown in table XIX-1. Notice that diagnostic tests are only performed in conjunction with other types of tests; this type of test serves to provide the analysis data to support corrective engineering efforts. When structuring a test program, certain elements must be present to accomplish the purposes of the testing; these elements are discussed separately for each purpose later in this chapter.

INSTRUCTIONS

In planning for test and evaluation, there are two vital instructions:

Test and Evaluation — OPNAVINST 3960.10.

Mission and functions of Operational Test and Evaluation Force (OPTEVFOR) — OPNAVINST 5440.47 (series).

OPNAVINST 3960.10 defines the types of priorities and services available, sets forth procedures for the prosecution of test and evaluation programs, establishes Navy test and evaluation policies, encloses milestone checklists for T&E planning, and implements the policies of higher authority through the Test and Evaluation Master Plan (TEMP) (directions for preparing the TEMP are included). OPNAVINST 5440.47 is useful in understanding the functions of COMOPTEVFOR. The 3960 series instructions provide considerable guidance in the establishment, planning, and implementation of T&E programs; OPNAVlNST 3960.10 should be followed in requesting formal status to obtain COMOPTEVFOR assistance and to request fleet services. The following portions of this chapter are intended to amplify these instructions and to provide more detailed guidance in structuring the TEMP.

GENERAL PLANNING FOR EACH PHASE

When program planning is initiated, T&E plans should be an integral part of the program plans. There are three types of plans for T&E — the TEMP, the master program test plan, and the detailed test plan. The TEMP should be established as early as possible since it is the planning summary which serves as a contact with the "outside world." The program T&E plan should always be more detailed than the TEMP itself. The master program T&E plan should initially outline the purposes, scope, and objectives of the T&E intended for each program phase. Referring to table XIX-l, testing occurs at several levels of complexity in each phase; it is useful to structure the master program test plan to conform to the Work Breakdown Structure (WBS) (see chapter III, Program Planning) so the individual test sequences can be scheduled, costed out, coordinated, and tracked at each level. The master program test plan will include the schedules for requesting services, for preparing test

Table XIX-1. Interrelating test program factors.

Level of Complexity	Environmental Condition	Exploratory Development Model					Advanced Development Model					Service Test Model (Engineering Development)					*TELCAM Screen Equipments			Preproduction Model							Production Model				
		Acceptance	Qualification	Verification	Evaluation	Diagnosis	NTE (Ver.)	OPEVAL (Qual.)	Acceptance	Qualification	Verification	Evaluation	Diagnosis	Acceptance	Qualification	Evaluation	Acceptance	Qualification	Verification	Evaluation	Diagnosis	Acceptance	Qualification	Verification	Evaluation	Diagnosis	Acceptance	Qualification	Verification	Evaluation	Diagnosis
System	Operational	X										X	X							X		X	X		X		X	X	X		X
	Simulated	X	X				X	X	X			X	X							X		X	X		X	X			X		X
	Uncontrolled	X	X				X	X															X			X					
Subsystem/ Set/Group	Operational											X	X					X		X		X	X		X			X	X		X
	Simulated	X	X				X	X	X			X	X				X	X	X	X		X	X		X	X			X		X
	Uncontrolled	X	X				X	X											X				X			X					
Unit	Operational											X						X		X		X	X		X			X	X		X
	Simulated	X	X				X	X	X			X					X	X	X	X		X	X		X	X			X		X
	Uncontrolled	X	X				X	X											X												
Assembly/ Subassembly/ Module	Operational														X		X							X							
	Simulated	X	X				X	X							X		X		X					X							
	Uncontrolled	X	X				X	X							X									X							
Part	Operational																X							X							
	Simulated	X	X				X	X							X		X		X					X							
	Uncontrolled																							X							
									(1)													(2)				(4)			(3)		

(1) Verifies the system specification/Technical Approach feasibility
(2) Verifies the design documentation
(3) Verifies the production line's capability to produce
(4) Verifies the equipment is suitable for OPEVAL
*Screening only performed at the level of complexity where the buy/modify alternative is being pursued.

facilities, for submitting and updating the TEMP, and for executing detailed test plans existing for each cell of the WBS; additionally, the scope and objectives will be continually updated within the master program test plan. The detailed test plans are formulated to conform to the master plan prior to the initiation of the test phase to which they apply; they contain the characteristics to be tested for; the test procedures to be followed; a description of the test setups, facilities, and test equipments needed, and the documentation to be generated in support of the T&E effort.

The TEMP and the master program test plan should be similar in content and different primarily in format. Generally, the master program test plan will be extended to a lower level of the WBS than the TEMP. It will also contain cost estimates for each detailed test and will list the alternative plans supporting backup approaches. Both documents are the responsibility of the government project manager.

The detailed test plans are normally written by the executing activity, whether in-house or contractor, and submitted to the government project manager for approval. The detailed tests respond to the applicable portions of system specification(s). To check the accuracy of a detailed test plan, the plan is compared to the section 4 provisions of the specification, which should contain all the inspections and tests to be performed to ensure conformance to the specification requirements (section 3). The Documentation section (chapter XX) contains a list of suggested data item descriptions (DIDS) to be used in requiring test plans and test reports in a contract data requirements list (CDRL). A test report is comprised of the detailed test plan plus test results consisting of a summation and analysis and of test data. Most formal test reports are prepared in accordance with MIL-STD-831.

The specifications quality assurance/conformance provisions must detail the following information:

- Parameters and attributes to be confirmed; accept/reject criteria
- Environmental conditions
- Environmental stress levels
- Extent of testing
- Standard test methods and procedures to be employed
- Data, analyses, and reports required to demonstrate conformance

Test requirements originating from other sources such as ILS plans must provide this same information. Table XIX-2 shows typical environmental test requirements. The parameters and attributes should include all the form, fit, and function characteristics which are required; the accept/reject criteria should be based upon the specified parameter tolerances and clearly defined attributes. The accept/reject criteria will normally change as a function of environmental stress level; the stress levels are:

Operational	The actual application environment
Simulated Operational	Laboratory-controlled environment
Overstressed	Allowed excursions beyond the specified normal conditions
Uncontrolled	Laboratory bench/ambient environment
Combined Environment	Simulated multiple environments

Table XIX-2. Equipment environmental tests and requirements.

General Requirements

Designator	Environment
1	Temperature (operating and nonoperating)
2	Temperature-altitude
3	Humidity
4	Thermal shock
5	Vibration
6	High-impact shock
7	Transport shock
8	Repetitive shock
9	EMC (interference and susceptibility)
10	EMP
11	Electrical transients (voltage and frequency/long term and short term)
12	Lightning
13	Magnetic field
14	Acoustic noise (airborne and structureborne)
15	Inclination
16	Radiation
17	Nuclear air blast
18	Gun blast
19	Wind
20	Icing with wind
21	Rain and snow, snow loading
22	Sunshine
23	Degree of enclosure
24	Dust
25	Salt fog, spray, solution
26	Damaging (corrosive) atmospheres
27	Explosive atmosphere
28	Fungus
29	Maintainability/bench handling
30	Reliability (burn-in, confidence, indexing, accelerated life, failure-mode analysis)
31	Combined-environment testing (temperature-humidity-vibration-electrical transients on/off cycling)
32	On/off cycling
33	Acoustic susceptibility (in high-noise environments)
34	Water impact/hydrostatic pressure
35	Underwater explosion (for hull-mounted equipments only)
36	Drop test
37	Equipment special environments

Special Requirement Categories

Category	Environments	Notes
Vital equipments	10,16,17	16 and 17 for exposed equipments operating
Semivital equipments	6	nonoperating (normal operating before and after shock) safety criteria
Nonvital equipments	6	
Exposed equipments	12,18,19,20,21,22,23,24	
Sheltered equipments	23	
Standard requirements	1,3,5,6,9,11,14,29,30,31,32,37	

Table XIX-2. Equipment environmental tests and requirements (continued).

APPLICATION REQUIREMENTS[1]

Application	Environments	General Equipment Spec	Test Spec	Notes

Shipboard	8,13,15,25,26, 27,33,34,35	MIL-STD-2036	MIL-STD-2036	for (5) MIL-STD-167
				for (6) MIL-S-901
				Environmental Interfaces MIL-STD-1399 for (15) per MIL-E-16400 except 30° (operating) and 60° (without damage or spillage) for submarines
				TELCAM levels use:
				for (5) 0.5 g to 50 Hz
				for (6) MIL-S-901 may be waived

Shore (fixed)	33	MIL-STD-2036	MIL-STD-2036	
Shore , (mobile), transportable, vehicular)	2,4,7,15	MIL-E-4158	MIL-STD-810 MIL-STD-169 MIL-STD-170 MIL-STD-210 MIL-STD-1474 MIL-D-13570	
Airborne	2,4,7,26,27,28	MIL-E-5400 Prop, Jet, and Helo Aircraft MIL-E-8189 Missiles, Boosters, and Allied Vehicles MIL-E-11991 Guided Missiles	MIL-STD-810 MIL-T-5422 (Navy) Gen Equip Spec	MIL-E-5400 to be replaced by a future revision to MIL-STD-2036
Portable	36 plus applicable general application	Same as general application	Same as general application plus detail spec	
Space	2,4,7,8,16,33	MIL-STD-1540	MIL-STD-1540	for (9) MIL-STD-1541 equipments are all considered vital
Test equipment	7,24,25,27,28, 33	MIL-T-28800	MIL-STD-810	
Amphibious				shipboard and shore (mobile) combined
Torpedoes	22,24,25,28,34	MIL-T-18404	MIL-T-18404	(37) includes acceleration
Shipboard fire control	2,8,13,15,25,26, 27,33	MIL-F-18870	MIL-T-18870	same as Shipboard except as modified by MIL-T-18870. (2) is nonoperating transportation test

[1]Environmental requirements should consider standard, sheltered or exposed, and vital-semivital-nonvital requirements in addition to those listed.

Most preliminary evaluation testing is performed in an uncontrolled environment; final evaluation testing, acceptance testing, and verification testing utilize simulated operational environmental levels. Simulated environments may be tested singly, doubly, or in multiple. Single simulations are normally used because diagnosis test data may be simultaneously extracted and readily analyzed to isolate the origins of undesirable behaviors and the causes of test failures. Double simulations are used when two environmental factors are very closely related, such as temperature and humidity. The combined environment test (CET) is a multiple simulation intended to closely resemble the actual operational environmental extremes. Temperature, humidity, vibration, electrical transients (voltage and frequency), and RFI environments can be economically tested together; since these environments may produce synergistic effects in combination which are not detectable in single-environment tests, CET is an essential tool for preliminary qualification testing (as for the TELCAM screen) and for developing confidence that equipments will operate satisfactorily in the operational environments (ref. NELC Technical Report 1605). CET is not normally applicable for test phases employing diagnosis because fault data cannot be easily traced to the environmentally susceptible portion of the design; therefore, CET is normally preceded by sequential single-environment testing which will often utilize overstress parameters. When synergistic faults do occur, a multiple linear regression model can be employed to break down the environmental performance of the equipment; since these models require many data points and computer support, it is usually more economical to rely, at least initially, on previous single-environment results to try to discover weak design points. All final qualification testing should utilize an operational environment. In addition, evaluation testing (especially of ADMs) of equipments which have critical interfaces (either operationally or functionally) with the ultimate platform should be performed in the operational environment; table XIX-3 illustrates the different fleet services which may be requested for such testing. Requests must be made in accordance with OPNAVINST 3960.10.

The confidence attainable through testing relies on four factors:

Accurate specifications of the test parameters and the environmental conditions

Accept/reject criteria

Extent of testing

Test methodology

The accuracy of the specification is primarily a function of the information available to put into it. Good records of prior work on the program, good test data practices, research of related investigations (see chapter IV, Conceptual Phase, Gathering Information), and previous experience with similar existing equipments (see chapter IV, Gathering Information; and chapter VII, Initiating Support, Monitoring the Performance of Equipments in the Fleet) will contribute to accurate parameter specifications; table XIX-3 and appendix A are provided to more precisely determine environmental conditions. The accept/reject criteria can be manipulated with respect to allowed parameter tolerances to yield bigger confidence results. As the environmental stress level is eased from operational to simulated to uncontrolled, the accept/reject criteria should normally be tightened with respect to the specified tolerances to compensate for the lost test accuracy. While common sense and knowledge of the design may temper the final determinations, a rule-of-thumb is to tighten the criteria by 10% for

Table XIX-3. Fleet services which may be requested through COMOPTEVFOR to support test programs.

Fleet Research Investigation	An examination of natural or special phenomena in operational environment, required by a development agency (DA) in the prosecution of research and for which the assistance of operating forces is required. The research investigation is not necessarily program oriented, but is primarily in the pursuit of basic research to provide a continuing data base which may have potential application in areas of naval interest. The DA is responsible for the planning of Fleet Research Investigations, and further advises the operational commander providing the support. COMOPTEVFOR shall make arrangements for needed fleet support, as requested by the DA.
Development Assist	Projects to provide fleet support for the test needed in gathering data to determine the direction in which development should proceed, in response to a requirement during the conceptual phase of a program. They may also relate to material improvements of equipments already in the Fleet. (Examples: proposed SHIPALTS, ORDALTS, Service changes.)
Operational Assist	An Operational Assist project is assigned by CNO in response to a favorable program initiation decision by SECDEF or comparable CNO decision. In addition, a DA may request an Operational Assist project for material improvement programs and for certain acquisition programs by submission of a project request. This project is primarily the responsibility of the DA, and its major purpose is to establish confidence in the program worth and readiness for the commitment of resources for full-scale development.
Technical Evaluation Project (TECHEVAL)	A TECHEVAL is assigned by CNO in response to a favorable program full-scale development decision by SECDEF or comparable CNO/CNM decision approving the commitment of resources for full-scale development. In addition, a TECHEVAL may be requested by a DA to determine suitability for other acquisition programs and material improvement including conversions, major modifications, and modernizations. In the case of aircraft or missile programs, the TECHEVAL will include the Navy Preliminary Evaluation (NPE) or the Navy Technical Evaluation (NTE).

Table XIX-3. Fleet services which may be requested through COMOPTEVFOR to support test programs.

A TECHEVAL is performed for the purpose of investigating systems or equipments and collecting information which will aid in answering technical questions and issues. The testing and analysis conducted by or for the DA during the time span of the TECHEVAL project are to permit the DA to determine whether the system or equipment is functioni-design and technical performance specifications, and is technically suitable for Operational Evaluation (OPEVAL).

The DA has primary responsibility for planning the test program, including the coordinated operational inputs of COMOPTEVFOR. TECHEVAL and OPEVAL are complementary test programs and complete initial operational test and evaluation. Together they generate data and address the spectrum of questions and issues to be considered prior to a major production decision. Accordingly, through close liaison, COMOPTEVFOR and the DA shall ensure that the test plans are mutually agreeable and integrated ot the extent that they adequately address the critical questions and issues posed in the governing DCP or comparable document, and provide for the maximum practicable use of common test data.

Testing during TECHEVAL may be conducted using production prototype or pilot production models. Prior to OPEVAL, the DA shall institute a design freeze on the equipment or system and certify it to CNO/COMOPTEVFOR as ready for OPEVAL.

Operational Evaluation

At the time the TECHEVAL is assigned by CNO, an OPEVAL will also be assigned, primarily for planning and scheduling purposes. Project operations under OPEVAL will not commence until the DA has certified the equipment. The project is the responsibility of COMOPTEVFOR with the development agency assisting as required; COMOPTEVFOR collects data of reasonable scope and depth to aid in the decision-making process at program milestones.

The primary objectives of OPEVAL are to ascertain that:

The system or equipment functions in an operationally satisfactory manner and performs reliably and effectively in accordance with program objectives in realistic operational conditions.

The system can be effectively operated and maintained by the level of personnel skill anticipated to be available under service conditions.

There is reasonable indication that logistic supportability in a deployed status is feasible.

Table XIX-3. Fleet services which may be requested through COMOPTEVFOR to support test programs.

	All test questions germane to a production decision are adequately examined.
Fleet Operational Appraisal	The assignment of a Fleet Operational Appraisal project by CNO may be initiated by a recommendation submitted by COMOPTEVFOR on completion of an OPEVAL or by request of a Fleet Commander in Chief or type commander. The purpose of this type project normally is to provide for follow-on operational test and evaluation, to develop optimum procedures and tactics for existent systems or equipment both new and existent in the Fleet, to verify the performance of production units, and/or to confirm the correction of discrepancies previiously disclosed. It also may be used to examine and/or develop concepts and procedures to better define and determine requirements for future systems development.

each easing of stress level and by 5% for each test phase preceding NTE/OPEVAL. The extent of testing involves the length of testing and the number of units subjected to test; higher confidences may be obtained with more test time and more guidance on the test time and equipment quantities which are required to achieve various levels of confidence. The standard test methodologies should be utilized wherever applicable, as modified by the application environment, since standard test procedures, test equipment, and test facilities are available and a wealth of experience with the methodologies has been developed over the years; table XIX-4 lists the more important test method standards. Parameters which lend themselves to statistical analysis may be tested satisfactorily with a sampling procedure; others dependent on nonvarying design features require the testing of all test items. Each parameter should be reviewed with sampling in mind when large quantities of test items are involved, since test costs can be significantly reduced by sampling procedures. Different numbers of test items may be used for various tests; generally, the test item population will be divided up, with some tests performed on the entire population and different tests run on the various portions of the population.

Overstressed environments may apply to either operational or simulated environmental test levels. When present in operational environments, the conditions of overstress and allowable degradation of the equipment should be included in the specification. Overstressed conditions may also be applied in simulated environments to (1) accelerate aging factors, (2) discover environmentally susceptible design features, and (3) increase test confidence. While very useful, the stress mechanisms should be understood as to how they should affect a design so that realistic acceptance criteria may be formulated. The nature of some test items precludes certain types of overstress (paper tape cannot be tested at 100% humidity, for instance). Where the stress mechanisms are not known, overstresses not reflected in the usage environment should be avoided.

Table XIX-4. Test methodology standards.*

MIL–STD–105	Sampling Procedures and Table for Inspection by Attributes
MIL–STD–108	Definitions of and Basic Requirements for Enclosures for Electric and Electronic Equipment
MIL–STD–167	Mechanical Vibrations of Shipboard Equipment
MIL–STD–170	Moisture Resistant Test Cycle for Ground Signal Equipment
MIL–STD–220	Method of Insertion-Loss Measurements
MIL–STD–271	Nondestructive Testing Requirements for Metals
MIL–STD–414	Sampling Procedures and Tables for Inspection by Variable for Percent Defective
MIL–STD–446	Environmental Requirements for Electronic Parts
MIL–STD–449	Radio Frequency Spectrum Characteristics, Measurement of
MIL–STD–462	Electromagnetic Interference Characteristics, Measurement of
MIL–STD–469	Radar Engineering Design Requirements for Electromagnetic Compatibility
MIL–STD–471	Maintainability Demonstration
MIL–STD–690	Failure Rate Sampling Plans and Procedures
MIL–STD–740	Airborne and Structureborne Noise Measurements and Acceptance Criteria of Shipboard Equipment
MIL–STD–750	Test Methods for Semiconductor Devices
MIL–STD–781	Reliability Tests
MIL–STD–810	Environmental Test Methods
MIL–STD–883	Test Methods and Procedures for Microelectronics
MIL–STD–1310	Shipboard Bonding, Grounding, and Other Techniques for Electromagnetic Compatibliity
MIL–STD–1311	Test Methods for Electron Tubes
MIL–STD–1344	Test Methods for Electrical Connectors
MIL–STD–1472	Human Engineering Design Criteria for Military Systems, Equipment, and Facilities
MIL–S–901	Shock Tests, High Impact; Shipboard Machinery, Equipment, and Systems, Requirements for
MIL–B–5087	Bonding, Electrical, and Lightning Protection for Aerospace Systems
MIL–T–5422	Testing, Environmental, Airborne Electronic and Associated Equipment
MIL–D–13570	Dust, Testing by Exposure to

*Additional methods are specified by the various general equipment specifications (MIL–E–16400, MIL–STD–2036, MIL–T–28800, MIL–E–5400, etc.) and by military, federal, and industrial standards. Refer to the DoD Index of Specifications and Standards for methods of less general application and for the most recent editions of the above standards.

ESTIMATING COSTS OF T&E

Estimating T&E costs is an important function to program planning (see chapter III). Early detailed T&E master planning can help significantly; nevertheless, there are many uncertainties for which contingency plans must be budgeted. The following list of factors should be considered in T&E cost estimating:

Facilities (ships, test beds, laboratories)
Test equipments
Instrumentation
Documentation (detailed test procedures, technical manuals, analyses, reports, equipment surveys, etc.)
Personnel (types, time needed)
Repair capabilities (including technicians, technical manuals, test equipments, tools, spare parts)

Failures will occur during testing; depending on the design and complexity of the equipment, the repair functions can double or triple the T&E period and increase costs by a factor of 2 to 10 (5 is considered a good planning figure). A failure to meet the test objectives is much more probable in early program phases than later if the test planning — the entire program planning, for that matter — is done properly. Therefore, T&E contingencies should be made larger in the early phases relative to the estimated “no failure” cost than in later phases. The T&E schedules should also reflect contingencies and possible slippages, and the program plan should incorporate the necessary flexibility to overcome these uncertainties. T&E personnel (such as NRaD Code 81) should be consulted in structuring the T&E portions of the program plan, in formulating the various test documents, and in scheduling their environmental and simulation facilities.

T&E PLANNING

It is essential that sufficient developmental and operational test and evaluation be accomplished to ensure that the systems introduced into service meet the defined operational requirements and are suitable for service use. The operational effectiveness and suitability of these systems must be determined to a high degree of confidence before they are approved. Complete and realistic programs for such determinations are, therefore, matters of concern to all levels of management.

The Commander, Operational Test and Evaluation Force (COMOPTEVFOR), has been assigned responsibilities as an independent test agency for the required operational test and evaluation of new systems. The objectives of COMOPTEVFOR are to ensure that early and realistic operational tests and evaluations are planned; to ensure that appropriate initial operational tests and evaluations are conducted prior to scheduled decision milestones; and to provide an independent assessment of the operational effectiveness and suitability of the system to CNO.

CNO has responsibility for ensuring the adequacy of the Navy’s overall test and evaluation program. T&E policy and guidance are exercised through the Director, RDT&E (OP-098), and in accordance with overall policies established by the Secretary of the Navy. The Director’s responsibilities include:

Reviewing proposed T&E objectives and requirements for fleet services to support T&E programs.

Assigning all T&E projects and their priorities to the operating forces for prosecution.

Receiving, reviewing, and assessing all OT&E reports for systems, and acting for CNO, as the sole releasing authority, for such reports and information to higher authority.

Ensuring that adequate funding for all required and approved T&E is identified in the programming and budgetary system.

TEST AND EVALUATION OF MAJOR SYSTEMS

Test and evaluation of systems is discussed in the following three subsections.

Developmental Test and Evaluation (DME)

This category or class of tests and evaluations is conducted under the sponsorship of the developing agency, and is undertaken for the specific purpose of facilitating the evolution of a system. The development test plan must be structured and executed in such a manner as to ensure the generation of data which can also be used to make the required assessments of the operational effectiveness and suitability of the emerging design. Test programs in this category include engineering tests, contractor/laboratory demonstrations, naval technical evaluations, and Navy preliminary evaluations and deficiency correction tests. The test articles required by the DT&E programs are characterized as advanced development, engineering, and production prototype models.

Operational Test and Evaluation (OME)

This category of testing includes all test and evaluation effort participated in, or undertaken, for the purpose of obtaining operational information throughout the life cycle of the system, and supports both the acquisition process and the optimum employment of the system. It is accomplished in two phases, Initial Operational Test and Evaluation (IOT&E) and Follow-on Operational Test and Evaluation (FOT&E).

IOT&E is that testing and evaluation accomplished by or under the supervision of the Navy's independent testing agency prior to the first major production decision. IOT&E reports address the operational effectiveness and suitability (including reliability, compatibility, and maintainability) of the system, including the critical issues identified in the DCP or comparable acquisition document in accordance with defined operational requirements. IOT&E is conducted in accordance with DCP.

FOT&E is the continuing test and evaluation of a system conducted under fleet conditions by fleet operational personnel using initial production systems for the purposes of verifying system performance, validating correction of deficiencies previously identified, and refining tactical employment doctrine and requirements for personnel and training.

Acceptance Trials

The Board of Inspection and Survey (BIS) is responsible to CNO for conducting acceptance trials prior to Navy acceptance from the contractor. The Board inspects the material condition, requires demonstration of equipments and systems to ensure performance in accordance with the requirements of the contract specifications, and determines compliance with the characteristics established by CNO. After completion of acceptance trials the Board reports its findings to CNO, identifying deficiencies for which they recommend corrective action prior to delivery. Upon successful completion of final contract trials, the Board reports to CNO its recommendations for final settlement of the contract.

T&E CYCLE

The usual sequence of test events followed during the acquisition of a system is illustrated in figure XIX-1. Those major programs subject to DSARC review shall adhere to the following procedures.

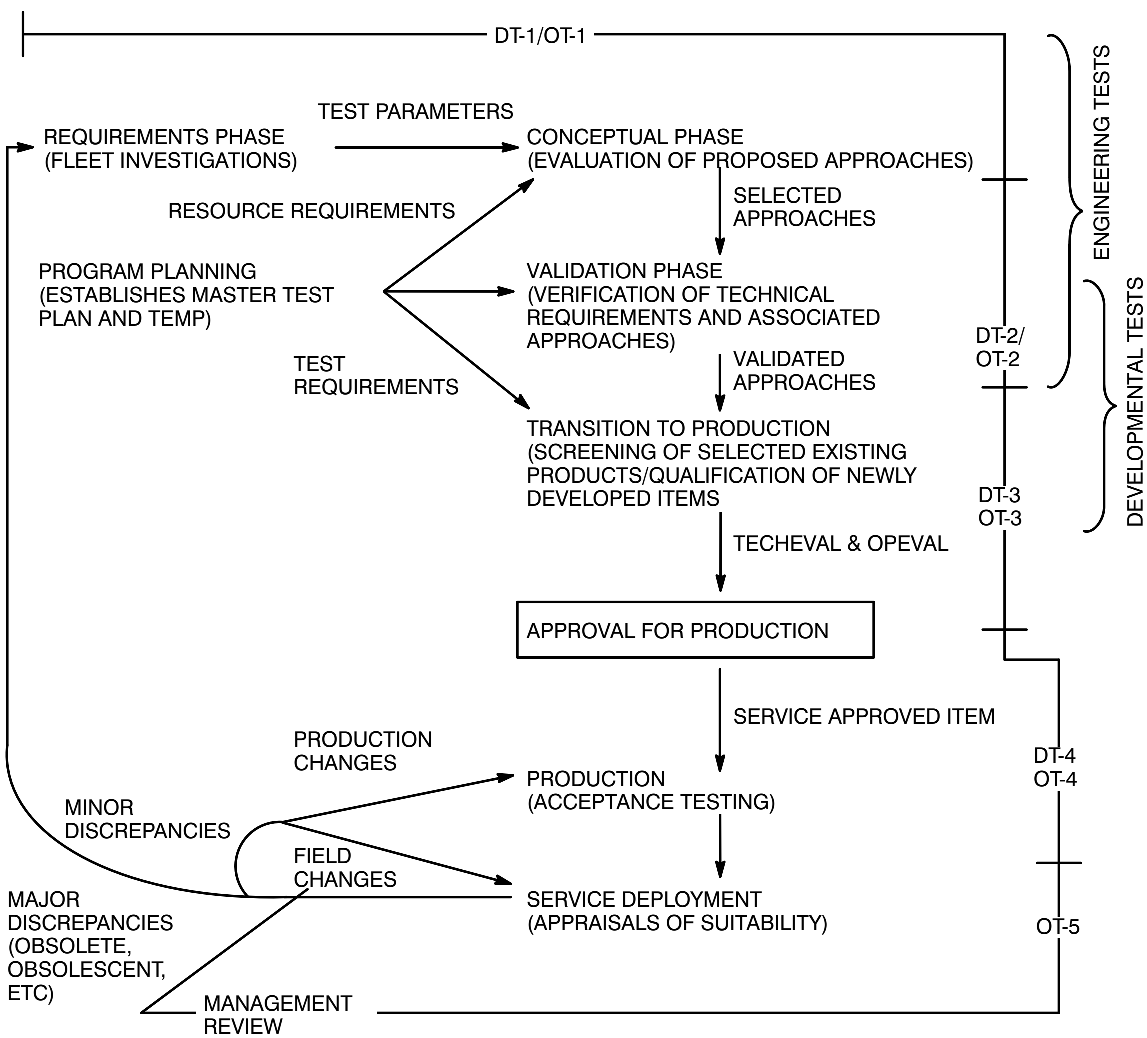


Figure XIX-1. Sequence of acquisition test events.

During the drafting of the initial DCP, the CNO development and program coordinators shall coordinate with the cognizant SYSCOM or development agency project manager and COMOPTEVFOR in preparing the statement of critical questions and issues which tests will address. Plans and estimates of the required test and evaluation shall be incorporated and schedule milestones identified. The proposed test and evaluation programs and schedules will be reviewed for compliance with Navy policy by CNO (OP-983).

During the advanced development or validation phase, subsequent to DSARC I, the development agency and OPTEVFOR will refine the critical questions and issues to be addressed by T&E. Prior to DSARC II COMOPTEVFOR will make an assessment of the operational suitability and effectiveness, based upon all valid IOT&E data extracted. The applicable portions of the DCP for DSARC II will be updated with this additional information by the CNO development and program coordinators. The refined critical questions and issues and the test program will be reviewed for adequacy and compliance with Navy T&E policy by CNO (OP-983). The revised DCP will reflect the status of developmental testing and indicate technical and operational risks outstanding.

Once full-scale development has been authorized by SECDEF, after DSARC milestone II, DT&E will be oriented toward resolving the applicable critical questions and issues and achieving a system that is, in all respects, ready for production and suitable for service use. Prior to DSARC milestone III IOT&E will address operationally oriented critical questions and issues, using data generated in the DT&E programs, BIS trials, and operational tests. OPTEVFOR will gather all valid IOT&E results, evaluate them, and prepare an independent assessment of system operational effectiveness and suitability. This report will be directly forwarded to CNO. CNO will provide an assessment of the test results in terms of the response to the critical questions and issues to the appropriate OSD offices.

Follow-on test and evaluation will be conducted, following a favorable production decision as directed by CNO. Follow-on OT&E may be desirable in order to verify performance of the new production units, further develop doctrine and tactics, and complete the evaluation of the reliability, maintainability, and logistic supportability of the production system.

INSURV conducts acceptance for service use and specifies conditions for acceptance from the contractor. Acceptance for service use is required prior to delivery by the contractor. The operational tests and evaluations by OPTEVFOR and the acceptance for service use by INSURV are mutually supporting. An integrated test program is desirable to prevent duplication and to make available to both OPTEVFOR and INSURV all test data as they become available.

T&E MANAGEMENT OF OTHER THAN MAJOR SYSTEMS

Programs of this category are not subject to the DSARC decision processes. They shall be subject to a similar review and decision process within the Department of the Navy. CNO monitors these programs and renders the productive decision after appropriate developmental and operational test and evaluation of the new system has been accomplished. CNO will delegate the review process to the cognizant SYSCOM.

Normally, CNO will exercise the review and decision process for those programs having an RDT&E cost in excess of $5 million, or a production cost in excess of $20 million. However, CNO may exercise the review and decision process for programs below these thresholds dependent upon the mission essentiality of the program. The test and evaluation requirements shall parallel those established for major programs.

T&E MANAGEMENT OF SHIP CONSTRUCTION

In the systems acquisition process, ship construction is a unique procedure. The test and evaluation for major or other new systems in a ship shall be accomplished with cognizant program. Appropriate information will be provided in the Ship Program DCP on which to base a ship production decision and schedule of specific follow-on management reviews for the ship program.

The requirement to test and evaluate a system prior to production approval may only be waived by the Secretary of the Navy.

Major programs require SECDEF approval.

NUCLEAR WEAPONS T&E

Joint AEC-DoD development of a new nuclear weapon is governed by the 1953 "Agreement between the AEC and the DoD for the Development, Production and Standardization of Atomic Weapons." Test, evaluation, and acceptance of nuclear weapons are to be conducted in accordance with that agreement and implementing DoD issuances and Navy instructions.

XX. DOCUMENTATION

The goal of the government with respect to documentation has always been to acquire only the data essential for adequate development, procurement, operation and support of systems and equipment. Yet the volume and cost of data have somehow grown over the years until today both are enormous. DoD is therefore obliged in the interest of meeting its goal to fight a constant holding battle against proliferation of data requirements. Directive after directive demands the exercise of judgment and restraint in the specification of data items for procurement.

The problem at the procuring level lies in determining the essential minimum, which is by no means necessarily the absolute minimum. Underordering can be as costly as overordering. The manager who habitually buys only contractor drawings is often one day obligated to pay sky-high prices for data which must be ordered on unfavorable terms after the original contract is let. (Furthermore, once pinched by his own frugality, such a manager is likely to err in the opposite direction — to routinely order all the documentation for which a need may conceivably develop.)

The answer to the problem lies in management. The project manager must define data requirements as rigorously as equipment requirements, especially when the emphasis is on low-cost acquisition.

PM GUIDELINES

The project manager can simplify the documentation task by obtaining assistance from data management specialists (Sustainability Division, at NRaD), by procuring documentation through the internal organizations established for that purpose (Technical Information Division, at NRaD), and by observing the following key guidelines:

1. On the basis of project requirements and the end use of the related system/equipment, and as early as possible, establish a preliminary shopping list of the types of documents that you, as the developer, and the government, as the user, conceivably could need to permit effective decisions, evaluations, and actions. On large, complex projects, get similar inputs from responsible task leaders. Include requirements specified by the sponsor. Use the standards in table XX-1 and the Acquisition Management Systems and Data Requirements Control List (AMSDL) to identify candidate data items. The AMSDL is available at the Data Management Office (DMO) or on the VSMF service; it is published as DoD 5010.12-L twice annually.

2. Rigorously evaluate the need for each data item on the shopping list. Who will need it? When? Why? What or who will suffer without it? How much? Will the information possibly be available elsewhere in other project documentation, or in documents already in the government's possession? In other words, determine as well as you can the true essentiality of each data item. Use an arbitrary scale of, say, five, and assign a value to each item.

3. Estimate the costs of engineering and publication efforts on each data item; weigh against the essentiality value given the item; and obtain a relative cost-effectiveness figure for the item.

4. Make initial decisions for or against inclusion of the items and establish an initial "minimum essential" data requirements list. When a contractor is involved and the total contract exceeds $1 million, or when contract data will cost over $100,000, contract data requirements must be approved by a data requirements review board as explained in NOSCINST 4000.1, Data Management Program. The Data Management Office will assist in determining the appropriate data items and in tailoring the Data Item Descriptions.

5. Subject the initial data requirements list to continuous review and validation in the light of project developments.

6. When ordering data from contractors, specify use of the contractor's format if it is suitable and the data item is to be used solely within the government. Impose MILSPEC and standard content and format requirements only for specifications, drawings, manuals, etc., that must meet very strict needs for procurement, operation, and support. Manuals should be procured, at NRaD, through the Technical Information Division.

7. On RFPs, encourage contractors to submit alternative data packages to the data package represented by the Contract Data Requirements List (DD Form 1423). Negotiate in favor of the least-expensive package submitted which satisfies the government's needs as specified in the statement of work.

8. If contractors are to provide data items, determine as early as possible when the items are needed for use. Order them under the appropriate contract and have them delivered as they are needed. These practices will help to assure that the government obtains data at the lowest possible cost, that the delivered data are usable rather than in need of revision, and that government storage and handling are minimized.

TYPICAL DATA ITEMS

Table XX-l contains a list of subjects of concern to project managers and engineers. The subjects to be dealt with will vary with the project. The AMSDL contains over 1000 Data Item Descriptions (DIDs) approved for use in 37 broad categories.

Documents covering the subjects listed in table XX-1 can be grouped into four broad categories according to their purpose:

Those used for program administration, control, and historical reference

Those describing systems and equipment

Table XX-1. Sources of data item descriptions for programs.

Configuration Management	MIL-STD-973
Design Reviews	MIL-STD-1521
Drawings	MIL-T-31000
Electromagnetic Compatibility	MIL-STD-461
Human Engineering	DOD-HDBK-763
Safety	MIL-STD-882
Software	MIL-STD-2167A MIL-STD-2168 MIL-STD-498
Specifications	MIL-STD-490
Product Assurance	MIL-STD-2107
ILS	MIL-STD-1702
Level of Repair	MIL-STD-1390
Reliability	MIL-STD-785 MIL-STD-756 MIL-STD-781 MIL-STD-1629 MIL-STD-2074 MIL-STD-2155 MIL-STD-1543
Maintainability	MIL-STD-470 MIL-STD-2080
Technical Manuals	MIL-STD-1790 MIL-STD-7298 MIL-STD-82376 MIL-T-31000
Training	MIL-STD-1379
Testability	MIL-STD-2165 MIL-STD-1345
Provisioning	MIL-STD-1388-2
Standardization/Parts Control Program	MIL-STD-965
Packaging, Handling, and Transportation	MIL-STD-2073-1 MIL-P-9024

NOTE: Use the most current editions of each standard or specification cited. After determining which data items are required, use the most recent edition of the identified DID, including superseding editions.

Those used to control design changes

Those required to support design, operation, maintenance, and support

The primary documents in each category are discussed briefly in the following paragraphs. Refer to Chapter XXII for more information on those items concerned with program control.

SYSTEM/EQUIPMENT DESCRIPTION

Specifications

Specifications provide narrative details of performance and physical characteristics and their quality assurance requirements for systems, equipments, assemblies, subassemblies, components, etc. Development-type specifications are prepared to establish initial baseline configurations for developing prototype models. Product-type specifications reflect the finally developed configurations and are used to procure operational models. Specifications are prepared to commercial/industrial or military standards. Program-peculiar military specifications are required by MIL-S-83490, which covers the requirements for Forms 1a, 1b, 2, and 3 and Types A, B, C, D, and E specifications. The detail requirements for Form 1a specifications of all types are presented by MIL-STD-490, while MIL-STD-961 provides overall requirements for military specifications in general. MIL-STD-962 provides requirements for military standards and handbooks.

An engineer, whether he is a circuit designer or has the total responsibility for the overall system design, should be familiar with MIL-STD-490, since it provides the guidance for writing specifications which will be followed throughout the various stages of military system development. A specification which is not comprehensive (i.e., does not cover such requirements as reliability, human engineering, support documentation, maintainability, or logistics) will practically guarantee higher support costs during a system's scheduled lifetime and may also shorten the duration of that lifetime.

Specifications document system/equipment requirements; therefore, they form a vital link in the systems engineering task of "requirements flowdown and traceability."

Engineering Drawings

Engineering drawings are the designer's primary means of communication. They may be prepared in accordance with commercial/industrial or military standards. The Department of Defense recognizes three levels of drawings based on intended use (DoD-D-1000). DoD-STD-100 provides the format and content requirements for the 4 dozen or so drawing types which may be required. The DoD-D-1000 levels define the depth of information contained in a drawing and determine what kinds of DoD-STD-100 drawings may be required.

Test Procedures and Reports

Procedures and reports are required for tests of specified performance and physical characteristics for developmental and production models. They are prepared by the development activity and manufacturer in accordance with their own or the buyer's requirements. Various requirements documents of the several military services and agencies address the content and format of test procedures and reports and may be imposed on the preparer.

In general, every specification requirement has a corresponding test or inspection procedure which will be reported each time the requirements are verified.

Engineering Reports

During equipment development, reports are often required by the purchaser on such engineering aspects as reliability and maintainability predictions and demonstration, human engineering, and safety. The specialty engineers involved prepare such reports to their own in-house requirements or may, in the case of items for the military, have to comply with applicable military specifications and standards.

Many detailed specification requirements and design characteristics result from engineering analyses rather than operational requirements. The systems engineer uses engineering reports to document further refinements to the design baseline and to ensure consistency between designer decisions and system design requirements.

Engineer's Notebook

An engineer's notebook should be established the moment a new design is begun. Instructions, dates, findings, decisions, reasons, conclusions, etc., should be included. A notebook's value varies with the circumstances and the extent of its contents. Potential benefits of a notebook include patent rights, applications to future projects, defense of actions taken, information for new personnel; and general future reference.

DESIGN CHANGE CONTROL

Equipment configuration management is a normal activity of most companies and government developers. Effective configuration-change control employs a system of recorded change data subject to review and approval. The design engineer provides the technical inputs for this documentation; the systems engineer is responsible for approving/rejecting proposed changes. Quality engineers and configuration managers track approved changes and assure their correct incorporation into the design.

Engineering Change Proposals (ECPs)

Configuration changes are formally initiated by a change-proposal form/document which must be reviewed and approved before the subject change(s) can be incorporated in the design or equipment. The designer himself may initiate the proposal or may cooperate with another engineer who has the original idea for a change. In either case, the designer must describe how the proposed change affects his area of design responsibility by completing the change proposal form/document and including appropriate drawing and specification (see SPECIFICATION CHANGE NOTICES) revisions for reference as well as required costs and schedule revision information. The military services must follow, and cite to contractors, the requirements of MIL-STD-973, which employ DD Form 1692 or 1693, respectively, as the engineering change proposal document. Variations of these forms may be used by industry and DoD for in-house-only applications. The completed form/document is reviewed by a configuration control board which may immediately decide for or against the proposal or return it to the originator(s) with a request for additional information. A signed, approved ECP constitutes authorization to proceed with the change, a process that normally includes the preparation of engineering change orders and specification change notices (see following).

Engineering Change Orders

Properly authorized engineering change orders provide the technical and procedural information necessary to fully implement the authorized change to the design/equipment and to the engineering documentation that baselines the configuration of the design/equipment. An engineering change order may be called a "Notice of Revision," "Engineering Change Notice," "Revision Directive," or other similar terms according to local practice. The designer will be required to contribute technical information within his purview to this document.

Specification Change Notices (SCNs)

Whenever a change to a design or equipment is authorized, the pertinent specification and engineering drawings must be changed accordingly. Instructions for document revision should be contained in engineering change orders. An approved SCN sheet should be included with these instructions along with the detailed infor-mation needed to produce revised copy for the specification. The SCN sheet and revised pages prepared for the specification eventually are attached to the latest approved version of the specification, thus updating the specification to agree with the updated configuration of its item. Military program-peculiar specifications must be changed only by using DD Form 1696 as prescribed by MIL-STD-490. Changes to specifications not under military control may be controlled by other SCN practices peculiar to the individual developer or manufacturer. In any event, the designer may be called upon to prepare or review revised portions of specifications as required by SCNs (which themselves are usually prepared by configuration management personnel).

Drawing Change Notices (DCNs)

DCNs are similar to SCNs except they are prepared by design engineers and implemented in accordance with DoD-STD-100.

SUPPORT DOCUMENTATION

While the engineering data and design change documentation delineated above are primarily applicable to the design and development cycles, the design engineer may be called upon to provide engineering data and information required for the preparation of such support documentation as technical manuals for operation and maintenance, maintenance standards books, computer programming documentation, operating instruction charts, and field change documents.

It is important for support documentation to be consistent with the product and the product documentation.

Technical Manuals

The design engineer generally is not required to prepare such documentation himself, as technical manual writing is a specialty occupation, but he may be required to develop the source data for the manuals and is in the best position to review and approve manuscripts for completeness, accuracy, and adequacy of purpose. Commercial manuals purchased with commercial off-the-shelf items should be required to meet the minimum standards for such documentation, as delineated in MIL-M-7298. Manuals for systems and equipment developed by or for the military services must be prepared in accordance with applicable military specifications and standards. Each service has its own requirements reflected by its own "limited" specifications. The military specification most commonly used for Navy electronic equipment manuals is MIL-M-15071. Technical manuals should be procured at NRaD, through NRaD Code 027 (Technical Information Division).

Maintenance Standards Books

These documents provide equipment maintenance instructions to Navy personnel in the field when the Programmed Maintenance System is not in effect. While these documents can be prepared manually from data already in the associated technical manuals, engineers may be required to provide additional information to the technical writers. Maintenance standards books are prepared in accordance with MIL-B-21741.

Operating Instruction Charts

Usually prepared by technical writers from information available in technical manuals, these charts may on occasion require some input from an engineer.

Field Change Documentation

If equipment already in the field is to be modified, the personnel responsible for making such modifications require clear, complete instructions as to the purpose and method of modification, checkout after modification, and other factors. In addition, existing technical manuals and other support documentation in the field will require changes that reflect the modification. Engineers, whether or not they were involved in the initial design of the subject equipment, may have to provide to the technical writer all the information required by the specification to which the field change and technical manual change documentation is prepared. The specification for field changes is MIL-F-17655.

Computer Programming Documentation

When the design of a computer or any associated system is accomplished, certain types of "user" documents are required to ensure that operating and maintenance personnel have the required information for the performance of their mission. (These "user" documents are in addition to the programming specifications that must be prepared during the design cycle.) While responsibility for providing the data and information for user computer program documentation usually falls primarily on the programmer, the character of the user documents is such that both the programmer and the hardware design engineer have to contribute to the inputs furnished the technical writer. They should also review such documents for completeness, accuracy, and adequacy. Depending upon the type and application of the computer-associated equipment in question, there are several specifications or instructions covering the requirements for content and format of the various documents required. MIL-STD-2167A provides guidelines for software documentation and can be tailored to peculiar program requirements.

Parts Provisioning Documentation

The engineer should be aware of the requirements for provisioning. Provisioning documentation is a direct result of maintainability tasks which determine the type and level of maintenance actions required for a design. The engineer's direct input to maintainability tasks, therefore, indirectly affects provisioning actions and associated costs. Provisioning documentation is generally prepared in accordance with MIL-STD-1561 by a logistician or by a technical writer who specializes in this field.

Other Support Documentation

The engineer must sometimes provide data, information, and guidance for the preparation of documents other than those described in previous subsections. Reference standards books, operators' handbooks, maintenance manuals, and training guides are examples of these, along with other specialized documents required for training, installation, operation, and maintenance in the field. Support documentation is prepared mainly by technical writing specialists; however; the engineer is expected to provide pertinent information, and in some cases to contribute written material.

Project Management Support Documentation

Plans in considerable variety are normally required to support the project management function. These plans should be kept to a minimum; however, they are sometimes important checks on contractor procedures:

Configuration Management Plan

Configuration Status Accounting reports

ILS Plan

Design-to-Cost Data

Reliability Program Plan

Maintainability Program Plan

Environmental Test Plan/Procedures

Human Engineering Program Plan

Maintenance Engineering Analysis Program Plan

LOR Program Plan

QA Program Plan

Inspection System Program Plan

Production Plan

Accession List

The use of an accession list is highly recommended. An accession list is a periodic report of all the documents which a contractor produces for internal use; the government obtains, through the accession list, access to this information for only the cost of reproduction. The data required by the government in the contract are limited to only known essential data items, thus reducing costs by not asking for data which may or may not be needed. The Statement of Work must contain the following task:

> "The contractor shall prepare and update (monthly) a list of all reports, records, memoranda, plans, procedures, and other data items generated in support of this contract. Upon request from the Government, the contractor shall provide copies of specific data items. The Government shall reimburse the contractor for reproduction costs incurred in this task."

The CDRL must reference the task in the SOW. The CDRL item for an Accession List Data/Internal Data can cite DIDs DI-A-3027A or UDI-A-26486.

An accession list may also be used by the knowledgeable systems engineer to watch for omissions in contractual efforts. When documentation should be created and it is not, the systems engineer can ask appropriate questions and redirect efforts to cover the omissions.

XXI. RISK MANAGEMENT

The project manager is charged with the responsibility to manage the tasks, funds, schedules, and risks.[1] Risks are encountered by everybody, everyday, in everything they do, from simply getting out of bed to taking a trip to the moon. Most risks are so small or inconsequential that most everyone ignores them; even the sometimes painful consequences are shaken off as bad luck. In a classic example, one seldom considers the risk of pain when driving a nail to hang a picture, and a throbbing finger easily obscures the concept that a risk was taken. A complex technical project deserves better attention to risk than driving a nail, and recognizing that any project entails many risks highlights the need for risk management.

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[1]DoD Directive 5000.1 of 13 July 1971.

Risk management has been developed into a highly effective tool by most successful project managers, although its application is often intuitive However, the insurance industry has consciously developed risk management into a rigorous science. The decisions facing a technical project manager will seldom yield to the statistical analysis of an actuary, but the qualitative techniques which have evolved are very useful. The sections which follow discuss risk management as it can be applied to technical projects. If this guidance at least stimulates conscious consideration of risk with the other project factors, it will have served its purpose.

GENERAL SUMMARY OF RISK CONSIDERATIONS

Risk is a probability of failure to achieve a well-defined goal. If success is the unqualified achievement of the goal, the probability of success is one minus the risk, since all probabilities are measured on a scale from zero (no chance of occurrence) to one (certainty of occurrence). Success and failure hinge on the definition of the goal; the well-defined goal consists of the following characteristics:

A complete description of that to be attained including tolerances on each descriptive parameter

The resources to be spent in attainment

The time in which the goal is to be reached

Any constraints which may exist an the actions that may be taken to achieve the goal

Obviously, there are many examples of partial success which were termed either satisfactory or unsatisfactory; this directly implies two underlying risk principles:

1. There are a number of elements which, taken together, describe the goal; there is a risk associated with each element.

2. There are consequences attached to the failure to attain each element which may vary from insignificant to catastrophic.

These seemingly trivial definitions and principles form the foundations of risk management.

Since risk and the probability of success sum to one, it is easy to jump to the conclusion that the objective of risk management is to minimize risk, thereby maximizing probability of success. If all risk could be reduced to zero, success would be certain. However, it would seem that both omniscience and omnipotence would be necessary to bring this condition about. More practically, some finite risk must always be assumed to exist. If success is not certain, the possible consequences of failure must be considered. This adds a new dimension to risk management — that of maximizing the probability of an acceptable outcome; this may even mean a lower probability of success per se.

This leads to the problem of defining what constitutes an acceptable and an unacceptable consequence. For purposes of this discussion, the categories will be defined as follows:

Critical	A failure which is of itself unacceptable, i.e., catastrophic
Potentially critical	A failure which is acceptable but which is unacceptable in combination with other failures
Probably noncritical	A failure which is acceptable and must occur in combination with several other failures to lead to an unacceptalbe result
Noncritical	A totally inconsequential failure

Another practical problem concerns the fact that everyday goals are simply not well defined. Indeed, some aspects may defy practical determination. In order to develop criteria for success, to identify risks, and to determine the consequences of failure, it is usually necessary to estimate aspects of the missing pieces. The estimation process at its best relies on educated guesses and at its worst on the other kind. In each case, the probability of estimating error and its consequences must be considered in the risk assessment.

The four characteristics formulating the well-defined goal are closely interrelated; thus, the associated risk elements are interrelated. Such functional relationships will obviously affect the tactics to be employed in managing the risks. These relationships may be categorized in the following manner:

Independent	Not affected by other risk elements
Dependent	Totally determined by the outcome of other elements
Interdependent	Functionally related to other elements such that each affects the others

The nature of the goal determines the exact relationships as well as the consequences associated with its risks. Nevertheless, the courses of action for dealing with the risks must clearly tackle independent elements directly, attack interdependent elements as a group, and approach dependent elements indirectly by manipulating the elements on which they are dependent.

If each of the four goal characteristics is a single element, it is relatively simple to analyze the goal, to assess risks, and to assign consequences to those risks; therefore, the risks should be fairly simple to manage. Unfortunately, this is not necessarily the case. Each goal element is toleranced; i.e., a range of acceptability is defined about the goal. If the tolerance is tight, it will be more difficult to stay within the range than if the tolerance is loose. When the elements are interrelated so that one must be traded off against another, tight tolerances make this task harder. If the intolerance is sufficiently loose, tradeoffs might be made such that the probable consequence of the associated is affected. This will depend on the nature of the risk, its relationships with other risks and the range of acceptability. Because the manipulating of one risk to change another appears intuitively to be a potent tool, it seems wise to identify those risks which will and will not lend themselves to alteration by this method; accordingly, the risks should be classed as follows:

Rigid	Those elements for which the risk consequences cannot be altered regardless of the degree of risk assessed or of relationships with other elements
Flexible	Those elements for which the risk consequences can be altered

A risk which is critical (or potentially critical) but flexible is obviously a good management target. Conversely, a rigid, noncritical risk makes an excellent tradeoff against related targets.

The more complex the goal is, the more important it is to be able to categorize goal elements. Within each goal characteristic, many subdivisions are normally possible before the goal is partitioned all the way down to the individual element. While the subdivisions may vary with each field of endeavor, the keys to discovering the functional relationships between the elements will probably be disclosed by studying the rules of partitioning. Nonarbitrary rules of partitioning must be invertible; otherwise, there could be no way to synthesize the whole from the parts. The inverted rules (rules of integration) will describe the desired relationships by necessity. Since these relationships are required knowledge for the risk manager, the implication is that the risk manager must be conversant with that field of endeavor. Very complex goals spanning several fields will require a multidisciplinary background for the management team, embodied in the management leader.

The preceding discussions have assumed that risk management can be reduced to practice. While this may have been a brash assumption for the general case, it is heartening to note that an entire industry is built on risk management — the insurance industry. Given the apparent success in that field, it seems reasonable to assume that somewhat effective techniques must be available to manage risks in a cognitive manner in general. In reviewing the general discussions above, there would seem to be at least eight categories of technique:

Defining the goal

Identifying risks

Assessing consequences

Assessing degree of risk

Manipulating consequences

Manipulating degree of risk

Assessing results

Developing a best plan of attack to achieve a goal

Both qualitative and quantitative methods are needed in order to adequately address the life cycle of attaining a goal from concept to success. Such results should describe practical guidelines of great utility to the technical project manager.

RISK IDENTIFICATION

The first step in risk management must be the identification of the risks to be managed. Indeed, once a risk is identified, its management often becomes obvious. There is no cookbook method or formula to identifying risks; at any given time, it is nearly impossible to identify all the risks for a project. However, the following procedure may be easily adapted to fit the peculiarities of the project and aid in risk identification.

For identification purposes, risks may be considered as either project oriented or technology oriented. Project-oriented risks are those which are associated with the goals of the specific project, such as cost targets, schedules, and resource constraints. Technology-oriented risks are those which would be essentially the same regardless of the project goals; such risks are usually associated with achieving a specified level of performance. There are also political risks which take on the character of either project- or technology-oriented risks. Opposition to project budget appropriations will have a project-oriented character; for instance, opposition to the operational requirement or technology animosity (as against nuclear power) may be regarded as technically oriented.

The identification of project-oriented risks is directly facilitated by project planning. The better a project is organized, the easier and more certain the risk identification process can be. By utilizing the work breakdown structure (WBS) organization described in chapter III, Program Planning, a risk can be envisioned for the performance, cost, schedule, and availability of resources, for each individual task element. In practice, the risk associated with many elements will be so small as to be neglected. However, before throwing out a risk, consider its impact on the next higher level in the WBS; if the impact is inconsequential, the risk may be neglected.

Generally, it will not be practical to consider the tasks below level 4 in the WBS, but even the smallest project will usually be concerned with tasks at the third level. It is handy to reproduce the project WBS and to circle the elements which present the greatest risk. On a complex project, a color code will be useful to identify each risk as high, medium, or low and the risk consequences as critical, semicritical, or noncritical. Assume that opposition will develop against the required resources for a task to determine whether political risks exist. Usually, such risks will impact on funding, but organizational relationships may also present risks in accessing certain facilities or personnel talent.

The identification of technology-oriented risks is controlled by the knowledge of that technology available to the project. The more information that is assimilated by the project, the easier it is to identify and manage the technical risks. The information may come from several sources:

Knowledgeable people

Research

Past experience

In general, the gathering of information requires both time and money. If a constant effort is expended to gather information, the information base will tend to grow as a logarithmic function of time. For these two reasons, the information-gathering effort is most effective at the start of a project. To limit the scope of effort needed, it is important to utilize talented personnel who have experience in the technology in the project planning phase; they will know much of the required information and will also know to a large what information is unknown. Thus, it will be possible to organize research efforts to gain that information which is needed most. There will always be unanswered questions and unknowns to which the project will be naive, so some risk must always be incurred. Chapter IV, Conceptual Phase, contains guidelines for gathering information and for organizing the technical effort in accordance with the perceived risk. The fixed political risks must be discovered by knowing the project's "chain of command" and the attitudes of personnel therein either directly or indirectly and also by being familiar with the policies, directives, and instructions which will apply. Anyone with review authority, approval authority, or budgeting authority in the project's chain of command can pose a problem or a solution; it is important to keep in touch with their attitudes to discover which may pose risks to the project. Once the project is underway, valuable experience becomes available to identify and manage risks; it is essential to document this experience through engineering notebooks, drawings, progress reports, and memoranda, especially if personnel are constantly changing, so that this information is not lost.

The risks associated with estimating may be considered technology-oriented risks even though they may concern project parameters such as cost and schedule. Knowledgeable people and their past experience may be pivotal in making accurate estimates. Also, they will be essential in characterizing the accuracy of an estimate from any source. The progress toward achieving all estimated parameters should be tracked through a testing program (for technical parameters) or an appropriate management information system (for project parameters). A lack of progress can be used as a measure of risk.

RISK CHARACTERIZATION AND ASSESSMENT

When a nonnegligible risk is identified, a method of managing it must be formulated; this method will depend on the kind of risk and how badly it can affect the project. Risk elements may be high or low, critical or noncritical, flexible or rigid, dependent or independent, and so forth as described in the introduction to this chapter.

The degree of risk may be considered inversely proportional to the knowledge of the associated task available to the project. One may assign subjective probabilities of success or even develop statistical probabilities in some instances. However, it is normally sufficient to characterize the degree of risk as follows:

Low	The task has been done before and this experience is available to the project.
Medium	The major portions of the task have been done before and the experience is available to the project.
High	One or more major portions of the task have not been done before or the experience is not available to the project.

The principle relating knowledge of a task to the risk is well established. However, if the risk is purely a matter of chance, as in a dice throw, the statistical probabilities of success/failure should be used. When an estimated parameter — cost, schedule, reliability, or whatever — is measured in the course of the project, a measure of risk may be developed by looking at the ratio of the percent of goal attained to the percent of resources remaining to accomplish the goal. If the ratio is below a threshold, say 0.95, consider the risk low, and, conversely, if it is above ceiling, say 1.05 or 1.10, consider the risk high. For the primary resource (usually funds), this ratio will be the actual expenditure to expected expenditure for the corresponding degree of progress.

The project WBS can reveal how critical or potentially critical or noncritical and how dependent or independent or interdependent the risk elements are. Tools such as the PERT/critical path method can also help. No specific guidance can be provided here beyond stressing the importance of honestly evaluating the risk elements as they affect the higher levels of the WBS and the critical path of the project. Each project presents its own difficulties in analyzing task relationships. Often it will be possible to develop numerical relationships by using subjective evaluations; these relationships are particularly useful in determining where to expend risk management resources.

Risk elements can almost always be characterized as flexible. Rigidity is normally imposed by limits on resources. Since flexibility and manageability are directly related, it is important to identify those limits and to plan tasks to maintain flexibility.

HANDLING RISK

The handling of risk is probably the most effective way to decide how to allocate project resources; after all, risk management strives to maximize the chances of achieving acceptable results. The risk decisions can be used to determine not only how resources should be allocated but also how the resources can best be applied.

Priorities must be established. The risks which bear the most critical consequences should be handled first. Of those critical risks, high risks should be treated as top priority. On a complex project, it is useful to assign priorities to the risks and to notate the WBS accordingly. Table XXI-1 illustrates one such priority system.

Table XXI-1. Risk priorities.

	Probability of Failure		
Risk Consequence	High	Medium	Low
Critical	1	2	3
Potentially critical	4	5	6
Probably noncritcal	7	8	9
Noncritical		10	

The overall project risk can be considered acceptable if all priority 1 through 5 risks can be managed. When the risks are not acceptable, the project should be terminated.

Next, appropriate techniques must be selected to handle the risks. Table XXI-2 lists some strategies and examples for handling risks. When a qualitative method has been selected, an attempt should be made to quantitatively express the risk situation as it applies to the project. This effort can reveal subtle interactions between project risks and can increase confidence in decisions based on the method even though subjectively derived probabilities are used. A risk approach can be modeled for virtually all major project decisions including source selections. The extent to which this form of decision analysis is implemented should depend on the scope of the project. In many cases, these guidelines will have served their purpose if the project manager consciously considers risks along with the technical, cost, and schedule factors of the project.

Table XXI-2. Risk strategies.

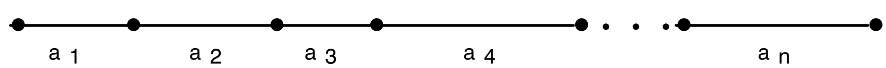
Method	Application	Conditions
I. Hedging Strategies: Hedging strategies offset risks by providing alternatives which have low risk and acceptable results although the ideal goal is only partially achieved.		
A. Parallel-path method	High, technology-oriented risks	Two or more paths are pursued concurrently; the paths must differ in risk characteristic and at least one path must be at low risk. (Parallel paths to secure price competition do not apply.)
B. Backup method	Medium and low, technology-oriented risks	One or more backup paths are identified; the paths must differ in the area of risk. For medium risks, resources to implement the backup are identified and retained
II. Transfor or Exchange Strategies: Transfer strategies exchange an unknown risk for a known acceptable risk or a known critical risk for a known less-critical risk.		
A. Warranties	Unknown project-oriented risk	A known price (warranty cost) is paid to fix a future condition (usually support costs); the warranty cost is then budgeted. The unknown risk is supplanted by a funding risk.
B. Insurance method	Critical or potentially critical project-oriented risks	A known price is paid to limit possible future consequences as in fire insurance, liability insurance, etc. This method can only be applied where an "insurer" can be found. Often this condition can be satisfied contractually with a supplier. The price paid must be within reason to the condition insured against.
C. Contractual method	Same as (A) and (B)	When a contract is involved, various contractual agreements can be made to transfer risks to the contractor. The contract must be fixed-price and negative price incentives may be indicated.
III. Reduction Strategies: Reduction strategies amount to better management and to careful control of resources which lead to a higher probability of success. They may be applied to virtually any risk situation including in combination with other strategies. To reduce technical risks, top personnel would be assigned to the task. Cost and schedule risks would require more intensive preplanning and must be taken. In the application of reduction strategies, care must be taken not to create risks on other tasks by stripping them of resources and not to interfere with the task through "micromanagement." If problems do occur, the goal is to minimize their effect.		

Method	Application	Conditions
IV. Avoidance Strategies: Avoidance strategies are alternate paths which avoid exposure to the particular risk. Primarily, avoidance strategies are applied to technology-oriented risks. Examples include the choice of one technical approach over another because of known past difficulties with the latter. A pseudo technology-oriented political risk might be avoided by structuring the project for sponsorship by nonhostile offices or to bypass a hostile office in the approval cycle. The crux of any avoidance strategy is knowing that a risk exists and devising a means of nonexposure.		
V. Evasion Strategies: Evasion strategies utilize prior planning to avoid risk consequences even though a failure occurs. Because of legal and technical restraints, evasion strategies are almost wholly limited to political risks. Usually this requires developing a “power base” of influential “friends of the project”; occasionally the “snow job” is a viable tool. The ultimate success of an evasion strategy in a technical project application relies on honest facts and the apparent ultimate achievement of the goal.		
VI. Risk Assumption: Assumption strategies recognize the unlikelihood of the expected. Applied to project-oriented risks, especially funding and scheduling, assumption strategies plan “padding” into project estimates; the key to successful risk assumption is limiting the extent of the padding to what is sufficient while ensuring an adequate amount. Applied to technology-oriented risks, assumption strategies tend toward ultraconservative design parameters. Care must be taken not to misapply such strategies, especially to technical problems, since they tend to produce gross overspecification with drastically increased costs. Risk assumption must not become a “cover your anatomy” ploy.		

BETTER ESTIMATES USING RISK ASSESSMENTS

An estimate is a judgment as to what is most likely; that is, it is an expected value. When estimates are made at a low level in the WBS, the combined estimate at the top level is more accurate because there is less chance of omitting key elements and because there is a statistical tendency toward eliminating the collective error in the estimates. However, a simple combination of estimates yields the most expected value for the estimated parameter disregarding the effects of interdependent and dependent tasks. Because of task dependencies, an overrun in a task can be propagated to other tasks whereas an underrun can remain isolated; therefore, a “best estimate” will almost always be overrun. A subjective risk assessment technique can be applied to correct higher-level estimates to yield a much more precise estimate.

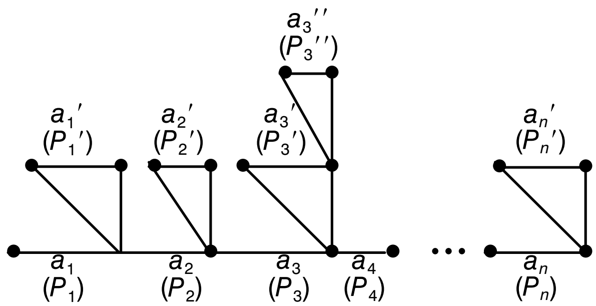
As an example, let us assume that a work package consists of n tasks for which a parameter is being estimated in an amount a_n. The parameter may be cost, time to completion, or any other expended resource. Figure XXI-1 shows the traditional estimate for the work package.



$$a_T = \sum_{1=i}^{n} a_i$$

Figure XXI-1. The traditional estimate.

Generate a probability of success for each task and designate it P_n; although the probability is subjective, the best estimate of the knowledgeable estimator of a_n will be a sufficiently accurate P_n. There is now an identified risk of $1\text{-}P_n$. Should a failure occur, additional resource will be utilized to attempt to complete the task; this effort will also have a probability of failure/success. This additional effort is a conditional task n'. Figure XXI-2 illustrates the combined work package estimate.



$$a_T = \sum_{1=i}^{n} (a_i + (1 - P_i) a_i' + (1 - P'_i) a_i'' + \cdots)$$

Figure XXI-2. An estimate with risks assessed.

Any number of reiterations may be accounted for until a sufficiently high probability of success is reached. In the illustration, task 3 has a second conditional task n'' which depends upon the failure of the first conditional task n'; on the other hand, task 4 is sufficiently certain that no condition task is estimated. The technique is surprisingly easy to use and becomes easier with experience. In conjunction with standard estimating techniques, this method produces estimates which are approximately an order of magnitude more accurate for complex projects. If the project is using a computerized WBS, this method can be integrated into the program.

The risk assessment estimate will be higher than the traditional estimate. Allocate the estimated resources to tasks according to the traditional method (which represents the most likely or expected amount) and hold the excess in a management reserve. This management reserve is justified by the estimated risk.

CHAPTER XXII. PROJECT MASTER PLAN (PMP)

Project planning and control can be done without writing everything down—but it is much better to commit project plans to paper. It is not the paper itself that is so important; it is the process of arriving at the detailed information that goes into the paper and the process of reviewing and updating the paper that is important. A Project Master Plan encompasses all aspects of the program plan, system engineering, and acquisition strategy. It serves as a "contract" between the project manager, the systems engineer, and the task leaders. It serves as catalyst to bring together the project resources, the project goals, the system design/implementation, the acquisition environment (the rules and regulations which apply to the project), and the project environment (the organizational relationships and task responsibilities and management tools).

This section does not dictate inviolable rule; rather, it is hoped that this section will be found to have invaluable guidance.

DESIGNING A PROJECT MASTER PLAN

In designing a PMP, it is useful to keep several principles in mind:

- The planning process is as important as the plan itself.
- The PMP should be a living document that changes as project requirements and environments change and as more detail becomes available.
- The PMP is a useful "contract" within the project management organization only if the project manager, the systems engineer, and the principle task leaders participate in mutually planning the tasks. A PMP is not an end in itself and should not be generated just to prove that lots of money can be spent cutting down trees and putting ink on pulp.
- A plan is only good if it is implemented correctly.
- A plan documents intended future actions rather than past performance. While it may acknowledge past decisions, its value is in the decision/action roadmap that serves to connect the present to the desired goals. When circumstances dictate a detour in the plan, the plan must change to account for the "now" rather than for the "expected" when the plan was first formulated.
- A good plan anticipates the possible detours and variations in future circumstances and provides alternate routes to the project goals. This function is an important element of managing risks.

A PMP should be generated by the project manager, the systems engineer, and the key task leaders—the project management team. It may not be possible to get all of the required task leaders together at the same time; this is acceptable as long as task leaders for tasks which interface with each other can participate in the planning process together. If one or more significant tasks is being accomplished under contract, the task leader will not be known until after the contract is let, so use the person who will be responsible for monitoring the contract. The task leaders should be selected to be knowledgeable in the critical issues associated with their tasks — outstanding in their field. Occasionally, a personality conflict will exist between task leaders whose tasks must interface; it then becomes incumbant upon the systems engineer or project manager to arrange "shuttle diplomacy" or other means to ensure that effective communications do take place. Often the communications modes established between task leaders during the planning process become the modes which are used during the execution of the project, so it is important for the systems engineer/deputy project manager to monitor the planning process and to ensure that effective interpersonal relations and communications are established.

The PMP design process should generally follow the steps below. A rigorous adherence to these steps is not required, but the thought processes they represent and the project team relationships they entail should be present in the planning process. Virtually every successful project studied has followed this general planning pattern.

1. Identify the project goals and the acquisition environment. This normally involves detailed discussions with the project sponsorship and may involve requirements definition tasking.

2. Select project leaders. The project leaders can be participants in the requirements definition process, key people in the functional organization having the project management responsibilities, and experts from key supporting organizations.

3. Enroll the project leaders in the project goals. Each participant must have a clear concept of what is to be accomplished and be able to project what role their task plays in achieving those goals. The enrollment process may be as simple as a detailed briefing and review of project documentation to visits to prospective user organizations and participation in exercises which illustrate the problems to be resolved by the project product. The extensiveness of the enrollment process may be tailored to the needs of the prospective task leader.

4. Strategize. A strategy establishes what kinds of tasks need to be accomplished and the major milestones to be achieved in order to attain the project goals. All of the project leadership should be involved in developing the strategy.

5. Identify the task interfaces.

6. Estimate the resources required by each task (costs, time, manpower, talent, facilities, equipments, contracts, and risks). Task leaders on interfacing tasks should work with each other to develop these high-level estimates. These estimates will be top-down in detail and from time-present to time-complete in flow (forward-looking estimates).

7. Breakdown the long-term milestones and major tasks into intermediate- and short-term milestones and more detailed taks. Continue this break-

down process as long as it is supportable by available information. Together with the acquisition environment, use this information to formulate a Work Breakdown Structure (WBS) and an appropriate schedule tracking system (GANTT or PERT, etc.).

8. Identify the information gaps and the approaches needed to fill these gaps. This may cause additional tasks to be identified.

9. Develop detailed estimates for each detailed task for all near-term milestones (all the identified milestones which have no predecessor milestones from the present planning time) and all tasks which are dependent on these immediate tasks. (The use of the risk estimating technique in chapter XXI is recommended.)

10. Develop estimates for other known tasks.

11. Accumulate estimates from the bottom to the top of the WBS and from time-complete to the present (working-back estimates).

12. Reconcile the top-down estimates with the bottom-up estimates, and the forward-looking estimates with the working-back estimates. The reconciliation process will identify risks caused by inadequate resources (especially time and funding) and potential alternatives which might be incorporated in the overall strategy.

13. Document the plan. Actually, the documentation should be generated as the planning process progresses, but it is useful to incorporate the documentation into a formal document which can be referenced and which can serve as a baseline for future revisions.

14. Repeat steps 4 through 13 every time a significant milestone is achieved.

15. Repeat steps 2 through 6 whenever a key task leader is replaced.

There are many schemes for actually reducing these steps to practice. The best PMP design tactics take the project team personalities into account. There are some schemes which have a proven track record of failure; the most prevalent of these failure modes include the following: (1) when the project manager or the project sponsor dictates all elements of the planning, (2) when a "belt-way bandit" (support contractor not actually involved in the work) writes the plan, or (3) when the PMP is generated to fulfill the need of having a document rather than as a planning instrument. The successful schemes provoke thoughtful planning of both strategies and tactics for achieving the project goals and promote communications between the members of the project management team.

USES OF A PMP

The primary purpose for creating a PMP is as an instrument of monitoring and controlling the project. The PMP design process becomes a method of enrolling the project management leadership into a team and of promoting communications between task leaders. The project leadership must have a basis for mutual trust and confidence. The task leaders must have a clear understanding of their responsibilities, authorities, and accountability. It is understood that the many gray areas between tasks cannot be unilaterally resolved by a single task leader; gray areas must be resolved by:

mutual consent
authority delegated by the project manager
higher authority (project manager or systems engineer)

Usually, the project manager does not know where all the gray areas are, so the task leaders must be trusted to recognize which problems must be resolved by which method. The task leaders are prepared to do this only if they share the project management goals. A clear concept of one's personal responsibilities/authorities does not require a clearly defined task in a management TEAM.

A well-developed PMP serves as a contract between the project manager and the other team/task leaders. The viability of this contract is totally dependent on the personal commitment of each individual. The project manager seldom has formal personnel authority over the members of the team, so the discipline, either encouragement or punishment, that can be imposed is limited. It may be limited to an encouraging word, a favorable memo to the supervisor, an occasional certificate of appreciation, or a chocolate doughnut; or it may be limited to a private "chewing out" or request to the supervisor for action. This extent of discipline is sufficient when the individuals have personal commitment.

The PMP, or at least an executive summary of the PMP, can be used as a contract between the project sponsor and the project management. Seldom can a sponsor deliver all of the funding when it is ideally required. Likewise, requirements change, unscheduled briefings are needed, schedules of ships and facilities needed for project tasks change, and other elements change. The PMP serves as a baseline for managing these changes. Some of these changes can be made "within scope," but others will require additional funding or a modification of tasking. The PMP serves the important role of identifying the impact of changes and helps the project manager to avoid getting backed into a losing corner. Good sponsors appreciate a PMP because the risk consequences of their decisions can be determined and because adequate justifications are easier to develop for project resources and project defenses (a project must be defended somewhere in the project's political environment about once a week); otherwise, the sponsor is left to make decisions in the blind which may adversely alter the acquisition environment in an untimely way. In other words, the PMP is useful to the project and to the project's chain of command.

An executive summary of the PMP can be useful in obtaining a form of a project charter. A project charter formally establishes the project's authorities and working relationships within a functional organization. The project manager can sometimes get his or her personal administrative chain of command to review and "approve" the PMP and then successfully negotiate special delegations of authority which can make the project more efficient. The project manager can also use the PMP as a basis of negotiating working relationships with the various supporting organizations; agreements with these organizations can be formalized in Work Agreements signed by the supervisors in the support organizations and the head of the project's line organization. Besides highlighting special project requirements of which the supporting line organizations should be aware, the Work Agreement helps to enlist the commitment of the supporting line organization beyond the personal commitment of its project participants. The commitment of line management is essential to obtaining the support of the greater organization in getting the resources needed to do work (supply, accounting, special test facilities, shops and labs, space, screen rooms, and so forth). An actual project charter is rarely issued, but if the participating line organizations can be informally committed to the project goals, the charter is not necessary.

PMP STRUCTURE

A PMP should be modular, because not all elements will be produced at the same time or by the same organization. Also, the PMP is a living document and subject to change. The following structural elements, outlined below, are suggested. These elements are neither exhaustive nor mandatory; nevertheless, they offer a flavor for what should be accomplished by a PMP. It is suggested that a specification-style numbering system be employed to enable ready reference to particular information of interest through the table of contents. The PMP should be a daily working tool, so it should be kept unclassified, if at all possible. Aspects which are classified may be published as a separate classified addendum or included by reference to formally published documents (TRs, TDs).

ABSTRACT — an abstract is suggested but not mandatory. The abstract should contain one or two paragraphs describing the project goals in “sales brochure” prose.

EXECUTIVE SUMMARY — the executive summary should contain a summary of the project background, a summary of the operational requirements, and the project charter.

LIST OF EFFECTIVE PAGES — this is almost mandatory because a PMP is likely to be very dynamic if it is actually being used. All the PMP users need to know that their working copy of the PMP is up to date. It is suggested that the page numbers be numbered in sequence within each major section (1-1, 1-2, 2-1, etc.)

TABLE OF CONTENTS — an indentured table of contents is suggested. (An indentured table of contents indents headings which are subordinate to other headings. Major headings are left justified while sections are indented once, subsections are indented twice, etc.)

1. INTRODUCTION

1.1 BACKGROUND

1.1.1 HISTORY — events leading to the establishment of the project.

1.1.2 SUMMARY OF PRIOR RELATED EFFORTS

1.1.3 REFERENCES — especially official documents such as the OR and TEMP plus significant reports and project documents referenced in the PMP.

1.2 OPERATIONAL REQUIREMENTS—This should include all of the elements found in the OR (OPNAVINST 5000.42) but not limited by the page limitations of the OR. Subordinate paragraphs may expand significantly on the known operational requirements and may prioritize requirements. A prioritization of requirements is particularly important when all requirements cannot be addressed within the scope of the currently funded efforts. Also, this section should distinguish between required thresholds of performance and desired thresholds. When system requirements tradeoff analyses are completed, they may be included in this section or referenced, if they are formally published.

1.3 CONCEPT OF EMPLOYMENT — This may be included here in its entirety or included by reference to a formally published document. If published separately, an unclassified abstract is desireable in this section. Any operational interfaces between the project system product and other operational systems should be included. Concept of employment scenarios should be sufficiently complete to illustrate operator interactions with the system.

1.4 CONCEPT OF SUPPORT — This should include support requirements peculiar to the concept of employment scenarios and the overall support strategy. References to LSA, LOR, and ILS documentation should be included when it is generated.

1.5 PROJECT CONSTRAINTS AND THRESHOLDS — Costs, schedule, and performance elements should each be identified. The performance thresholds should include combat operational performance, peace-time operational performance (if different from combat), and support element/systems effectiveness performance. They should cross-reference to the OR or TEMP as appropriate.

1.6 SPECIAL ACQUISITION CONSIDERATIONS — Other projects which are related by operations or technology should be noted here. Also, any special restrictions which may affect the acquisition strategy should be documented in this subsection.

1.7 RISK PERCEPTION SUMMARY—The external factors which affect the overall risk of the project should be noted here. These might include an overly ambitious schedule, inadequate funding, a highly dynamic threat, dependency on immature technologies, or inadequately defined requirements. Attention should be drawn to those sections of the PMP which are specifically structured to address these risks by referencing the PMP appropriate paragraphs.

1.8 SECURITY CLASSIFICATION GUIDE — If a separate guide is available, it may be referenced here. Generally it is necessary to identify project-peculiar security issues and to establish the classification policies implementing the more general requirements of higher authority. Authorities for classification are provided here. The Security Officer can provide much of the detail required for this subsection.

2. PROJECT ORGANIZATION — The first 3 subsections are often simply lists players, including the organization, the designated point-of-contact, the telephone number, facsimile number, e-mail address, and mailing address for each entry. A back-up point-of-contact is also desireable.

2.1 SPONSOR PARTICIPANTS — Those organizations and points-of-contact which form the project chain-of-command (and which obtain project funding and determine major milestones and set operational performance thresholds).

2.2 DESIGN PARTICIPANTS — Those key persons and organization under the control or authority of the project manager for execution of project tasks.

2.3 SUPPORT PARTICIPANTS — Those organizations and individuals who are tasked to support the project manager but who do not come under the project manager's authority. (Typically this includes operational units which are tasked by higher authorities to provide operational expertise, to participate in user conferences or advisory panels, to provide test facilities, and the like.)

2.4 ORGANIZATIONAL RELATIONSHIPS, FUNCTIONS, AND RESPONSIBILITIES — This subsection spells out who does what to whom on the project. A subsubsection may spell out those authorities reserved by the sponsor. The project charter is normally included under the project manager's paragraphs. The taskings to the various supporting organizations is normally also included here.

2.5 PROJECT ORGANIZATIONAL STRUCTURE — This is normally provided in chart form showing lines of authority and special lines of communication. Points of contact normally are repeated here with their telephone number.

2.6 PROJECT FACILITIES — Special facility requirements and the organizational responsibilities for providing and maintaining those facilities are noted in this subsection. Of special interest are requirements for secure facilities and controlled access facilities and for the control of COMSEC material. The project procedures associated with secure facilities should be reviewed by the Security Officer. The project procedures associated with COMSEC materials must be reviewed by the COMSEC Material Custodian.

2.7 PROJECT DOCUMENTATION CONTROL — It may be necessary to establish a project library. Consult with the NRaD Librarian to determine what procedures are appropriate to maintain and control a document library. If classified material is involved, the procedures should be cleared through the Security Officer. If intelligence information is involved, the Intelligence Officer should be consulted to ensure that proper procedures are followed. In any case, the responsibility for maintaining the current status of project-generated documentation should be clearly defined.

3. PROJECT STRATEGY — This section summarizes the major tasks and milestones and the management tools necessary to accomplish the project. It also provides the justifications and rationales for the major procurements anticipated for the project. Some of the detail for this section will not become available until later in the project, but the major elements will be known at the beginning. This section should be updated whenever the TEMP is updated.

3.1 MAJOR TASKS AND MILESTONES — This subsection should be very similar to the TEMP in content. However, this section should also contain a rationale for each task and milestone, explaining how each task fits into the overall project picture. The overall costs of each task will also be summarized here. It is suggested that a summary integrated schedule be included here using the schedule management tool selected for the project.

3.2 MANAGEMENT CONTROLS — The management information systems which will be used and the reporting requirements of the project participants will be spelled out in this subsection. Both formal and informal procedures will be covered; the rationale for the program assessment methods will be included. The procedures implementing management/organizational controls, schedule control, cost controls, technical performance measure tracking, and risk controls will be included, as required.

3.3 MAJOR PROCUREMENT PLANS — Each individual contract anticipated for the project requires advanced planning; this subsection provides the rationale and justifications for each contract. For contracts which are large enough to require an externally approved ACQUISITION PLAN or Advanced Procurement Plan, these plans will be appended to this subsection. This section does not cover minor contracts for material nor small purchases of project parts, but it does include small support taskings to outside organizations.

3.4 RESOURCE SUMMARY — The required funding profile will be shown here. Also, special resources will be identified such as facilities, test resources, organizational talent, special equipments, and the like. Each resource should be tied to the major tasks or milestone with which it is associated. As a minimum, the date of required availability should be stated in the same level of detail as that provided in the TEMP.

4. WORK BREAKDOWN STRUCTURE (WBS) — The WBS should be prepared in accordance with MIL-STD-881 and provided in this section. It is probably wise to maintain a three-level executive summary WBS for distribution outside of the project. When the PMP is distributed to outside organizations, this summary WBS should be substituted in this section. Refer to HOW TO USE A WORK BREAKDOWN STRUCTURE, below.

5. SYSTEM DESIGN PLAN — This section provides the detailed planning for the CONCEPTUAL PHASE and the DEMONSTRATION AND VALIDATION PHASE. Each plan will include the detailed tasks, deliverables, schedules and milestones, and resource summaries for the phase. The rationales for the system design decisions will be incorporated for each task as the system analyses and tradeoffs are performed; this is normally done by appending the minutes and reporting documents for the design reviews to this section. The task leader, performing organization, and special organizational requirements will be noted for each task. Even when projects do not have a formal conceptual phase or a formal validation phase, the elements of the system design plan should be developed and included in this section. Even when the project is proceeding as a nondevelopmental item (NDI), the system design planning elements will be documented in this section. When the system design is complete and validated, this section will document how the system design and the acquisition strategy are related.

5.1 CONCEPTUAL PHASE PLAN — In developing and reporting the conceptual phase plan, MIL-STD-1521 requirements for the SYSTEM REQUIREMENTS REVIEW and for the SYSTEM DESIGN REVIEW should be incorporated in detail as appropriate to the project. All plans for the execution of technical investigations, breadboarding, exploratory development, and field investigations will be included in this subsection. Upon completion of this phase, the system specification will be referenced from this subsection. The system specification may be attached to this section if it is not otherwise subject to formal document publication controls. Each requirement of the system specification will be referenced to an operational requirement or to a system tradeoff report; this may be done by a table presented in this subsection.

5.2 DEMONSTRATION & VALIDATION (D&V) PHASE PLAN — In developing and reporting the D&V phase plan, MIL-STD-1521 (and MIL-STD-2167A for software) requirements for the INTERFACE DESIGN REVIEWS and the PRELIMINARY DESIGN REVIEW (PDR) should be incorporated. All plans for technical demonstrations, brassboarding, advanced development, and operational assists should be detailed in this subsection. The method of validation should be referenced to each system specification requirement (analysis, simulation, or testing) and the results should be documented and referenced in this section. Upon the completion of this phase, the development specifications will be referenced in this subsection, and each development specification requirement will be referenced to either the system specification or a design analysis report; this may be done by a table presented in this subsection.

6. TRANSITION-TO-PRODUCTION PLAN — This section provides detailed plans for Full-Scale Engineering Development (FSED) (if any), for TECHEVAL and OPEVAL, for preproduction prototyping, and for the implementation of the product assurance plans in the production phase. The plan should include the detailed tasks, deliverables, schedules and milestones, and resouce summary. The task leader, performing organization, and special organizational requirements will be noted for each task. Unless formally reported elsewhere, a subsection entitled "configuration control" should be incorporated to document design changes, including the specification requirements affected, the rationale and justification for approving the change, an impact assessment, and the actions taken to implement the change. The plan should take into account the requirements of MIL-STD-1521 (and MIL-STD-2167A for software) for the Critical Design Review, the Test Requirements Review, the Functional Configuration Audit, the Physical Configuration Audit, and the Formal Qualification Review. The production or procurement specification(s) requirements should be referenced to the system specification, the development specifications, or to quality provisions derived from detailed design decisions; this may be done in a chart or table. The actual contents of this section vary considerably from project to project, so no detailed guidance can be provided here. Projects developing a one-of-a-kind system have substantially different requirements than those which will lead to large-scale production. In general, those projects with small production requirements will provide more actual detail in this section, whereas projects having large production requirements will incorporate information into the PMP by reference and summary tables.

7. PRODUCTION/PROCUREMENT PHASE PLAN — This section provides the detailed plans for buying the necessary number of systems. The details will include the advanced procurement planning necessary for the production contract(s), including the long-term plans for multiple-source, leader-follower, warranty-weighted, and other types of production contracts. Plans for First Article Testing, follow-on testing, interim training and logistics support, disposition of preproduction assets, and disposition of production tooling and test fixtures are all to be included in this section, as appropriate.

8. OPERATIONAL SUPPORT PHASE PLAN — This section may include plans for implementing and maintaining logistics support, logistics status reviews, implementing and tasking an in-service engineering agent, implementing preplanned product improvements (PPPI), and other tasks determined by the ILS/LSA tasks for the in-service system support.

9. SYSTEM PHASE-OUT PLAN — This section incorporates the advanced planning for system phase-out. It may incorporate performance thresholds for identifying the onset of system obsolescence (and the need to develop a replacement) or cost thresholds derived from the system life-cycle cost model which might indicate the need for action to restore or replace the system. If the system contains hazardous or precious materials, this section can be used to cover the disposal or recovery procedures and identify the organization(s) responsible.

10. DETAILED INTEGRATED SCHEDULE — A detailed schedule derived from all of the plans (sections 5 through 9) and incorporating all of the identified work packages from the WBS is provided in this section using the selected schedule management tool (see 3.2). The integrated schedule shows task dependencies and interdependencies and when information is expected to become available for generating more detailed information for follow-on phase planning. Ideally, the schedule is calendar-based and includes expected achievement dates, earliest expected achievement dates, and latest allowable achievement dates. (An achievement date is either a date of delivery for product oriented tasks or a decision date for project-oriented tasks.)

11. LIFE-CYCLE COST MODEL — The project LCC model is an important decision tool; this section documents the model and provides the underlying assumptions and rationales for nonstandard elements of the model. The actual detailed LCC estimates are normally not included in this section but may be attached as an appendix. It is suggested that the LCC model elements be keyed to the WBS.

APPENDICES — PMP appendices should include management planning documents which can stand alone or which are required as separate documents by outside agencies or which provide supporting detailed information to sections of the PMP. (If these documents are separately published and controlled, a single appendix which provides a management executive summary for each can be included instead.) The commonly encountered plans include the following topics:

Advance Procurement/Acquisition
Configuration Management
Data Management
Design-to-(unit production)-Cost
Electromagnetic Compatibility/TEMPEST
Environmental
Facilities
Human Engineering
ILS
Logistic Support
Maintainability
Quality
Packaging, Handling, Storage, and Transportation

Personnel and Training (and Manpower)
Product Assurance
Reliability
Safety
Security
Standardization/Parts Control
System Engineering Management
Testability
T&E
Value Engineering

It can be seen that there is a potential for lots of detailed information, resulting in a voluminous document. In some cases, this is desireable because the PMP becomes the central source of information for project decisions and becomes the key document for recording the project history. Small projects do not need to be burdened with substantial publication costs, so the evolutionary generation and maintenance of a PMP can be a cost-effective solution. On the other hand, large projects may have so many details to manage that the PMP simply serves as a summary and roadmap reference to all those details. These details may reside in a host of supporting documents that may include a System Engineering Management Plan (see MIL-STD-499B) and the multitude of plans supporting systems effectiveness, product assurance, and logistics support. This host of supporting plans may have a lot of information which duplicates parts of the PMP, often word for word, but there is much utility in a stand-alone document used by a substantial group of project participants who share common interests and who need not be burdened by details outside of their project tasking. The result is that a good PMP for a large project may be substantially smaller than that for a small project.

<u>Although there is a multitude of considerations in the management and systems engineering of a project, these considerations are tailored to the project environments and requirements, so the conduct of the project results in a system acquisition that is both effective and efficient</u>. The PMP should reflect this tailoring process that is incorporated in the strategies and tactics of the project management planning.

HOW TO USE A WORK BREAKDOWN STRUCTURE (WBS)

OVERVIEW

Work breakdown structures have long been used for project planning, estimating, and control. The basic structure for a WBS is defined in MIL-STD-881. However, merely constructing a MIL-STD-881 WBS will not provide a useful tool for any of these project uses. In fact, the WBS is used in markedly different ways for each purpose. A complete work breakdown structure consists of three main sections:

- structural breakdown
- work packages
- estimating categories

These sections are interrelated to provide the usefulness of the WBS tool and to enable interfacing the WBS to other program/project management techniques such as Gantt charts and project flow/sequence diagrams. This is important because the WBS provides a special planning visibility to the project that other techniques do not provide, but the other techniques offer perspectives that cannot be visualized through the WBS. For instance, a WBS provides a detailed relationship of tasks and subtasks which is essential for cost estimating, but it has no framework for displaying scheduling information. Each of the WBS sections can be structured in a variety of ways; however, it is recommended that the guidance provided here be followed in order to avoid some of the pitfalls normally encountered and to derive the full benefit of the WBS.

STRUCTURAL BREAKDOWN

The structural breakdown is the main portion of a work breakdown structure. The structural breakdown starts at the very top task — the entire project — and proceeds to divide or break down the task to successively more detailed subtasks. Each breakdown iteration is called a level. The top level (level 1) is always the total project. There are two approaches toward this breakdown process:

- task-oriented
- functionally oriented

The task-oriented approach achieves its breakdown through logical divisions decided strictly by the project/product task characteristics without regard to the means of accomplishment, sequence of work, or team assigned to the task. The functionally oriented approach breaks down each task by the functional project team assignments (i.e., code, company, or organizational component) and then by tasked responsibilities.

The functionally oriented approach is used to support various forms of work agreements across organizational lines. It is strong in displaying who is responsible for accomplishing a task, but it is weak as a planning or estimating tool. Use of a functionally oriented WBS often results in a failure to expose all of the tasks to be accomplished and in large underestimates. This normally occurs because the functional breakdown does not reflect the system design decisions which partition the product into its functional components; this obscures naturally occuring product interfaces which must be controlled. However, the functional breakdown does emphasize organizational interfaces and the needs for project communications.

Task-oriented approaches are assumed by MIL-STD-881. The task-oriented approach is recommended because it provides a more consistent framework for all forms of estimating and because it usually is more effective in helping the project planners to identify obscure or hidden tasks. When properly instituted, a task-oriented WBS can do everything achieved by a functionally oriented WBS, but the opposite is not true. Except for parenthetical comments, the remaining text will only address task-oriented approaches to work breakdown structures.

The task-oriented structure consists of two main sections:

- product tasks
- project tasks

Product tasks are those which are directly related to the design and production of the product. As such, the product tasks describe a breakdown of the major assemblies, set, groups, and other units which make up the product. The levels recognized by military specifications are listed in table XXII-1. Project tasks are those which relate to the management, installation, testing, documentation, and support needed to develop, implement, and support the product. MIL-STD-881 defines the project tasks for the second and third levels of the WBS. These second- and third-level project tasks are summarized in table XXII-2.

Table XXII-1. Levels of product complexity.

Level	Description
1	System—a composite of equipment, skills, and techniques capable of performing or supporting an operational role, or both. A complete system includes all equipment, related facilities, material, software, services, and personnel required for its operation and support to the degree that it can be considered a self-sufficient unit in its intended operational environment (MIL–STD–280A).
2	Subsystem—a combination of sets, groups, etc., which performs an operational function within a system and is a major subdivision of the system. (Examples: Data processing subsystem, guidance subsystem). (MIL–STD0–280A)
3	Set—a unit or units and necessary assemblies, subassemblies, and parts connected together or used in association to perform an operational function. (Examples: Radio receiving set, sound measuring set. “Set” is also used to denote a collection of related items such as a “tool set” or “drawing set” or “set of tires”.)
4	Group—a collection of units, assemblies, or subassemblies which is capable of performing a complete operational function. A group may be a subdivision of a set or may be designed to be added to or used in conjunction with a set to extend the function or utility of the set. (Example: Antenna group.) (MIL–STD–280A)
5	Unit or Weapon Replaceable Assembly—an assembly or any combination of parts, subassemblies, and assemblies mixed together, normally capable of independent operation in a variety of situations. A unit/WRA possesses specific attributes which cannot be broken into constituent parts without losing those attributes. These attributes are usually such that they are recognizable by operators/field personnel. (Examples: Radio receiver, internal combustion engine, hydraulic jack.) (MIL–STD–280A and MIL–STD–1390)
6	Assembly—a number of parts or subassemblies or any combination thereof jointed together to perform a specific function and capable of disassembly. (MIL–STD–280A)
7	Subassembly/Shop Replaceable Assembly—two or more parts whcih form a portion of an assembly or a unit replaceable as a whole, but having a part or parts which are individually replaceable. (MIL–STD–280A and MIL–STD–1390B)

Note: the distinction between as assembly and a subassembly is determined by the individual application. An assembly in one instance may be a subassembly in another where it forms a portion of an assembly.

Level	Description
8	Module—two or more component pieces joined together which are not subject to disassembly without destruction of the designed use. (Note: a module may or may not be repairable; if it is repairable, it is repairable at the depot level.)
9	Piece Part—an item which is not subject to disassembly without destruction of the designed use. (Examples: Composition resistor, electron tube, audio transformer.) (MIL–STD–280A) (Note: a piece part is never repairable.)

Work packages are the task assignments which actually accomplish the project work. In a task-oriented structure, they will be found near the bottom of the breakdown structure. In fact, they would always be the lowest level except that a WBS may be carried to greater detail for estimating purposes than is sensible for task assignment purposes. (In a funtionally oriented structure, the work packages always start at level 2, and subsequent levels are known as work details). The general catagories of work packages include electronic design, software design, mechanical design, prototype development, fabrication, item test, item documentation, item procurement, etc.; i.e., all the activities necessary to develop, produce, and support the item represented at the next highest level in the WBS.

PROJECT ORGANIZATION AND PRODUCT TASK BREAKDOWN

At the beginning of a system development, the complexity of the system may not be definable (until some design/development work is accomplished), so the work packages will appear as higher level tasks. The system design/definition process is a part of Systems Engineering, which is defined as a project task. As the system becomes defined, the work packages are broken down into component tasks and appear at the more detailed levels; the system units defined become the higher level tasks in their stead. These higher level tasks will/should follow the system-partitioning decisions which are embodied in the system design concepts.

As design tasks proceed from concepts through detailed design and product design, ever greater levels of detail are identified down to the minutest of components. The WBS can be carried down to this highly detailed level (and might be in some instances for estimating purposes or to track risks); however, the WBS work packages are maintained at the level identified in the system design. (It is possible to break down the work packages to these detailed levels, but there is little or no useful information gained while it becomes more complex to track). Work packages occur at/near the bottom of the structural breakdown and represent the actual task assignments to performing organizations and task managers. A task manager should be identified for each work package. Although a single individual may be the task manager over several WBS work packages, several guidelines should be observed:

- the work package tasks should be similar in nature
- the task manager should have a single supervisor in the project organization
- the task manager should not supervise more than three or four work packages at the most

If these guidelines cannot be met, the WBS work packages may be at the wrong WBS level (usually too detailed level) or the project organization may be flawed (which may simply mean that it would be wise to find an additional task manager).

At each higher task level, there should be an "integration and assembly (I/A)" task broken out. This I/A task represents the actual activity of putting together all of the lower-level pieces. The I/A work package assures that the appropriate estimates are considered when accumulating estimates from the most detailed to the system level; this avoids a common pitfall of doing a wonderful job of estimating the details but forgetting their ultimate assembly into a system. (If a separate I/A task is not broken out, the integration and assembly estimates are added to the accumulated estimate at the next highest level; thus, the accumulated estimate should always exceed the sum of the next lowest level estimates from which it comes. The separate I/A task avoids this apparent inconsistency.)

Work packages are typically the only activities that get carried over into scheduling information systems and technical flow/sequence networks from the WBS. It is in these other techniques that task dependencies (sequencing) are displayed. The common element used to hold together the work packages when displayed in these other techniques is the WBS element number.

The activities more detailed than a work package are usually reflected on a drawing tree (summarizes hardware design details), a flow chart (summarizes software design details), or an activity listing (summarizes project details which are not reflected in the design, such as "procurement" or designer participation in project tasks). (A project organization may be responsible for many work packages. It is common for the organizational manager to accumulate the activity listings for all work packages within the group into a functional WBS. This allows the manager to easily visualize the work assignments and to ensure the organization is responsive to the needs of the project.) Activity listings are simply a listing of all the various actions which are necessary to accomplish the work package. These may include "design circuits," "order parts," "write procurement documents," and other common and repetitive actions; task managers often maintain activity lists in the form of a Gantt chart. Usually, activity lists and drawing trees are not considered part of the WBS. Activity lists (usually under the title of "subproject") are considered part of the task manager's documentation, and drawing trees and flow charts are considered part of the engineering documentation.

The system design documentation should track exactly with the WBS because the product task breakdown should be derived from the system partitioning. The system design specification tree should directly reflect the WBS and vice versa.

WBS ELEMENT NUMBER

The element number is usually constructed to carry the information of the WBS structure. Each level of the WBS is numbered to show the higher level structure of which it is a part. There are many ways to formulate this element number, and there is no particular favored method. One method of element numbering is described in figure XXII-1; it has the advantage of inherent level identification, structure encoding, and functional assignments of work packages. The method described in figure XXII-1 is highly recommended, but it is by no means the only good method of numbering a WBS. In choosing a numbering system, you should consider the following factors:

- it should clearly identify WBS levels
- element dependencies should be readily distinquished
- it should be compatible with the other information systems and project management tools (some computer programs severely limit the field size used for the WBS element number)
- cost center factors and task management responsibilities should be visible (i.e., the project organizational chart should be related to the WBS and this relationship displayed in the numbering scheme)
- product tasks, project tasks, and work packages should be distinquishable from each other (if not accomplished by the element numbering system, colors can be useful)

CH03.1.6.2.3.E

CH03 — project number. Using the project number or some similar project identifier for the top-level element number serves to distinquish the WBS from others and maintains a means of readily identifying the WBS level by observing the periods separating the levels. For brevity, a general character such as "@" or "*" can be used, but be careful that the character selected doesn't have a special use in any spreadsheet or automated project management tool you are using.

.1.6.2.3... — the work breakdown of project and product levels. ".1" is the second level, ".6" is the third level, and so forth for as many levels that are created and displayed. It is recommended that "1" through "9" be used for project tasks since there are nine project tasks specified in MIL-STD-881 which can be used for every project or program. (MIL-STD-881 project tasks are summarized in table 2). For product tasks, use "10," "20," "30," ... or letters which would be descriptive of the subsystem (such as "C" for communications subsystem and "L" for launch subsystem), but ensure that letters, if used here, differ from the work package descriptors.

.E—the work package descriptor. The letter is used to be readily distinquishable as a work package. It is recommended that the letters be selected to be unique to a task manager or to the functional performing organization performing the task. Also, it is useful for the letter to be related to the nature of the work package, i.e., "E" for electronic design, "M" for mechanical design, and so forth. Letter combinations can be used to provide more information. For instance, "E9" might be used to show electronic design performed and managed by Code 90 as opposed to "E5" for electronic design performed by Code 50. "Ej" might denote "an electronic design task managed by John", and "Sk" might denote "a software design task managed by Karen". The work package descriptor is consistent throughout the WBS so that sorts can easily be run on each descriptor to extract information for tracking progress, managing resources, and making refined estimates.

Figure XXII-1. Recommended WBS element numbering.

In any case, the element number is the "glue" which holds together both the WBS and the other management information systems used by the project.

USING THE WBS AS AN ESTIMATING FRAME

The WBS is tremendously powerful as an aid to estimating and tracking resources. Typically, the resources are estimated at the work package level and accumulated to the top of the WBS. Thus, if the work package is level 7 in the WBS, the estimates are made at level 7. Level 6 will reflect all of the estimates at level 7 combined as appropriate to describe their effect at level 6. (Most resources are additive, such as costs, workhours, etc., but some are nonlinear, such as risk factors, and are combined using a formula. If unit production costs are being estimated, each item is accumulated according to the number of times it is used in the next highest level.) Each estimating category has its own rules for accumulating the estimate to the next level. The process is repeated up to level 1, so that the resource requirement/impact is visible at each level. The typical estimating categories encountered in DoD are as follows:

bid costs (development cost goals)

development costs

design-to-cost targets (unit production cost goals)

unit production costs

support cost targets

support costs

life-cycle cost targets

life-cycle costs

cost risks

technical performance measure goals

technical performance measures

schedule risks

technical risks

time-to-complete

workhours (by labor category)

These estimating categories are typical; however, each project has its own peculiar requirements which may add to or subtract from this list. Notice that costs are usually estimated first as targets and that actual costs are tracked separately; this is a useful mechanism for all resources that must be tracked and reported to an outside agency. Also notice that “time-to-complete” is a resource that is virtually impossible to accumulate without a technical flow/sequence diagram or network to determine critical path relationships. Labor category workhour estimates are not useful in themselves; they are used for “resource leveling” by the technical manager. (Resource leveling trades off available manpower/talent against schedule; therefore, knowledge of the critical path is necessary.) The risk estimates may be combined to create new estimating/tracking categories such as “most likely cost,” but they are most useful when used in establishing estimated targets.

The many relationships which are possible between estimating categories and for accumulating estimated resources are difficult to maintain manually, even on small projects. Typically, a spreadsheet is used to display and maintain the estimating categories and the estimated quantities. Popular electronic spreadsheets allow building these complex relationships into the spreadsheet cell relationships; this effectively automates the maintenance of the estimates once the original estimates are made. Project expenditure data can be dumped into the spreadsheet and automatically compared to the estimates to highlight potential problem areas. The presentation of the estimates for any one estimating category keyed to the WBS is often required by contracts or work agreements; most typical examples are cost work breakdown structures of various sorts.

Abbreviated examples of the two basic types of work breakdown structure are shown in figures XXII-2 and XXII-3.

LEVEL 1 XYZ COMMUNICATION SYSTEM
cg01

LEVEL 2 TRANSMITTER RECEIVER ANTENNA GRP (PROJECT TASKS)
cg01.10

LEVEL 3 EXCITER PWR AMP
cg01.10.1 cg01.10.2

LEVEL 4 TUNER MODULATOR
cg01.10.1.1 cg01.10.1.2

LEVEL 5 FREQ SYNTH REMOTE CONTROL
cg01.10.1.1.1 cg01.10.1.1.2

LEVEL 6 VCO PHASE CONTROL CONTROL FILTER
cg01.10.1.1.1.1 cg01.10.1.1.1.2 etc.

LEVEL 7 E DESIGN M DESIGN
cg01.10.1.1.1.1.e cg01.10.1.1.1.1.m

Figure XXII-2. A partial sample task-oriented WBS.

LEVEL 1 XYZ COMMUNICATION SYSTEM
cg01

LEVEL 2 M DESIGN E DESIGN PROG MGT SYS ENGR T&E ....
cg01.m etc.

LEVEL 3 DESIGN DRAFTING FABRICATION ASSEMBLY
cg01.m.D cg01.m.d etc.

Figure XXII-3. A partial functionally oriented WBS.

Table XXII-2. Project tasks from MIL-STD-881
(expanded version showing PM/SE elements).

- 1 Program/System Management
  - 1.1 Program Management
    - 1.1.1 Management Staff
    - 1.1.2 Management Reports
      - 1.1.2.1 Financial Reports
      - 1.1.2.2 Progress Reports
    - 1.1.3 Management Information System (use and maintenance)
      - 1.1.3.1 Work Breakdown Structure
      - 1.1.3.2 Schedule/Milestone Chart
        - * 1.1.3.2.1 Milestone 0
        - * 1.1.3.2.2 Milestone 1
        - * 1.1.3.2.3 Milestone 2
        - * 1.1.3.2.4 Milestone 3
      - 1.1.3.3 Technical Flow/Sequence Network
      - 1.1.3.4 (etc.)
    - 1.1.4 Travel
    - 1.1.5 Presentations
    - 1.1.6 Team (staff) Training
    - 1.1.7 Contractor/Vendor Liaison
    - 1.1.8 Project Master Plan (including Proposal Preparation)
    - 1.1.9 Vendor Proposal Evaluations
  - 1.2 System Engineering
    - 1.2.1 System Engineering Management
      - 1.2.1.1 System Engineering Staff
      - 1.2.1.2 Risk Management
      - 1.2.1.3 Technical Management Information System
        - 1.2.1.3.1 Technical Performance Measure Tracking
        - 1.2.1.3.2 Production Cost Tracking
        - 1.2.1.3.3 Life-Cycle Cost Tracking
        - 1.2.1.3.4 Specification Tree
        - 1.2.1.3.5 Documentation Tree
      - 1.2.1.4 Contractor/Vendor Reviews
      - 1.2.1.5 System Engineering Management Plan
    - 1.2.2 System Technical Direction
      - 1.2.2.1 Requirements Analysis
        - X 1.2.2.1.1 Affordability Analysis
        - 1.2.2.1.2 Mission Analysis
        - 1.2.2.1.3 System Trade Studies
        - 1.2.2.1.4 System Design
          - 1.2.2.1.4.1 Conceptual Design
          - 1.2.2.1.4.2 Risk Assessment
          - 1.2.2.1.4.3 Cost Assessment
          - 1.2.2.1.4.4 Feasibility Demonstration

Table XXII-2. Project tasks from MIL-STD-881
(expanded version showing PM/SE elements) (continued).

**				1.2.2.1.4.4.1	Exploratory Development
			1.2.2.1.4.5		Minimum Performance Specifications
			1.2.2.1.4.6		Technical Performance Measures
	1.2.2.2				System Requirements
		1.2.2.2.1			System Specification (MIL-STD-490 TYPE A)
		1.2.2.2.2			Requirements Flowdown/Traceability
		1.2.2.2.3			Performance Verification
**			1.2.2.2.3.1		Advanced Development
		1.2.2.2.4			Design Reviews
SRR			1.2.2.2.4.1		System Requirements Review
SDR			1.2.2.2.4.2		System Design Review
( )SR			1.2.2.2.4.3		Development Specification Reviews
PDR			1.2.2.2.4.4		Preliminary Design Review
			1.2.2.2.4.5		In-process Reviews
CDR			1.2.2.2.4.6		Critical Design Review
TRR			1.2.2.2.4.7		Test Requirements Review
FCA			1.2.2.2.4.8		Functional Configuration Audit
PCA			1.2.2.2.4.9		Physical Configuration Audit
FQR			1.2.2.2.4.10		Formal Qualification Review
		1.2.2.2.5			Change Control Board
		1.2.2.2.6			Quality Program
	1.2.2.3				System Integration
		1.2.2.3.1			Interface Specifications & Design Control
		1.2.2.3.2			Intersystem/Intrasystem Compatibility Assurance
		1.2.2.3.3			Electromagnetic Compatibility (EMC)
		1.2.2.3.4			TEMPEST
		1.2.2.3.5			Technical Usage/Environmental Criteria
		1.2.2.3.6			Platform Integration/Installation

Table XXII-2. Project tasks from MIL-STD-881
(expanded version showing PM/SE elements) (continued).

	1.2.2.4	Software System Design		
		1.2.2.4.1	Software Requirements Allocation	
		1.2.2.4.2	Hardware/Software Interface Control	
		1.2.2.4.3	Software Performance and Interface Specifications	
		1.2.2.4.4	Software Documentation Audit	
		1.2.2.4.5	Software Design Reviews	
	1.2.2.5	Mission Operations Planning		
		1.2.2.5.1	Operations Plan Generation	
		1.2.2.5.2	Employment Procedures	
COE			1.2.2.5.2.1	Concept of Employment
		1.2.2.5.3	Facility Support Requirements	
	1.2.2.6	System Effectiveness		
		1.2.2.6.1	Reliability	
		1.2.2.6.2	Availability	
		1.2.2.6.3	Maintainability	
		1.2.2.6.4	Safety	
		1.2.2.6.5	Logistics/LSA/ILS/LOR	
		1.2.2.6.6	Contamination Control	
		1.2.2.6.7	Transportability (PHST)	
		1.2.2.6.8	Human Factors Engineering	
		1.2.2.6.9	Personnel and Training	
		1.2.2.6.10	Parts, Materials, and Processes	
		1.2.2.6.11	Testability	
	1.2.2.7	System Test Planning and Audit		
TEMP		1.2.2.7.1	System Test and Evaluation Master Plan	
		1.2.2.7.2	Design for Test Criteria	
		1.2.2.7.3	Design Analysis Review	
		1.2.2.7.4	Test Procedure Review	
		1.2.2.7.5	Design Audit	
		1.2.2.7.6	Test Data Review	
		1.2.2.7.7	Test Support	

2 Documentation
- 2.1 Technical Publications
- 2.2 Engineering Data
- 2.3 Management Data
- 2.4 Support Data
- 2.5 Data Depository

3 System Test and Evaluation
- 3.1 Developmental Test and Evaluation
  - 3.1.1 DT I
  - 3.1.2 DT IIA
  - 3.1.3 DT IIB (TECHEVAL)
  - 3.1.4 DT III (FIRST ARTICLE)

Table XXII-2. Project tasks from MIL-STD-881
(expanded version showing PM/SE elements) (continued).

3.2 Operational Test and Evaluation
3.2.1 OT I
3.2.2 OT IIA
3.2.3 OT IIB (OPEVAL)
3.2.4 OT III
3.3 Mockups and Simulations
3.3.1 Mockups
** 3.3.1.1 Human Factors Mockup
3.3.2 Simulations
3.4 T&E Facilities
3.5 T&E Support
4 Training
4.1 Services
4.1.1 Interim
4.1.2 Operational
4.2 Facilities
4.2.1 Interim
4.2.2 Operational
4.3 Equipment
4.3.1 Interim
4.3.2 Operational
5 Peculiar Support Equipment
5.1 Operational/Intermediate Level
5.2 Depot Level
6 Common Support Equipment
6.1 Operational/Intermediate Level
6.2 Depot Level
7 Facilities
7.1 Maintenance
7.2 Equipment Acquisition/Modernization
7.3 Construction/Conversion/Expansion
8 Initial Spares/Repair Parts
8.1 (for Subsystem 10)
8.2 (for Subsystem 20)
.
:

9 System Implementation
9.1 Platform Conversion
9.2 Installation Kits
9.3 Installation and On-site Checkout

Table XXII-3. Elements tracked by a work breakdown structure.
(May be tracked in Spreadsheet Form).

PROJECT MANAGEMENT/CONTROL ELEMENTS (13 or more)

Cost-to-complete	(Development/Acquisition Cost)
Target Bid Actual	(Note: Acquisition Costs may be broken down into Development, Procurement, and Installation/Implementation Costs—each element separately tracked by target and actual)
Workhours Target Bid Actual	(Note: "Target" represents the expected value, ""Bid" includes contingency estimates, "Actual" is the experience for the progress achieved.)
Schedule (Calendar time Target Bid Actual	

Risk Factor
Recovery ("Fix-it") Risk Factor
Recovery Cost Factor
Recovery Schedule Factor

SYSTEM ACQUISITION ELEMENTS (9)

Production Quantity

Design-to-Cost (DTC)	(unit production cost)
Target Minimum Expected Maximum Acceptable Fixed-Cost Target Fixed-Cost Actual Base Cost Target Base Cost Actual	(Note: "Target" represents the expected value at the time the plan was promulgated, "Actual" represents the currently expected value here and below.)

SYSTEM ENGINEERING INFORMATION ELEMENTS (14 or more)

Technical Performance Measure (TPM)
- Specification Requirement
- Minimum Acceptable
- Actual
- Variance Limit

Table XXII-3. Elements tracked by a work breakdown structure.
(May be tracked in Spreadsheet Form) (continued).

Life-Cycle Costs (LCC) = Acquisition Costs + LCSC

Life-Cycle Support Costs (LCSC)
- Nonrecurring Cost Target
- Nonrecurring Cost Actual
- Recurring Cost Target
- Recurring Cost Actual
- Recurrence Frequency Factor Target (such as Failure Rate)
- Recurrence Frequency Factor Actual
- LCSC Target
- LCSC Actual

USES OF A FUNCTIONALLY ORIENTED WORK BREAKDOWN

Functionally oriented work breakdowns should never be used for an entire project, but they can be effective for planning work packages in a task-oriented WBS. Functional work breakdowns are particularly helpful in accomplishing short-range planning, in planning schedule compressions, and in managing related tasks accomplished in parallel. Detailed short-range planning helps to identify and mitigate risks on each task by facilitating tracking and control of the tasks.

To perform a functional breakdown, the task leader of each work package involved analyzes the activities needed to accomplish the task and determines how they are related in time (time to accomplish, weeks of effort, and so forth). The task leader should then recommend the measure of accomplishment for each of the activities. The task leader and the project leader overseeing the task should agree on the measure and its method of report. The measure of accomplishment might be a report, a completed test which proves meeting a requirement, a delivery, or any other element that can be reported as a detailed milestone. In meeting the milestone, there should be no shades of gray—it is done or it is not done. If an activity is almost fully accomplished, but it must await accomplishment of a test or other related activities, the prime activity should be broken down into subactivities. (This will facilitate reporting of a percent completion more accurately.) The level of effort and other costs can then be estimated in detail for each activity. In general, the work hours associated with each activity compared to the total work hours for the work package become the basis for the percent completion measure. These steps are fundamental to performing short-range planning.

When planning schedule compressions or when managing related tasks in parallel, the project leader and the task leaders of the affected work packages work together to identify the communications between the tasks. When are pieces of information needed? When is information developed? When are data validated? How does information need to be communicated? These questions help to identify the task relationships and when the tasks need to be coordinated. These points of coordination together with the functional breakdown planning steps determine the detailed milestones needed for task management and task coordination. An analysis can then be done to see how one task might have to wait on the availability of information from another task. The analysis might indicate how a task might not be able to be completed as quickly as hoped for because of waiting for a result. Alternatively, the analysis may allow adjusting the task priorities of one task in order to expedite another. In either case, the project leader can more accurately assess schedule risks and take appropriate steps to control the tasks.

CONTROLLING THE PROJECT

Project management involves a continuing effort to plan, organize, monitor, and control. The planning is accomplished through the generation and maintenance of the PMP, which serves to document the plan. Organization occurs as the plan is implemented by assigning resources and responsibilities to specific task leaders. The PMP also documents the organization decisions. Monitoring is accomplished through the management information systems, the reports and data produced by project efforts, and by the personal communications with task leaders and other project participants. The PMP spells out the monitoring and reporting procedures used in the project. Control is the "quality assurance" aspect of management. The delegation of responsibility and authority must also mean accountability. The control effort maintains this accountability. There are too many details for the project manager to care for them all; therefore, good project control mechanisms implemented in the project's management information systems allow only significant deviations from the plan to be flagged for the project manager's attention.

Technical performance, cost, and schedule are related to each other. It is not possible to tightly control all three simultaneously because the control of any two will determine the limits for the third. Figure XXII-4 illustrates the typical functional relationship. Notice that there is an optimum planning point for any given project (the minimum cost/schedule point for the specified performance). In practice, it is nearly impossible to determine this optimum point; however, it is possible to plan into the zone around this point through good estimation practices. Simply because this optimum zone is known does not mean that the sponsorship bureaucracy will allow the project manager to actually propose and execute the program in this zone. There are a host of political operating factors which may dictate schedules or distort funding profiles, resulting in a less efficient plan.

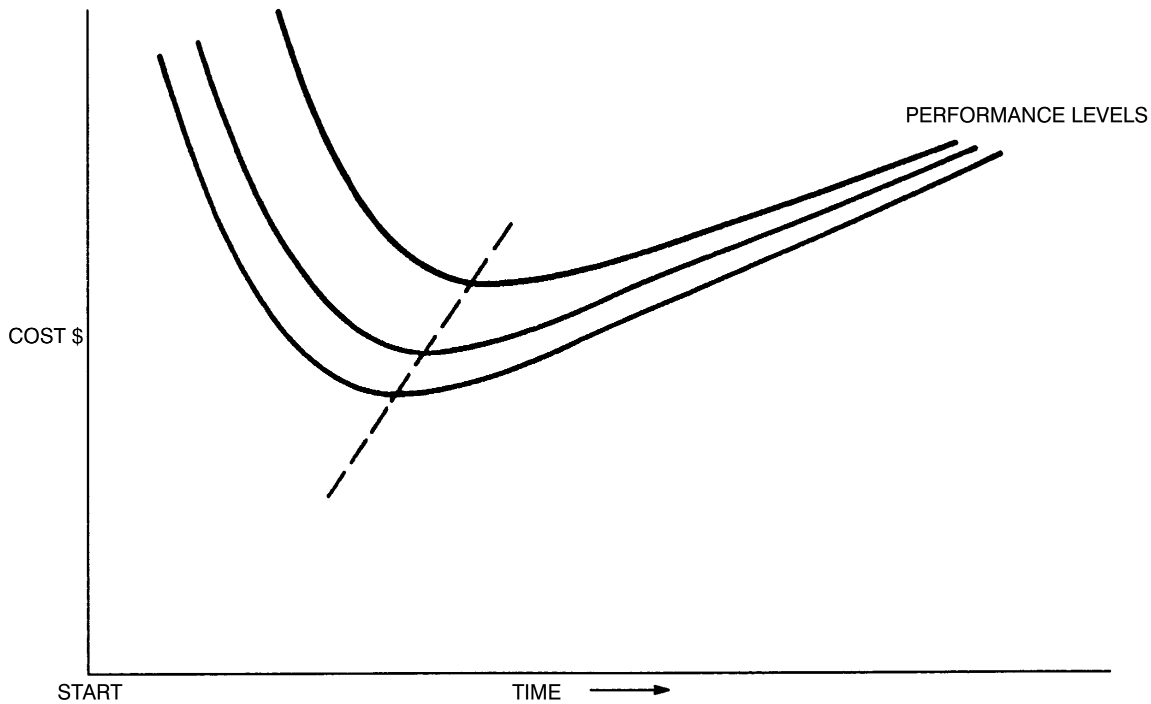


Figure XXII-4. The functional relationship of performance, cost, and schedule.

PROJECT CHANGE CONTROL

Any time a plan is established, a decision is made, or a design is documented, it costs in order to effect a change. Moreover, the later a change occurs, the more it costs. This is true for design changes and project plan changes alike. As a result, it is important to manage changes. The need for change must be recognized early, and appropriate decisions must be made correctly and documented thoroughly. The manager must decide when a change is necessary and avoid unnecessary changes; likewise, the manager needs to recognize when a change decision should be made. If a change is implemented too late, unnecessary change costs will be incurred; if a change is made before circumstances are stable, additional change upon change will result. Change is inevitable, so plans must include contingencies for change. Risk assessment/risk management techniques greatly assist the project manager or systems engineer to manage change. Configuration management techniques can be applied to the project plans as well as the system designs to help control changes. Effective management information reporting is necessary to detect the potential need for change. As a rule-of-thumb, the costs associated with a change will grow by an order-of-magnitude each time the project transitions from one phase to the next; 100%-200% is added to change costs each time an associated milestone is reached without resolving the issue.

ORGANIZATIONAL CONTROL

Organizational control is effected through leadership more than management controls. While it is important to have the agreements and contracts in place to set the ground rules, the work must be accomplished through people; people are more effective and productive when they are led as part of a team instead of being managed like an inert asset. The project manager can effect control of the project team well beyond the project charter authority by following good leadership principles and by being a model for the team members.

Project leadership is implemented to personal contact. It is difficult to lead from an isolated ivory tower. Regular project meetings can be an important forum for exercising organizational control. Likewise, regular contact with the project “worker bees” by making periodic visits to their work sites contributes to the control exercised by the project leadership. It is the responsibility (and in the best interests) of the project manager and systems engineer to create as favorable a work environment for the task leaders and the project workers under their control. While it may not be possible to remodel an office or build a new building simply to provide this environment, it is usually possible to improve the work environment by contributing new tools, test equipment, and other things to help the accomplishing organizations. An active system of “attaboys” to the good performers’ supervisors also helps create a positive work environment. Generally, people like to know where they stand and how their efforts contribute to the overall success of the project. These steps of leadership greatly affect the required organizational control.

On those occasions when a person or organization fails to perform satisfactorily, the project manager should take immediate steps to remedy the situation. Although a good project manager can lead ordinary people to do extraordinary things, some project participants may insist on being “bad apples.” The project manager normally should try to correct the situation through personal disciplinary measures first, but should insist that the person or organization be replaced if the unacceptable performance continues.

When contractual support is used, the project manager must implement organizational controls through the contract. This means that the contract must be planned to have those controls in place at the time it is issued and that the methods of organizational performance measurement are clearly spelled out. The PMP and the associated procurement plans provide adequate justification for the selection of appropriate contract clauses to maintain control. The manager wants to avoid an adversarial relationship with the contractors, but this is usually more feasible when the contract has good organizational control “teeth.”

A similar situation applies to work agreements and taskings to other organizations. Also, the project manager must have contigency plans for the failure of an organization to perform. These contingency plans may or may not be part of the formal PMP. Sometimes a Government organization is “the only game in town” as far as accomplishing a specific task. The effective project manager can still elicit cooperation and gain effective organizational control by understanding the bureaucracy associated with the organization and tailoring the project requirements to fit it as closely as possible. Where this is not possible, the active role of the organization in project planning can be used to elicit cooperation because the justifications for the taskings will become apparent to the performing organization.

COST/SCHEDULE CONTROLS

Many elaborate systems have been developed for the control of project costs and schedule. Some of the systems, used widely on large military contracts, are as follows:

Contract Performance Report (CPR) System

Contract Funds Status Reporting (CFSR) System

Cost/Schedule Status Reporting System (C/SSRS)

Uniform Cost Accounting and Reporting System (UCARS) (see MIL-STD-1260)

All of these systems are reporting data intensive and assume automated accounting systems which are set up to report in DoD formats according to standard military contract requirements. They are not universally appropriate. However, they each illustrate the common requirement for cost and schedule control — costs must be reported as a function of work scheduled and work performed. Figure XXII-5 shows a sample cost summary trend chart from DI-A-2011. By comparing the actual costs, the budgeted cost for work scheduled, and the budgeted cost for work performed, the project manager can see if the right amount of work is being accomplished for the amount of funds expended at any given time. These reports are generated for each work package, so there can be a lot of reporting data. The project manager is really only interested in those tasks which are behind in accomplishing the work and ahead of budgeted expenditures. These are the tasks that demand management attention to correct whatever is not going according to plan. By working with the task managers during the planning phase, realistic reporting methods can be designed to reduce the reporting burden on the task manager while effectively highlighting the tasks which need management attention.

Another method of effective cost and schedule control is to plan the project with short-term milestones (2 weeks to 2 months apart). While this creates a planning burden, the cost and schedule control is effectively reduced to meeting milestones. This method works reasonably well with highly modular tasks, such as some software design tasks.

The schedule should be watched closely over a horizon of no more than 6 months, and preferrably over a shorter period. Each active task should have at least one reportable milestone in the horizon period. Since the project is planned with major milestones and then intermediate milestones (with projected costs), these become a baseline plan. Each task manager should periodically (monthly, bimonthly, quarterly) provide a detailed task plan which covers the horizon period plus the interval between plan updates. This keeps the planning and reporting efforts to a minimum and still provides timely cost and schedule control.

Whatever method of cost and schedule reporting is selected, the project manager uses an allowed variance from the budgeted cost for work scheduled to trigger management attention. A practical variance for a significant task is 2 to 5 percent. Larger, riskier, and more important tasks merit tighter variance limits that small, relatively unimportant tasks.

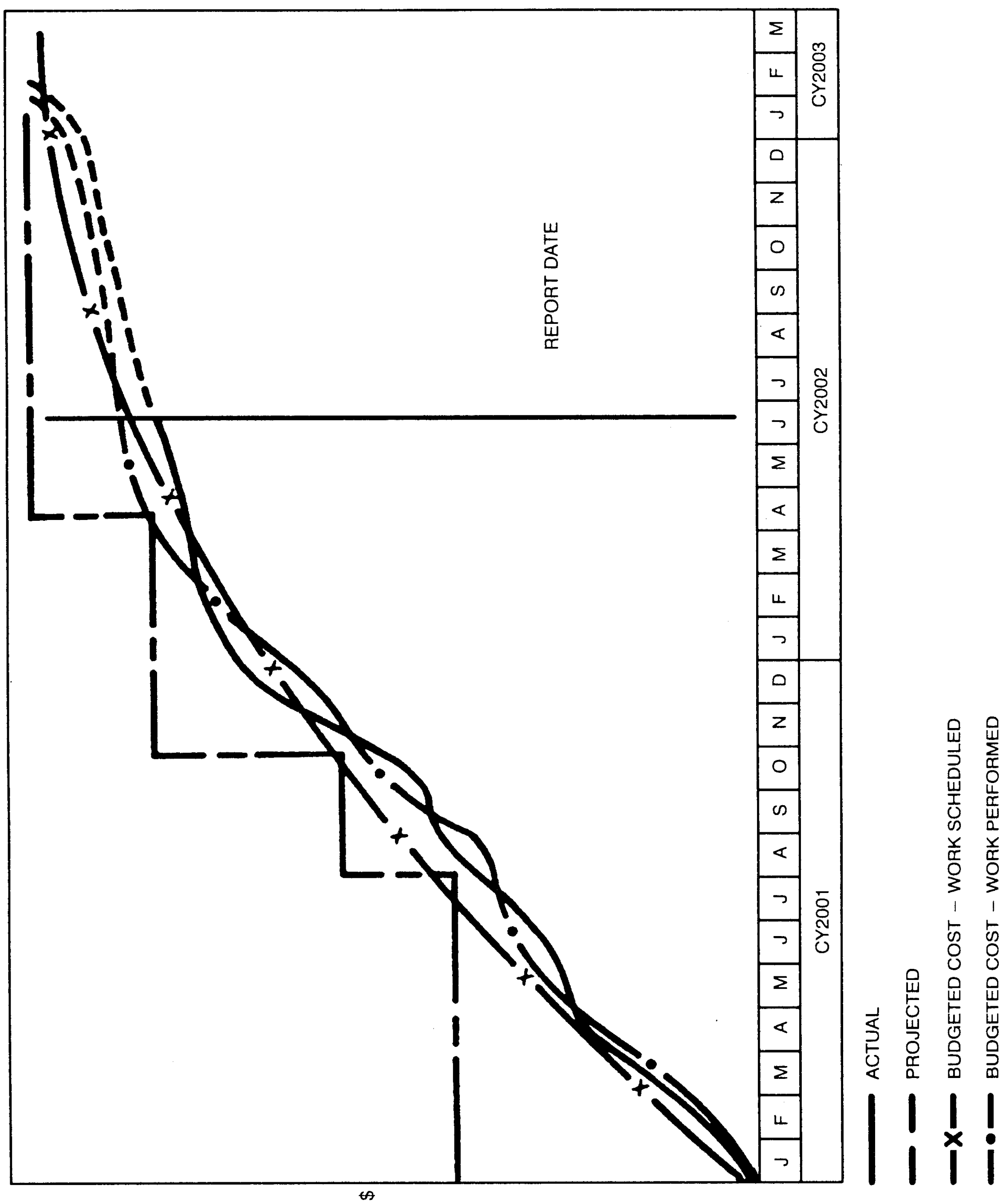


Figure XXII-5. Sample cost/schedule/control.

TECHNICAL PERFORMANCE CONTROL

Chapter IV discusses performance measures as a step in system design and as a method of contract evaluation. The individual specification parameters that become part of the system specification are usually a composite of many technical parameters that have been combined through systems analysis and design tradeoffs. As the system is partitioned, these system design parameters must be allocated to the system elements which result. The parameter values allocated to partitioned elements become Technical Performance Measures (TPMs). These TPMs exist at the smallest system partition; therefore, they can be correlated to the product WBS, which also reflects this system design. More than one TPM may exist at the work package level of the WBS, but the system design shows how the TPMs are related. As design progresses, as parts are selected, and as tests are performed, the measured or projected value of the TPMs varies. But as the designer works toward task completion, the TPMs the designer is responsible for should converge toward the specification targets. Figure XXII-6 illustrates a Performance Trend Chart (from DI-A-2012). This sample shows the principles of performance tracking:

the TPM is correlated to the WBS and to the schedule (calendar)

the requirement, projected value, actual value and variance limits are all readily visible

In practice, most TPMs have only a single variance limit which converges on the specified value at task completion. The project manager and systems engineer are only interested in tasks which report actual values outside of the variance limits. (Anything else will meet performance requirements). When a TPM goes out of limit, the systems engineer takes action to bring the TPM within limits. This may involve a focus of management attention or engineering talent on the problem, or it may mean tweaking the system design to reallocate performance within the system partitions. As with the cost and schedule controls, the planning of the allowed variance limit(s) depends on the significance of the TPM to the overall system design. In no case should the variance allow less than minimum acceptable performance.

RISK CONTROL

Risk control amounts to “stamping out forest fires” while they are still smoldering rather than after they get out of control. Risk control is an important aspect of risk management (see chapter 21). Cost, schedule, and technical risks are effectively controlled through adequate planning (including contingency planning), good communications of project status (including an effective management information system), and timely action in addressing problems. The timeliness of action is often dependent on the setting of variance limits for the management system reports that can trigger management attention. High risk priority tasks (see Table XXI-1) should have tighter variance limits than lower risk priority tasks. A cost variance limit of 2 per-cent of the total task expenditure for the planning horizon (usually 6 months — see figure 22-7) is usually appropriate for tasks with a risk priority of 1 through 4. A cost variance limit of 5 percent is usually appropriate for tasks with a risk priority of 5 through 8; a

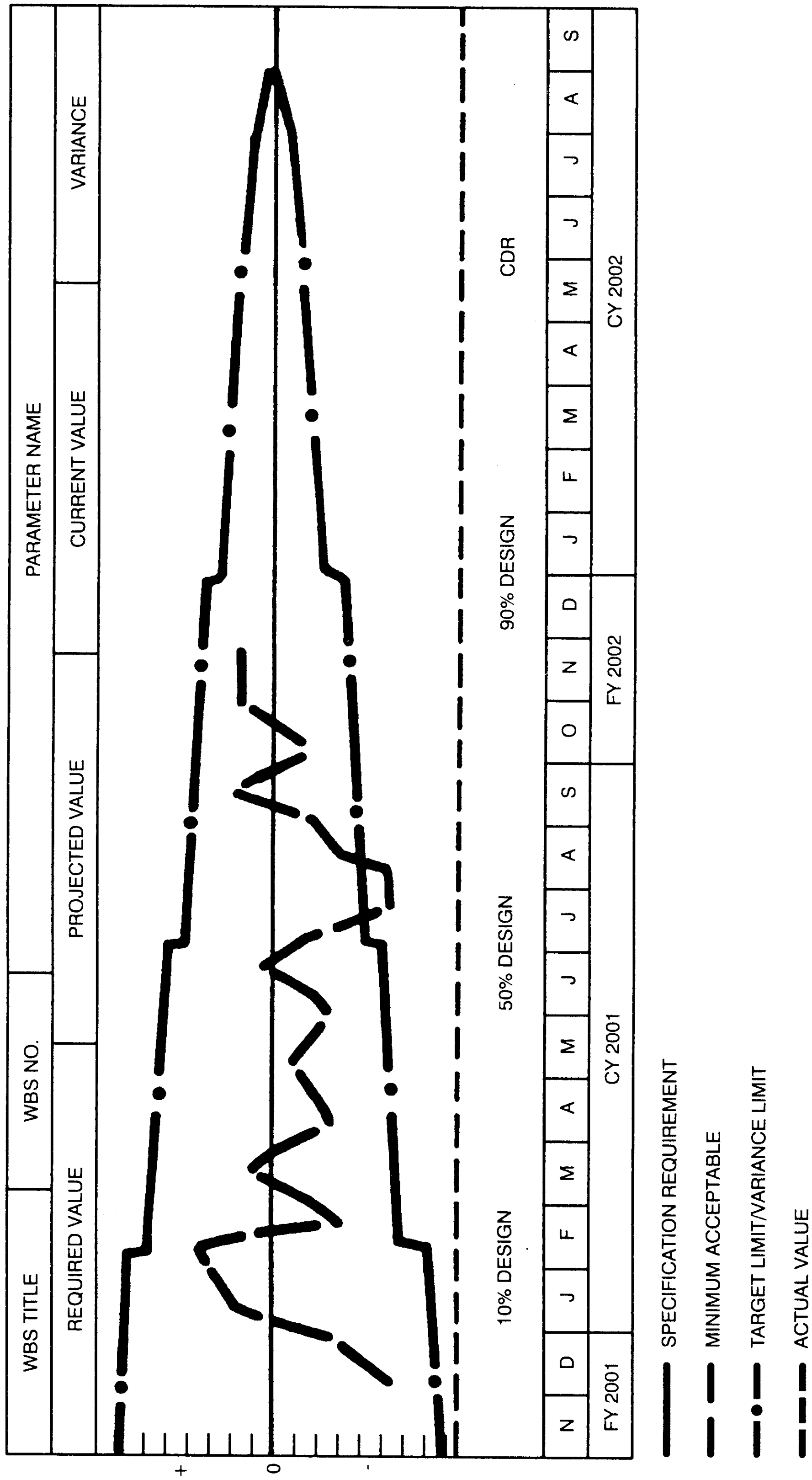


Figure XXII-6. Performance Trend Chart.

cost variance limit of 10 percent is usually workable for tasks with a risk priority of 9 or 10. These limits may be adjusted for unusual tracking requirements, but they must also be adjusted for the availability of contingency funds. The lack of contingency overhead in any project plan artificially increases the risk.

For technical risks, the variance limits should be tightened at a rate that will expose a parameter that is not converging on its specification requirement in time to effect a design change, if that is required. The timing of this threshold will depend on the dependencies and interdependencies between tasks as well as the specification contingencies built into the system design (intentional overspecification to provide room for underdesign).

In all cases, risk control is greatly enhanced by timely, open, and honest communications between the task leaders and the systems engineer, project financial manager, and the project manager.

Project political risks require an entirely different set of controls. As with other project risks, political risks require an effective management information system, except that this is an intelligence system for political risks. Political risk strategies mostly involve avoidance or evasion. Both strategies require expert knowledge of the persons in the administrative and project chains of command (anybody who might have review or approval authority over any aspect of the project) and of the rules and procedures under which each person operates. THESE ARE MINIMUM REQUIREMENTS. In addition, it is helpful to know the personality quirks of the key people and their personal perferrences as they relate to the project. If the project manager or the project sponsorship can develop good working relationships and personal friendships with these key people, it is all the better. Political risk control also requires a detailed knowledge of the competition (projects competing for the same budgetary resources or addressing similar operational requirements or developing a competing technology). This knowledge must sometimes be developed through cooperation and sharing of information with the competing project. (It is important not to undermine the competition; afterall, we are all on the same side developing systems to serve the defense of our nation. The overall success does NOT require the success of our project, but the success of each project should enhance the broadest goal of the security of our nation.) The intelligence gained by the project manager allows timely decisions and actions to be taken to avoid negative issues and their impact. Sometimes competing projects can cooperate in their political intelligence and develop a mutual approach which enhances both projects. In almost all cases, the personal integrity of the project manager can influence the reputation of the project.

APPLICATION OF SUPPORTING "ILITY" TASKS

Most of the military standards covering the support engineering tasks have application matrices which show when (in which program phase) the various tasks should be performed. MIL-STD-2107 covers many of the topics which are not easily determined from the supporting standards and specifications. Table XXII-4 provides a breakout of support engineering tasks and provides an application matrix for these tasks. A survey of Table XXII-4 shows that many of the tasks must be tailored; the project planner is exhorted to include expertise for these support engineering areas in the generation of project plans. Also see figure XXII-7.

Table XXII-4. Support task application matrix.

CONFIGURATION MANAGEMENT REQUIREMENTS PER MIL-STD-480B

CON	D&V	FSD	PRO	O&S	No.	Task
					100	PROGRAM CONTROL
A	A	A	A	A	101	CM PLAN
					101.1	CHANGE PROCEDURES AND AUTHORITIES
					101.2	INTERFACE CONTROL
					101.3	REVIEWS AND AUDITS
T	A	A	A	T	102	CONFIGURATION MANAGEMENT RESOURCES
					102.1	CM TEAM MEMBERS
					102.2	SUBCONTRACTOR CM
					102.3	AUTOMATED TOOLS
C	C	A	A	C	103	CONFIGURATION CONTROL BOARD
					200	BASELINE IDENTIFICATION
A	A	A	A	I	201	FUNCTIONAL BASELINE
	A	A	A	I	202	ALLOCATED BASELINE
		A	A	A	203	PRODUCT BASELINE
					300	STATUS ACCOUNTING
C	C	A	A	A	301	DATABANK ESTABLISHMENT
C	C	A	A	A	302	LIBRARY INDEXING
	C	A	A	A	303	STATUS REPORTING
	C	A	A	A	304	FOLLOW-ON AUDITS
A	A	A	A	A	305	PROPOSED CHANGE STATUS TRACKING
					305.1	DESIGN IMPACT EVALUATIONS
					305.2	QUALITY EVALUATIONS
					305.3	SAFETY EVALUATIONS
					305.4	COST EVALUATIONS

LOGISTICS SUPPORT ANALYSIS TASKS PER MIL-STD-1388-1A

CON	D&V	FSD	PRO	O&S	No.	Task
					100	PROGRAM PLANNING AND CONTROL
A	A	T			101	EARLY LSA STRATEGY (Describes proposed supportability objectives and tasks required to achieve those objectives. Becomes part of the overall project acquisition strategy.)
					101.1	CONCEPTUAL LSA (Part of Functional Baseline at SRR)
					101.1.1	IDENTIFY MISSION AND FUNCTIONAL REQUIREMENTS
					101.1.2	IDENTIFY PROGRAM CONSTRAINTS (funding, schedule, available personnel, strategic materials, and other key resources)
					101.1.3	IDENTIFY DATA BASES available for use in supporting LSA tasks
					101.1.4	IDENTIFY DELIVERY MILESTONES FOR LSA PRODUCTS
					101.1.5	IDENTIFY ANALOG SYSTEMS/EQUIPMENT available to support LSA
					101.1.6	TAILOR LSA TASK REQUIREMENTS TO FIT PROGRAM CONSTRAINTS

Table XXII-4. Support task application matrix (continued).

							101.2		ALLOCATED BASELINE UPDATE (at SDR/MS I)
							101.3		DEVELOPMENT BASELINE UPDATE (at PDR/MS II)
							101.4		DESIGN CONFIGURATION UPDATE (at CDR)
							101.5		PRODUCT CONFIGURATION UPDATE (at MS III)
A	A	A	A			102			LSA PLAN (describes tasks and milestones and interfaces to other project activities) (May be part of another plan, such as an ILSP, ALP, PMP, etc.)
							102.1		GENERATE LSA PLAN
								102.1.1	IDENTIFY LSA TASKS (Tailor from MIL-STD-1388-1A)
								102.1.2	IDENTIFY PROJECT TEAM PARTICIPANTS AND ORGANIZATIONAL RELATIONSHIPS
								102.1.3	SPECIFY DESIGN TEAM PARTICIPATION
								102.1.4	RELATE TO OTHER PROJECT PLANS
								102.1.5	IDENTIFY MILESTONES AND DELIVERABLES
							102.2		ALLOCATED BASELINE UPDATE (at SDR/MS I)
							102.3		DEVELOPMENT BASELINE UPDATE (at PDR/MS II)
							102.4		DESIGN CONFIGURATION UPDATE (at CDR)
							102.5		PRODUCT CONFIGURATION UPDATE (at MS III)
A	A	A	A			103			PROGRAM AND DESIGN REVIEWS (Defines which LSA elements are to be reviewed at project design reviews, at program reviews, or at special LSA reviews. Specifies review participants, review elements (content), special procedures, and schedules.)
					200				MISSION AND SUPPORT SYSTEMS DEFINITION
A	A	A				201			USE STUDY
							201.1		SUPPORTABILITY FACTORS
							201.2		SYSTEM EFFECTIVENESS FACTORS
							201.3		USAGE ENVIRONMENT FACTORS
							201.4		USE STUDY REPORT (include in Functional Baseline)
							201.5		ALLOCATED BASELINE UPDATE (at SDR/MS I)
							201.6		DEVELOPMENT BASELINE UPDATE (at PDR/MS II)
							201.7		DESIGN CONFIGURATION UPDATE (at CDR)
							201.8		PRODUCT CONFIGURATION UPDATE (at MS III)
A	A	A	T	T		202			STANDARDIZATION STUDY
							202.1		MISSION HARDWARE
								202.1.1	SUPPORTABILITY CONSTRAINTS
								202.1.2	SUPPORTABILITY CHARACTERISTICS
								202.1.3	LEVEL OF STANDARDIZATION DECISION INPUTS
								202.1.4	DOCUMENTATION REQUIREMENTS
								202.1.5	BUILD, BUY, MODIFY DECISION INPUTS
								202.1.6	RISK ASSESSMENT
							202.2		MISSION SOFTWARE
								202.2.1	SUPPORTABILITY CONSTRAINTS
								202.2.2	SUPPORTABILITY CHARACTERISTICS
								202.2.3	LEVEL OF STANDARDIZATION DECISION INPUTS
								202.2.4	DOCUMENTATION REQUIREMENTS
								202.2.5	BUILD, BUY, MODIFY DECISION INPUTS
								202.2.6	RISK ASSESSMENT
							202.3		SUPPORT HARDWARE
								202.3.1	SUPPORTABILITY CONSTRAINTS
								202.3.2	SUPPORTABILITY CHARACTERISTICS
								202.3.3	LEVEL OF STANDARDIZATION DECISION INPUTS

Table XXII-4. Support task application matrix (continued).

					202.3.4	DOCUMENTATION REQUIREMENTS
					202.3.5	BUILD, BUY, MODIFY DECISION INPUTS
					202.3.6	RISK ASSESSMENT
					202.4	SUPPORT SOFTWARE
					202.4.1	SUPPORTABILITY CONSTRAINTS
					202.4.2	SUPPORTABILITY CHARACTERISTICS
					202.4.3	LEVEL OF STANDARDIZATION DECISION INPUTS
					202.4.4	DOCUMENTATION REQUIREMENTS
					202.4.5	BUILD, BUY, MODIFY DECISION INPUTS
					202.4.6	RISK ASSESSMENT
					202.5	STANDARDIZATION CONCEPTS REPORTS/PLAN (incorporated into system design as part of allocated baseline)
A	A	A			203	COMPARATIVE ANALYSIS
A	A				203.1	IDENTIFY COMPARATIVE SYSTEMS (see 101.1.5)
A	A	A			203.2	BUILD BASELINE COMPARISON SYSTEM (amalgamation of analogs modified to system design requirements)
A	A				203.3	ANALYZE COMPARATIVE SYSTEM CHARACTERISTICS
A	A	A			203.4	IDENTIFY QUALITATIVE SUPPORTABILITY PROBLEMS
A	A	A			203.5	IDENTIFY SUPPORTABILITY, COST, AND READINESS DRIVERS
A	A				203.6	IDENTIFY UNIQUE SYSTEM DRIVERS
A	A	A			203.7	IDENTIFY RISKS AND ASSUMPTIONS
A	A	A			203.8	ANALYSIS REPORT (include in Allocated Baseline and update with system design)
A	A	T			204	TECHNOLOGICAL OPPORTUNITIES (Using inputs from the comparative analysis (203), identify and evaluate design opportunities for improvements in support characteristics. Provide recommended system design specifications.)
A	A	A	C		205	SUPPORTABILITY AND SUPPORTABILITY RELATED FACTORS (Using inputs from tasks 202, 203, and 204, perform an operational support cost analysis (part of a Life-cyle cost analysis) and a support system effectiveness analysis (numerical analysis of supportability impacts on operational availability) to determine quantitative supportability factors and to provide system design objectives, goals, constraints, and thresholds. The results of this analysis are doumented in a report describing the system design and become part of the Allocated Baseline, being updated accordingly.)
					300	PREPARATION AND EVALUATION OF ALTERNATIVES
A	A	A	C	C	301	FUNCTIONAL REQUIREMENTS IDENTIFICATION
A	A	T	C	C	301.1	DETERMINE FUNCTIONAL REQUIREMENTS
A	A	T	C	C	301.2	IDENTIFY UNIQUE FUNCTIONAL REQUIREMENTS
					301.2.1	DETERMINE CORRECTIVE MAINTENANCE TASKS (using results of FMECA IAW MIL-STD-1629)
					301.2.2	DETERMINE PREVENTATIVE MAINTENANCE TASKS (using results of reliability centered maintenance (RCM) analysis)
					301.2.3	DETERMINE OTHER MAINTENANCE TASKS
A	A	T	C	C	301.3	FORMULATE DESIGN ALTERNATIVES
T	A	A	C	C	301.4	UPDATE SYSTEM DESIGN AS REQUIRED
A	A	A	C	C	301.5	UPDATE ANALYSIS PRIOR TO IDENTIFIED REVIEWS

Table XXII-4. Support task application matrix (continued).

A	A	A	C	C	302	SUPPORT SYSTEM ALTERNATIVES
A	A				302.1	ANALYZE TASK 301 RESULTS FOR SUPPORT SYSTEM ALTERNATIVES
A	A	T			302.2	MAINTAIN UP-TO-DATE CONCEPT OF SUPPORT
T	T	A	C	C	302.3	DETERMINE DESIGN CONSTRAINTS FOR NEW DESIGNS (from TASK 205)
T	T	A	C	C	302.4	ASSESS RISKS
A	A	A	C	C	302.5	UPDATE SUPPORT PLANS
A	A	A	C	C	303	EVALUATION OF ALTERNATIVES AND TRADE-OFF ANALYSIS
A	A	A	C	C	303.1	TRADEOFF PROCEDURES
					303.1.1	IDENTIFY SUPPORTABILITY CRITERIA
					303.1.2	CONSTRUCT/SELECT APPROPRIATE ANALYTICAL MODEL(S)
					303.1.3	EVALUATE ALTERNATIVES USING MODEL(S) AGAINST CRITERIA
					303.1.4	CONDUCT SENSITIVITY ANALYSIS
					303.1.5	ASSESS PEACETIME VS WARTIME REQUIREMENTS
					303.1.6	ASSESS SUPPORT SYSTEM IMPACTS
					303.1.7	ASSESS RISKS
A	A	A	C	C	303.2	SUPPORT SYSTEM TRADEOFFS
A	A	A	C	C	303.3	SYSTEM DESIGN TRADEOFFS
A	A	A			303.4	READINESS SENSITIVITIES
A	A	T			303.5	MANPOWER AND PERSONNEL TRADE-OFFS
A	A	A	C	C	303.6	TRAINING TRADEOFFS
T	A	A	C		303.7	LEVEL OF REPAIR ANALYSIS (see MIL-STD-1390)
A	A	T			303.8	DIAGNOSTICS TRADEOFFS
A	A	T	C		303.9	COMPARATIVE EVALUATIONS
A	A	T	C		303.10	ENERGY TRADEOFFS
A	A	A	C		303.11	SURVIVABILITY TRADEOFFS
A	A				303.12	TRANSPORTABILITY TRADEOFFS
A	A				303.13	STORAGE TRADEOFFS
A	A				303.14	PACKAGING, PACKING, AND HANDLING TRADEOFFS
					400	DETERMINATION OF LOGISTIC SUPPORT RESOURCE REQUIREMENTS
T	A	C	C		401	TASK ANALYSIS
T	A	C	C		401.1	ANALYZE TASKS RESULTING FROM TRADEOFF RESULTS (TASK 303) (including constraints from 205)
T	A	C	C		401.2	DOCUMENT RESULTS IN LSAR (MIL-STD-1388-2)
T	A	C	C		401.3	IDENTIFY NEW/CRITICAL REQUIREMENTS
T	A	C	C		401.4	RECOMMEND TRAINING REQUIREMENTS
T	A	C	C		401.5	RECOMMEND DESIGN IMPROVEMENTS
T	A	C			401.6	UPDATE MANAGEMENT PLANS
A	T	C			401.7	CONDUCT TRANSPORTABILITY ANALYSIS
T	A	C			401.8	DETERMINE PROVISIONING REQUIREMENTS
T	A	C			401.9	VALIDATE 401.3 REQUIREMENTS ON PROTOTYPES
T	A	C			401.10	UPDATE LSAR WITH DESIGN CHANGES
		A		C	402	EARLY FIELDING ANALYSIS
					402.1	ASSESS INTERIM ILS
					402.2	ASSESS ILS PLANS AGAINST EXPERIENCE
					402.3	ASSESS IMPACT OF RESOURCE SHORTFALLS
					402.4	ASSESS COMBAT RESOURCE REQUIREMENTS
					402.5	DEVELOP PLANS FOR PROBLEM RESOLUTION

Table XXII-4. Support task application matrix (continued).

				C	403	POST PRODUCTION SUPPORT ANALYSIS (assess life-cycle support requirements incorporating 402 results before the production line shuts down; provide insurance items in sufficient quantities).
					500	SUPPORTABILITY ASSESSMENT
A	A	A	A	C	501	SUPPORTABILITY TEST, EVALUATION, AND VERIFICATION
A	A	T			501.1	T&E STRATEGY
	A	A	T		501.2	T&E OBJECTIVES AND THRESHOLDS
	A	A	T		501.3	UPDATES AND CORRECTIVE ACTIONS
A	T				501.3.1	XDM
	A	T			501.3.2	ADM
		A	T		501.3.3	EDM
		A	T		501.3.4	STM
		A	T	T	501.4	SUPPORTABILITY ASSESSMENT PLAN (POST DEPLOYMENT)
			A	A	501.5	SUPPORTABILITY ASSESSMENT (POST DEPLOYMENT)

MAINTAINABILITY TASKS PER MIL-STD-470A

CON	D&V	FSD	PRO	O&S		
					100	PROGRAM SURVEILLANCE AND CONTROL
	A	A	A	A	101	MAINTAINABILITY PROGRAM PLAN
	T	A	A	T	102	MONITOR/CONTROL OF SUBCONTRACTORS/VENDORS
T	A	A	A	T	103	PROGRAM REVIEWS
	T	A	A	T	104	DATA COLLECTION, ANALYSIS, AND CORRECTIVE ACTION SYSTEM
					200	DESIGN AND ANALYSIS
T	T	A	C		201	MAINTAINABILITY MODELING
T	T	A	C		202	MAINTAINABILITY ALLOCATIONS
	T	A	C	T	203	MAINTAINABILITY PREDICTIONS
	T	A	C	T	204	FAILURE MODES AND EFFECTS ANALYSIS — MAINTAINABILITY INFORMATION
T	A	A	C	T	205	MAINTAINABILITY ANALYSIS
	T	A	C	T	206	MAINTAINABILITY DESIGN CRITERIA
	T	A	C	T	207	PREPARATION OF INPUTS TO THE DETAILED MAINTENANCE PLAN AND LOGISTIC SUPPORT ANALYSIS (LSA)
					300	EVALUATION AND TEST
	T	A	C	T	301	MAINTAINABILITY DEMONSTRATION

PHST PROGRAM REQUIREMENTS PER MIL-STD-1367

CON	D&V	FSD	PRO	O&S		
					100	PROGRAM CONTROL
A	A	A	A	A	101	INTEGRATION WITH OTHER PROGRAM ELEMENTS (system engineering, ILS, product assurance, work breakdown structure, standardization, safety, human engineering, etc.)
A	A	A	A	C	102	INCORPORATE PHST IN TECHNICAL/PROGRAM REVIEWS
A	A	A	A	C	103	ESTABLISH PROCEDURES FOR INCORPORATING SUBCONTRACTORS IN THE PHST PROGRAM

Table XXII-4. Support task application matrix (continued).

T	T	A	A	C		104	PLAN PHST TEST AND EVALUATION INTEGRATED WITH PROGRAM T&E
					200	PHST ANALYSIS TASKS	
T	A	A	C	C		201	DETERMINE PHST REQUIREMENTS FROM LSA (including requirements for logistical and tactical movement)
T	A	A	C	C		202	EXTRACT SPECIAL STORAGE AND STOWAGE REQUIREMENTS (need for controlled environments, special security considerations, cyclic inspection requirements, etc.)
	T	A	C	C		203	DETERMINE DIMENSIONAL AND WEIGHT CONSTRAINTS FOR TRANSPORTATION MODES
	T	A	C	C		204	ANALYZE ITEM DESIGNS FOR COMPATIBILITY WITH STANDARD CONTAINERS AND PACKAGING MATERIALS
C	C	A	C	C		205	IDENTIFY SPECIAL HANDLING REQUIREMENTS (hazardous materials, susceptibility to transportation shock, special security requirements, need for controlled environments, etc.)
		A	C	C		206	IDENTIFY LIMITED SHELF LIFE ITEMS
T	T	A	C	C		207	IDENTIFY ITEMS TO BE FORWARD-POSITIONED RESERVES
		A	C	C		208	DETERMINE PRODUCT CLEANLINESS AND CONTAMINATION CONTROL REQUIREMENTS
		A				209	PHST ECONOMIC ANALYSIS
					300	PHST DESIGN TASKS	
	A	C				301	DETERMINE ITEM DESIGN CHARACTERISTICS REQUIRED BY PHST CONSTRAINTS
	T	A	C			302	DETERMINE SPECIAL-HANDLING EQUIPMENT OR ITEMS REQUIRED
		A				303	DESIGN SPECIAL-HANDLING EQUIPMENT (ref. MIL-STD-1365)
		A	C	C		304	DETERMINE ITEM PRESERVATION AND PACKING REQUIREMENTS
		A	C	C		305	DETERMINE ITEM STORAGE INSPECTION REQUIREMENTS AND PROCEDURES
		A				306	DETERMINE ITEM HANDLING PROCEDURES
		A	C	C		307	DETERMINE UNIT PACKING REQUIREMENTS AND QUANTITY PER UNIT PACKAGE
	T	A	C			308	DETERMINE TYPES AND QUANTITIES OF STANDARD PHST EQUIPMENTS REQUIRED
		A	C	C		309	DETERMINE PACKING AND UNPACKING PROCEDURES
	T	A	C	C		310	DETERMINE MANPOWER, SKILLS, AND TRAINING REQUIREMENTS RELATED TO PHST FOR EACH STORAGE/USAGE SITE
	A	A	A	C		311	INTEGRATE PHST DESIGN REQUIREMENTS INTO ITEM DESIGNS AND DOCUMENTATION
		A		C		312	INTEGRATE PHST PROCEDURES INTO TECHNICAL MANUALS AND PROCEDURAL GUIDES

RELIABILITY PROGRAM TASKS PER MIL-STD-785

CON	D&V	FSD	PRO	O&S			
					100	PROGRAM SURVEILLANCE AND CONTROL	
T	T	A	A	C		101	RELIABILITY PROGRAM PLAN
T	T	A	A	C		102	MONITOR/CONTROL OF SUBCONTRACTORS AND SUPPLIERS
T	T	A	A			103	PROGRAM REVIEWS
	T	A	A	T		104	FAILURE REPORTING, ANALYSIS, AND CORRECTIVE ACTION SYSTEM (FRACAS)
	T	A	A	T		105	FAILURE REVIEW BOARD
A	A	A	A			106	THERMAL MANAGEMENT CONTROL (TMC) PROGRAM

Table XXII-4. Support task application matrix (continued).

					200		DESIGN AND EVALUATION
T	T	C	C			201	RELIABILITY MODELING
T	A	C	C			202	RELIABILITY ALLOCATIONS
T	T	C	C			203	RELIABILITY PREDICTIONS
T	T	C	C			204	FAILURE MODES, EFFECTS, AND CRITICALITY ANALYSIS (FMECA)
		T	C			205	SNEAK CIRCUIT ANALYSIS (SCA)
		T	C			206	ELECTRONIC PARTS/CIRCUITS TOLERANCE ANALYSIS
T	T	A	A	C		207	PARTS CONTROL/APPLICATION PROGRAM
T	T	A	A	A		208	RELIABILITY CRITICAL ITEMS
	T	A	A	C		209	EFFECTS OF FUNCTIONAL TESTING, STORAGE, HANDLING, PACKAGING, TRANSPORTATION, AND MAINTENANCE
A	A	C	C			210	THERMAL/RELIABILITY DESIGN TRADE STUDIES
	A	A	C			211	THERMAL/RELIABILITY DESIGN ANALYSIS
					300		DEVELOPMENT AND PRODUCTION TESTING
	T	A	A	C		301	ENVIRONMENTAL STRESS SCREENING (ESS)
	T	A				302	RELIABILITY DEVELOPMENT/GROWTH TESTING
	T	A	A	C		303	RELIABILITY QUALIFICATION TEST (RQT)
		T	A	C		304	PRODUCTION RELIABILITY ACCEPTANCE TEST (PRAT)
	T	A	C			305	THERMAL DESIGN VALIDATION TEST (TDVT) PROGRAM

SYSTEM SAFETY PROGRAM REQUIREMENTS PER MIL-STD-882B

CON	D&V	FSD	PRO	O&S			
					100		SYSTEM SAFETY PROGRAM
A	A	A	A	C		101	SYSTEM SAFETY PROGRAM PLAN
T	T	T	T	T		102	INTEGRATION/MANAGEMENT OF SUPPORTING SUBTEAMS
T	T	T	T	T		103	SYSTEM SAFETY PROGRAM REVIEWS
A	A	A	A	C		104	SYSTEM SAFETY GROUP/WORKING GROUP SUPPORT
T	A	A	A	A		105	HAZARD TRACKING AND RISK RESOLUTION
A	A	A	A	T		106	TEST AND EVALUATION SAFETY
A	A	A	A	C		107	SYSTEM SAFETY PROGRESS SUMMARY
T	T	T	T	T		108	QUALIFICATION OF SUPPORT TEAM SAFETY ENGINEERS AND MANAGERS
					200		DESIGN AND EVALUATION
A	T	T				201	PRELIMINARY HAZARD LIST
A	A	A	C	C		202	PRELIMINARY HAZARD ANALYSIS
	A	A	C	C		203	SUBSYSTEM HAZARD ANALYSIS
	A	A	C	C		204	SYSTEM HAZARD ANALYSIS
T	A	A	C	C		205	OPERATING AND SUPPORT HAZARD ANALYSIS
A	A	A	C	C		206	OCCUPATIONAL HEALTH HAZARD ASSESSMENT
T	A	A	T	C		207	SAFETY VERIFICATION
	T	T	T	T		208	TRAINING
T	T	T	T	T		209	SAFETY ASSESSMENT
T	T	T	T	T		210	SAFETY COMPLIANCE ASSESSMENT
	A	A	A	A		211	SAFETY REVIEW OF ECPs AND REQUESTS FOR DEVIATIONS AND WAIVERS
						212	(RESERVED)
T	A	A	A			213	GFE/GFP SYSTEM SAFETY ANALYSIS

Table XXII-4. Support task application matrix (continued).

					300	SOFTWARE HAZARD ANALYSIS
T	A	A	C	C	301	SOFTWARE REQUIREMENTS HAZARD ANALYSIS
T	A	A	C	C	302	TOP-LEVEL DESIGN HAZARD ANALYSIS
T	A	A	C	C	303	DETAILED DESIGN HAZARD ANALYSIS
T	A	A	C	C	304	CODE-LEVEL SOFTWARE HAZARD ANALYSIS
T	A	A	C	C	305	SOFTWARE SAFETY TESTING
T	A	A	C	C	306	SOFTWARE/USER INTERFACE ANALYSIS
T	A	A	C	C	307	SOFTWARE CHANGE HAZARD ANALYSIS

TESTABILITY PROGRAM PER MIL-STD-2165

CON	D&V	FSD	PRO	O&S		
					100	PROGRAM MONITORING AND CONTROL
	A	A			101	TESTABILITY PROGRAM PLANNING
A	A	A	T	C	102	TESTABILITY REVIEWS
	T	A	A		103	TESTABILITY DATA COLLECTION AND ANALYSIS PLANNING
					200	DESIGN AND ANALYSIS
A	A	A			201	TESTABILITY REQUIREMENTS
	T	A	T		202	TESTABILITY PRELIMINARY DESIGN AND ANALYSIS
	T	A	T		203	TESTABILITY DETAIL DESIGN AND ANALYSIS
					300	TEST AND EVALUATION
	T	A	T		301	TESTABILITY INPUTS TO MAINTAINABILITY DEMONSTRATION

PRODUCT ASSURANCE PER DOD-STD-2107 (Partial)

CON	D&V	FSD	PRO	O&S		
	R	R	R		4.1.1	GENERAL
	A	A	A		4.1.2	MANAGEMENT POLICY
A	A	A	A		4.1.3	PROGRAM PLANNING
	R	R	R		4.1.4.1	EDUCATION AND TRAINING
		T	R		4.1.4.2	CERTIFICATION OF PERSONNEL
	R	R	R		4.1.5.1	AUDIT CONDUCT
	R	R	R		4.1.5.2	AUDIT REPORT AND CORRECTIVE ACTION
	R	R	C		4.1.6	INTEGRATED DATA SYSTEM
	R	R	R		4.1.7	INTEGRATED TEST PROGRAM
	C	A	A		4.1.8	PROBLEM/FAILURE REPORTING, ANALYSIS, AND CORRECTIVE ACTION
						4.1.8.1 PROBLEM/FAILURE REPORTING
						4.1.8.2 PROBLEM/FAILURE INVESTIGATION AND ANALYSIS
						4.1.8.3 CORRECTIVE ACTION
A	A	A	A	R	4.1.9	CONFIGURATION MANAGEMENT (see MIL-STD-480)
						4.1.9.1 CONFIGURATION IDENTIFICATION
						4.1.9.2 CONFIGURATION CONTROL
						4.1.9.3 CONFIGURATION CONTROL BOARDS
						4.1.9.4 CONFIGURATION STATUS ACCOUNTING
						4.1.9.5 CONFIGURATION AUDITS

Table XXII-4. Support task application matrix (continued).

		T	A	C	4.1.10	NONCONFORMING MATERIAL CONTROL (MIL-STD-1520 ALTERNATE)
						4.1.10.1 IDENTIFICATION AND SEGREGATION
						4.1.10.2 MISSED OPERATIONS
						4.1.10.3 PRELIMINARY REVIEW
						4.1.10.4 MATERIAL REVIEW BOARD
						4.1.10.5 NONCONFORMANCE REQUESTS FOR DISPOSITION
						4.1.10.6 SUBCONTRACTOR MATERIAL REVIEW BOARD
		A	A	C	4.1.11	SAMPLING PLANS
			A	A	4.1.12	QUALITY COST DATA
T	T	T	T	C	4.1.13	SOFTWARE
	T	A	A	C	4.1.14	TECHNICAL DATA QUALITY ASSURANCE
	T	A	A	T	4.2	SUPPLIER QUALITY ASSURANCE PROGRAM REQUIREMENTS (MIL-STD-1535 ALTERNATIVE)
	T	A	A	T	4.2.1	GENERAL
	T	A	A	T	4.2.2	SELECTION OF PROCUREMENT SOURCE
			A	A	4.2.3	APPROVED SOURCE LIST
	T	T	T		4.2.4	SURVEYS OF SUBCONTRACTORS OPERATIONS
A	A	A	A	C	4.2.5	PROCUREMENT DOCUMENT PROVISIONS
	A	A	A		4.2.6	PROCUREMENT DOCUMENT REVIEW
	A	A	A	C	4.2.7	PROCUREMENT DOCUMENT CHANGE CONTROL
	T	T	T		4.2.8	CONTRACTOR/SUBCONTRACTOR COORDINATION AND CORRECTIVE ACTION
A	A	A	A		4.2.9	CONTRACTOR SOURCE SELECTION
A	A	A	C		4.3	DEVELOPMENT
A	A	A			4.3.1	MISSION/SYSTEM ANALYSIS
T	A	A	C	C	4.3.2	DESIGN ANALYSIS
						4.3.2.1 PARAMETER STUDIES
						4.3.2.2 CLASSIFICATION OF CHARACTERISTICS (see DOD-STD-2101)
						4.3.2.3 SNEAK ANALYSIS
						4.3.2.4 FAILURE MODE, EFFECT, AND CRITICALITY ANALYSIS
						4.3.2.5 STRESS ANALYSIS OF PARTS AND MATERIALS
						4.3.2.6 WORST-CASE ANALYSIS
						4.3.2.7 MAINTAINABILITY AND RELIABILITY ANALYSIS
						4.3.2.8 LOGISTICS ANALYSIS
						4.3.2.9 PRODUCIBILITY ANALYSIS
T	A	A	C		4.3.3	DESIGN PRACTICES AND DOCUMENTATION
	T	A	C	C	4.3.4	PARTS AND MATERIALS SELECTION & IDENTIFICATION
T	T	T	C	C	4.3.5	HUMAN ENGINEERING PROGRAM
A	A	A	A		4.3.6	DESIGN REVIEW
		T	T	T	4.3.7	KEY COMPONENTS
		T	T	C	4.3.8	CONTROL OF KEY COMPONENTS
R	R	R			4.3.10	DEVELOPMENT TESTS
	R	R			4.3.10.1	DESIGN TESTS
	T	R			4.3.10.2	ENGINEERING EVALUATION TESTS
	T	R			4.3.10.5	QUALIFICATION TESTS
		T	T		4.3.10.6	RELIABILITY DEMONSTRATION TESTS
		R	T		4.3.10.7	MAINTAINABILITY DEMONSTRATION TESTS
R	R	R	T	C	4.3.11	RELIABILITY AND MAINTAINABILITY ACCOUNTING
						4.3.11.1 RELIABILITY MODELING
						4.3.11.2 RELIABILITY PREDICTION
						4.3.11.3 RELIABILITY APPORTIONMENT
						4.3.11.4 RELIABILITY EVALUATION
						4.3.11.5 MAINTAINABILITY MODELING
						4.3.11.6 MAINTAINABILITY PREDICTION
						4.3.11.7 MAINTAINABILITY APPORTIONMENT

Table XXII-4. Support task application matrix (continued).

						4.3.11.8 MAINTAINABILITY EVALUATION
						4.3.11.9 AVAILABILITY EVALUATION
R	R	R	T		4.3.12	TEST AND INSPECTION DURING DEVELOPMENT
						4.3.12.1 DEMONSTRATION AND VALIDATION
						4.3.12.2 FULL-SCALE DEVELOPMENT
	T	A			4.3.13	MATERIAL IDENTIFICATION AND HANDLING
	T	A			4.3.14	MANUFACTURING CONTROL DURING DEVELOPMENT
		A	C		4.3.15	READINESS REVIEW FOR PRODUCTION OPERATIONS
		T	A	C	4.4	PRODUCTION
						4.4.1 GENERAL
						4.4.2.1 PARTS AND MATERIALS CONTROL
						4.4.2.2 PROCESS CONTROLS
						4.4.2.3 ASSEMBLY OPERATIONS
						4.4.2.4 ENVIRONMENTAL AND CLEANLINESS CONTROL
						4.4.2.5 WORKMANSHIP STANDARD
						4.4.3 TEST AND INSPECTION PLANNING
						4.4.4 QUALITY VERIFICATION
						4.4.4.1 RECEIVING TEST AND INSPECTION
						4.4.4.2 IN-PROCESS TEST AND INSPECTION
						4.4.4.3 NONDESTRUCTIVE TESTING PROCESS
						4.4.4.4 CONFIGURATION VERIFICATION
						4.4.4.5 ACCEPTANCE TEST AND INSPECTION
						4.4.4.6A FIRST ARTICLE INSPECTION
						4.4.4.6B QUALIFICATION TESTS
						4.4.4.6C PERIODIC PRODUCTION TESTS
						4.4.4.7 INSPECTION INDICATIONS
						4.4.4.8 TEST AND INSPECTION RECORDS
						4.4.5.1 MATERIAL PROTECTION
						4.4.5.2 SHIPPING INSPECTION
				A	4.4.6	DOCUMENTATION CONTROL DURING PRODUCTION
	T	A	A	C	4.5	TEST AND INSPECTION EQUIPMENT AND STANDARDS
					4.5.1	CALIBRATION SYSTEM (see DoD-STD-45662)
	T	T	T		4.5.1.1	CALIBRATION PROCEDURE PRECEDENCE
	T	T	T		4.5.1.2	INITIAL INTERVALS OF CALIBRATION
	T	R	R		4.5.1.3	IDENTIFICATION OF STANDARDS
	T	R	R		4.5.1.4	SEALING
	T	R	R		4.5.1.5	MEASUREMENT AND TEST EQUIPMENT CONTROL
	T	T	T		4.5.1.6.1	QUALITATIVE DATA
	T	T	T		4.5.1.6.2	QUANTITATIVE DATA
	T	T	T		4.5.1.7	ALLOWABLE ERROR OF STANDARDS
	T	R	R		4.5.1.8	MEASURING DEVICES
			R	C	4.5.2	TEST AND INSPECTION EQUIPMENT DESIGN AND EVALUATION
						4.5.2.1 DESIGN
						4.5.2.2 EVALUATION
			T	T	4.5.3	TEST AND INSPECTION STATION OPERATIONAL PROOFING AND CORRELATION
			R	C	4.5.3.1	OPERATIONAL PROOFING
			R	R	4.5.3.2	TEST AND INSPECTION STATION LOGS
			T	T	4.5.3.3	TEST AND INSPECTION STATION CORRELATION

Table XXII-4. Support task application matrix (continued).

CALIBRATION REQUIREMENTS PER DOD-STD-45662 (PER MIL-STD-2107)

CON	D&V	FSD	PRO	O&S		
	R	R	R		4.1	GENERAL
					4.2	QUALITY ASSURANCE PROVISIONS
	T	R	R		5.1	CALIBRATION SYSTEM REQUIREMENTS
	T	R	R		5.2	ADEQUACY OF STANDARDS
	T	R	R		5.3	ENVIRONMENTAL CONTROLS
	T	R	R		5.4	INTERVALS OF CALIBRATION
	T	R	R		5.5	CALIBRATION PROCEDURES
	T	R	R		5.6.1	EVALUATION OF SUSPECT PRODUCT
	T	R	R		5.6.2	EVALUATION OF CALIBRATION SYSTEM ACCURACY
	R	R	R		5.7.1	DOMESTIC CONTRACTS (CALIBRATION SOURCES)
	T	T	T		5.7.2	FOREIGN CONTRACTS (CALIBRATION SOURCES)
	T	R	R		5.8	APPLICATION AND REPORTS
	T	R	R		5.9	CALIBRATION STATUS
	R	R	R		5.10	CONTROL OF SUBCONTRACTOR CALIBRATION
	R	R	R		5.11	STORAGE AND HANDLING
	R	R	R		5.12	AMENDMENTS AND REVISIONS

HUMAN FACTORS ENGINEERING PER MIL-H-46855B

CON	D&V	FSD	PRO	O&S		
A	A	A	A			GENERAL PROVISIONS
A	C	C	C		3.1.1.A	ANALYSIS
T	A	A	C		3.1.1.B	DESIGN AND DEVELOPMENT
O	A	A	C		3.1.1.C	TEST AND EVALUATION
T	T	A	C		3.1.2	HE PROGRAM PLANNING
A	A	A			3.1.3	NONDUPLICATION
A	A	A			3.2	DETAIL REQUIREMENTS
A	A	A	C		3.2.1	ANALYSIS
A	A	O			3.2.1.1	DEFINING AND ALLOCATING
A	A	O			3.2.1.1.1	INFORMATION FLOW AND PROCESSING ANALYSIS
T	A	O			3.2.1.1.2	ESTIMATES OF POTENTIAL OPERATOR/MAINTAINER PROCESSING CAPABILITIES
A	A	O			3.2.1.1.3	ALLOCATION OF FUNCTIONS
T	A	O			3.2.1.2	EQUIPMENT SELECTION
A	A	A	C		3.2.1.3	ANALYSIS OF TASKS
T	A	A	C		3.2.1.3.1	GROSS ANALYSIS OF TASKS
O	A	A	C		3.2.1.3.2	ANALYSIS OF CRITICAL TASKS
A	A	A	C		3.2.1.3.3	WORKLOAD ANALYSIS
T	T	A	C		3.2.1.3.4	CONCURRENCE AND AVAILABILITY
T	T	A	C		3.2.1.4	PRELIMINARY SYSTEM DESIGN
T	A	A	C		3.2.2	HE IN EQUIPMENT DETAIL DESIGN
A	A	A			3.2.2.1	STUDIES, EXPERIMENTS, AND LABORATORY TESTS
						3.2.2.1.1 MOCKUPS AND MODELS
						3.2.2.1.2 DYNAMIC SIMULATION
O	A	A	C		3.2.2.2	EQUIPMENT DETAIL DESIGN DRAWINGS
T	A	A	C		3.2.2.3	WORK ENVIRONMENT, CREW STATIONS, AND FACILITIES DESIGN

Table XXII-4. Support task application matrix (continued).

O	A	A	C	3.2.2.4	HE IN PERFORMANCE AND DESIGN SPECIFICATIONS
O	A	A	C	3.2.2.5	EQUIPMENT PROCEDURE DEVELOPMENT
T	T	A		3.2.3	HE IN T&E
					3.2.3.1 PLANNING
					3.2.3.2 IMPLEMENTATION
					3.2.3.3 FAILURE ANALYSIS
A	A	A	A	3.2.4	COGNIZANCE AND COORDINATION
A	A	A	A	3.3	DATA REQUIREMENTS
T	T	A	A	3.3.1	TRACEABILITY
A	A	A	A	3.3.2	ACCESS
A	A	A	A	3.4	DRAWING APPROVAL

CODES: A — APPLIES
C — CONDITIONALLY APPLIES, ESPECIALLY FOR CHANGES
O — OPTIONAL AS PART OF OVERALL PROGRAM TAILORING
R — HIGHLY RECOMMENDED
T — TAILORED REQUIREMENTS

figure 7

DEALING WITH CONTRACTORS

The Project Manager (PM) and Systems Engineer (SE) must both work with contractors, especially when significant portions of the project tasks are being accomplished under contract. In this relationship, the PM/SE must strike a balance between competing elements without compromise. These elements include:

The Public Interest (long term)	The Public Interest (short term)
Being a good customer	Ethics
Maintaining team spirit	Objectivity
Responsibility	Accountability

These are not mutually exclusive elements, but the unwary PM/SE can fall into serious traps if the right balance is not maintained.

BEING A GOOD CUSTOMER

It is important to be a good customer, but this is made difficult by the assumed adversarial relationships inherent in many contractual procedures and by the requirements to maintain an ethical profile avoiding even the appearance of any impropriety. Still, it is possible. The key to being a good customer is OPEN BUT PROPER COMMUNICATIONS. The first of these communications are the statements of requirements in the statement of work, specifications, contract data requirements, and contract clauses. State the requirements:

clearly and concisely

completely

to be tailored to obtain all that is required without overspecification

to minimize change, but identifying known changes and making provisions for necessary changes in an orderly manner

In the statement of work, delineate the responsibilities between the Government and the contractor, and state the provisions for open but proper communications. In the CDRL, obtain all the INFORMATION that is needed while minimizing data. In the contract, hold the contractor accountable for performance, cost, and schedule with default provisions having teeth (but also allowing for agreed-upon changes).

Too often, contracts are established without clearly identifying requirements; this practice exposes the Government to unnecessary costs and puts the contractor in the uncomfortable position of being unable to perform the tasks satisfactorily and professionally. This is the sort of thing that embarrassing news stories are made of.

Remember — VERBAL AGREEEMENTS AREN'T WORTH THE PAPER THEY'RE PRINTED ON (but they can cost much more).

Remember — a contract places requirements on both parties; make sure that the Government lives up to its part in the bargain by providing GFE/GFM on time and that meets specifications, by providing timely reviews and approvals, and by making prompt payments (which are often held up by the failure of a PM or SE to sign the receipt forms on time).

Remember — "Do not muzzle the ox"; contractors are entitled to fair and equitable compensation for their efforts.

Remember — contractors are people. They deserve to be treated professionally and with respect. (Likewise, the PM/SE should act in a way to command the respect of the contractors.) Treat contractors as part of the team as people, but remember that the contractor organization exists to make a profit at your project's expense. Ensure that it is money well spent and that the project obtains what is required by the time the contract is finished.

OPEN BUT PROPER COMMUNICATION

Good project communications must include the contractor(s) participating on the project team. These communications must be

timely,

accurate,

complete,

but within established contractual channels.

All verbal communications should be strictly unofficial and backed up by official written communications or records. Reviews and meetings are an excellent forum for discussing issues and reaching conclusions on required actions, but a formal written record should be maintained. Telephone conversations should also be documented in telephone conversation records and filed appropriately. All decisions and communications which affect the contractual requirements (including SOW and specification requirements) must be communicated and approved through the contracting officers. It should be made contractually impossible for verbal direction to change the contracted requirements. Proper communications protect sensitive information, including

security information,

privacy information,

and proprietary information.

Do not communicate information to a contractor that can compromise future program plans or contractual negotiations except through official channels on a need-to-know basis.

XXIII. OTHER MANAGEMENT TASKS

EMX MANAGEMENT

One of the most severe environments encountered by equipments in military applications is the electromagnetic (EM) environment. The severity of military EM environments tends to grossly exceed that of otherwise comparable commercial EM environments; therefore, an effective program of EM management, assessment, and engineering is required to assure system effectiveness. This need extends equally to off-shelf equipments and to equipment developments, although the actions taken are affected by the equipment source.

Problems arising from EM sources are of three types:

- Unwanted emissions from the equipment
- Damage to the equipment by the EM environment
- Undesirable modification to equipment performance due to emissions from other equipments

The damaging effects of these problems fall into one or more of the following categories:

- Hazards to personnel
- Hazards to ordnance
- Hazards to other equipments
- Degraded equipment performance
- Degraded security

The engineering tools which are available to combat EM problems include:

- Filtering
- Shielding
- Grounding
- Application of special technology
- Careful component selection and application
- Installation control

Each of these tools costs money to implement; how much money depends on the degree of protection needed and on the point at which protective measures are applied in the design of the equipment. When design changes are mandated, they are always more expensive than proper initial design; furthermore, design changes are always more extensive as the equipment design matures. The variety and impact of the problems and prospective solutions demand management attention in order to effect an acceptable product and to efficiently utilize project resources.

There are a number of terms which are somewhat peculiar to the EM field:

EMC	Electromagnetic compatibility—a term encompassing the issues of an equipment operating properly within its EM enviornment and not causing interference to other equipments
EMI	Electromagnetic interference—negative effects of one equipment on another
EMP	Electromagnetic pulse—an EM effect of a nuclear blast
EMX	A blanket term covering all EM-related problems
HERO	Hazardous electromagnetic radiation to ordnance (see MIL–STD–1377)
RADHAZ	Electromagnetic radiation hazard to personnel
TEMPEST	A term covering security problems which are EM design oriented

This list is not complete but is sufficient for the discussion which follows.

Hazards to personnel include shock hazards and RADHAZ. The approaches toward reducing these hazards include safety interlocks, protective enclosures around high-hazard sections, good grounding techniques, and warning labels and signs. Requirement 1 of MIL-STD-454 covers these approaches. No equipment or system should be exempted from these provisions.

Hazards to ordnance are normally treated by control of the ordnance design and by ordnance handling procedures which require shutting down all emitters in the 2−32-MHz band (the frequencies of greatest ordnance susceptibility). The equipments which may be connected to ordnance, directly or indirectly, must be designed to protect sensitive circuits (particularly firing circuits) from the EM environment. The steps required include proper grounding techniques, shielding, filtering against transient and spurious signals, and designs to preclude false signaling; safety interlocks and fail-safe designs should be integral to all equipments connected to ordnance.

If an equipment will be operating remotely and independently from any other equipment, EMI/EMC is not a particular problem; however, most applications will require shared power systems, antenna systems, control systems, or installation spaces. Usually, EMC will be important. Figure V-3 shows the relationship between the significant EMI and EMC specifications and standards. “Suggestions for Designers of Navy Electronic Equipment” (NOSC TD 250) contains many tips on good EM engineering techniques. The project manager should ensure that lead engineers are familiar with EM design practices and that the test program incorporates EM testing. MIL-STD-461 is the primary EMI requirements standard. It describes the “normal worst case” EM environment; as such, it overspecifies some applications and underspecifies others. Where more precise validated information is available for a particular application, it should be used in lieu of MIL-STD-461. For general applications or other applications in which a large number of equipments are collocated and are subject to changes in configuration, then apply the more stringent requirements. The test requirements of MIL-STD-462 are valid even if the test parameters are modified by better information. However, the broadband tests of CE01 and the requirements of CE05 are difficult, if not impossible, to test in a valid manner; they should be excluded from or modified for project test requirements. Particular attention should be paid to spurious emissions.

Off-shelf equipments should be tested during the screening process to assure compliance to EM requirements. because of the peculiarly stringent military EM environments, many off-shelf commercial equipments will require filters and careful installation control to adequate compatibility. Some commercial equipments will show susceptibility to damage in military EM environments and should be disqualified if the damaging conditions occur during normal operations or frequently and if adequate protection cannot be added economically.

In the conduct of an EMC program, MIL-HDBK-235, MIL-HDBK-237, and MIL-HDBK-238 should prove useful. MIL-HDBK-237 discusses EMC program management.

MIL-HDBK-235 describes specific EM environments. MIL-HDBK-238 describes numerous radiation hazards and ways to handle them. Also, MIL-HDBK-241 provides guidance for designing power supplies and filters for EMC.

EMP is a very difficult problem and an expensive one to solve. Because it is so expensive to treat, EMP management should be applied only to vital systems. Consider all systems wiped out by EMP damage except your system and EMP qualified systems; if your system is still essential to critical operational missions, then it is a candidate for EMP. All the EMX tools must be brought into play to attack EMP; therefore, it is essential that design personnel be familiar with the EMP problem and approaches to its solution. Courses are available on EMP which should be attended by all designers. bake a common sense approach to the problem. Must the system operate flawlessly <u>during</u> the EMP, or can some downtime be tolerated? Specially designed microcircuits and semiconductors may be required to survive EMP. EMP is characterized by extremely fast rise times and very broadband high-intensity fields; both effects must be considered. Fast-acting protective devices may be indicated. Another approach is to design the equipment so that EMP damage will be confined to a known component or module, then a spare can be designed into the system, <u>but out of the circuit</u> to provide a low downtime. Include EMP testing in your program. Knowledgeable personnel and early design attention are essential to efficient EMP management.

TEMPEST is similar to EMI in its basic manifestations, causes, and cures. However, TEMPEST is concerned with signal intelligence whereas EMI is not; this is reflected in the respective testing philosophy. The power and frequency ranges at which intelligence can be recovered are, in general, more stringent than those which cause interference. TEMPEST requires early consideration of knowledgeable design practice. The standards for TEMPEST are NACSIM 5100A and NACSEM 5103. Because it is a specialized engineering discipline, project managers for equipment which handles classified information should request guidance, technical assistance, and publications from the Naval Electronic Systems Security Engineering Center (NESSEC), 3801 Nebraska Avenue NW, Washington, DC 20390. Commands and activities of the Navy should send requests directly to the Commanding Officer, NESSEC.

Industrial organizations performing on contract should submit requests though the contracting officer and the sponsoring activity. Other naval commands and activities, and non-Navy agencies, may contact NESSEC for similar assistance. It is essential that this contact be established early to assure adequate planning, funding, and execution of TEMPEST-related tasks.

When installation control is to be employed, as it must be in secure systems and EMP-protected systems, the control requirements must be cited in the installation planning documentation (see chapter XVIII). Special installation controls will involve additional design, planning, and supervision by the installing activity. Wherever possible, it is advisable to build features into the equipment which force proper installation to avoid installation control problems; however, systems with interconnecting cabling to units in remote locations must contend with the problems of installation control.

Standards for bonding and grounding techniques are found in MIL-STD-1310 and MIL-B-5087.

PARTS MANAGEMENT

The management of parts selection and application is essential to the success of any engineering project. Unlike other management tasks, parts management is not subject to the rigorously well-defined guidance that are other tasks, such as configuration management.

Parts management policy must be set by the project manager to conform to the conditions which exist for that project; the policy is implemented by the designers. In this context, a part must be considered any piece part, module, subassembly, assembly, or unit which might be stocked as an item of supply support or the components making up such an item. Obviously the parts management policy must eventually dictate the provisioning decisions for an equipment, since the policy dictates the design which must be provisioned. Past attempts to mandate a general parts management policy have amounted to a blanket standard piece parts/standard module policy which has not always been consistent with individual project goals; i.e., utilization of commercial equipment, specialized technologies, or low-cost/high-availability parts or attainment of reliability goals. A much broader policy of standardization is enunciated by NAVMATINST 4120.97 (series) which is summarized in chapter XIV in the section titled Standardization of Components/Equipment (C/E). The Low Cost Electronics study shows that the provisions of this instruction are largely ignored or inappropriately applied because of a lack of good technical guidance to project/acquisition managers. This section will attempt to provide such guidance.

In general, five factors must be considered in setting a parts management policy:

Performance
Reliability
Maintenance
Provisioning
Cost

In addition, the project manager must consider parts availability, since delays in parts deliveries may have a very negative effect on the project schedule. These fac-tors, as they interact with each other, may be lumped into three categories of issues:

Standardization
Effectiveness
Efficiency

STANDARDIZATION

There are two types of standardization—intrasystem and intersystem. The goals of intrasystem standardization are to:

- Increase the producibility of the system by reducing the number of different kinds of components.
- Increase system supportability through widespread intrasystem commonality of designs, modules, etc.
- Decrease system documentation costs through commonality of designs, modules, etc.
- Create a situation in which all items provisioned can be ordered in economically large quantities (see fig VI-1).
- Decrease system downtime for parts (see fig IV-4).
- Decrease system design time by limiting the choices available to the designer.
- Establish standard intrasystem interfaces.

Most simply, intrasystem standardization strives to make the widest possible use of the fewest possible different kinds of parts and designs. The greatest advantages of such programs as the Standard Electronics Module (SEM) and the Standard Hardware Program (SHP) lie in the ready availability through them of design building blocks for application in intrasystem standardization efforts. The goals of intersystem standardization are to minimize the number of different logistics items which must be supported and to maximize interchangeability between items of like functions.

The following steps are recommended to implement the standardization objectives of parts management:

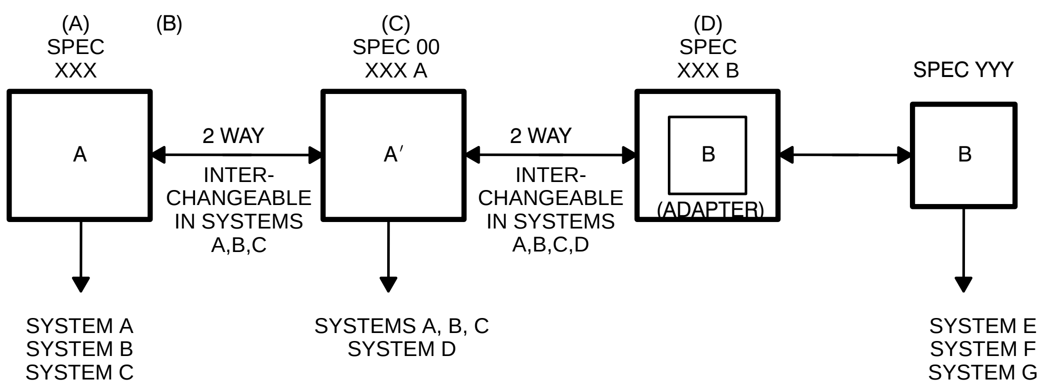
1. Establish a project policy of maximizing intrasystem standardization.
2. Wherever possible, make use of existing standards (standard interfaces, standard modules, standard parts, standard equipments, standard test provisions, etc.); however, do not enforce this provision to these degradation of other project requirements. Established industry standards should be considered as well as military standards.
3. Minimize system-peculiar designs and components.

4. In selecting parts, choose preferred parts (MIL-STD-242) over other standard parts (controlled by military specification), standard parts over controlled parts (nonstandard parts already supported in the National Stock System), and controlled parts over all other parts. This step is implemented in accordance with MIL-STD-965 and MIL-STD-143.

5. Where other factors (such as cost or availability) militate against the use of the part which would otherwise be selected under step 4, select a part which can be replaced by the step 4 selection for repair/provisioning purposes and show the step 4 selection in the provisioning documentation. This step is implemented in accordance with Requirement 7 of MIL-STD-454.

6. Document all system interfaces, down to the level of standardization, using functional specifications as discussed in chapter VI.

Step 6 is particularly important, since it establishes the mechanism for future design evolution within the framework of standardization; figure XXIII-1 illustrates this mechanism.



(A) ITEM A IS DEVELOPED FOR SYSTEM A AND DOCUMENTED BY SPEC XXX.

(B) ADDITIONAL USE FOR ITEM A IS FOUND IN SYSTEM B AND SYSTEM C.

(C) TECHNOLOGY ADVANCES LEAD TO ITEM A′, CAN ALSO BE UTILIZED IN SYSTEM D, WHICH REQUIRES THE IMPROVED CHARACTERISTICS. ITEM A IS DOCUMENTED BY SPEC 00 XXX A.

(D) A NEW GENERATION OF TECHNOLOGY LEADS TO ITEM B WHCH IS DEVELOPED FOR SYSTEM E AND DOCUMENTED BY SPEC YYY. ITEM B IS FUNCTIONALLY LIKE ITEM A′ BUT SIGNIFICANTLY SMALLER IN FORM FACTOR AND LESS EXPENSIVE, SO SPEC XXXB IS DEVELOPED TO ADAPT ITEM B TO SYSTEMS A, B, C, AND D AND TO SUPERSEDE SPEC XXX AND SPEC 00XXX A. LATER, NEW APPLICATIONS FOR ITEM B ARE FOUND IN SYSTEMS F AND G.

Figure XXIII-1. Growth of a standard.

EFFECTIVENESS

Parts management for overall system effectiveness is most often cloaked as "good engineering practice." The performance of the system hinges on proper parts selection and application. The reliability of the system depends on (1) the inherent failure rate of the selected parts and (2) the stresses put on the parts by their design application. The availability of the system depends on its achieved reliability and the time to restore it to operation when a failure occurs. The availability of parts is a major factor in the ability to repair a system; therefore, consideration of both current and future part availability is warranted. Undoubtedly, performance factors play a major role in part selection; a partial list of these factors would include size, weight, form factor, power consumption, environmental ratings, and tolerance. “Suggestions for Designers of Navy Electronic Equipment” (NOSC TD 250) provides many points to aid in avoiding pitfalls in part selection; the appropriate military specifications and “selection and use” standards are also useful. Beyond these standard factors, parts should be selected as follows:

1. Select high-reliability parts.
2. Use parts well within their rated limits; derate the parts for the environment they must endure in service (temperature, EMI, vibration).
3. Choose parts whose dominant failure mode has minimum effect on the equipment.
4. Select parts and designs which do not require other components to correct their deficiencies (for instance, vibrator-type power supplies will normally require filtering to take out the EMI they produce).
5. Take into account part tolerances and value changes under stress and aging.
6. Choose parts which are produced by mature, large-volume manufacturing processes where other factors (size, weight, speed, etc.) do not dictate a less mature technology.
7. Avoid sole source and proprietary parts.
8. Conform to standardization steps 4 and 5. When specialized screening is indicated, cite the screening requirements which are in excess of high reliability/standard parts qualification requirements.

EFFICIENCY

Cost and availability of parts are factors which must always be weighed in part management decisions. However, these factors should not be given primacy over other part selection factors since the initial cost of components is only a small portion of an equipment’s cost (typically 10% for military electronics) and supposed savings are quickly obscured by high support costs. Nevertheless, a number of alternatives may be available to the project in its parts decisions.

1. In more complex parts (assemblies and units), off-shelf items should be considered in preference to developing a new item.
2. Manufacturers’ high-reliability lines of commercial parts are often much more readily available than military parts and are usually less expensive; these parts can be used to advantage in design and even in limited production as long as the military standard part is used as the provisioning part (see standardization step 5).

3. High reliabilities meeting or exceeding military standards are often attainable by applying an appropriate screen to commercial parts; this applies to piece parts and whole equipments alike. In applying screens to piece parts, large enough volumes of parts must be screened to amortize the screening setup costs and the costs of rejected parts. When a high-reliability/standard part exists, it should be specified in provisioning documentation.

4. When parts-peculiar are justified (such as custom LSI), consideration should be given to total life-cycle procurement techniques to preclude uneconomical small-lot reprocurements. (A total life-cycle procurement combines initial requirements and all projected support requirements.)

CONFIGURATION MANAGEMENT

The purpose of configuration management (CM) is to ensure that the knowledge required to design, operate, reproduce, improve, and support a system is retained. This knowledge is initially in the minds of the designers, but eventually it must be documented and controlled. During design, task leaders should be held responsible for ensuring that the proper documentation is created and maintained accurately; this is a function of data management (see chapter XX and NAVMATINST 4000.15 (series)). Once the documentation has been produced, verified, and accepted, it becomes subject to the more formal controls of configuration management to ensure that the equipment and its descriptive data are indeed of the same design.

Configuration management should be executed in accordance with SECNAVINST 4130.2 (series). CM is implemented through three information baselines:

Functional baseline—based on the system specification

Allocated baseline—based on detailed system partitioning and the specifications describing each configuration item

Product baseline—based on the established system design implemented in product design

The functional and allocated baselines consist of total functional descriptions of the identified configuration items. The product baseline consists of the total design description of all system items down to, and including, the level of standardization (see chapter VI); this will normally consist of a mixture of functional and fabrication specifications, drawings, and associated lists. Once a baseline is established, it can only be changed through an engineering change proposal (ECP). Two classes of ECP and defined by MIL-STD-973—Class I and Class II. Class I changes must be justified on the basis of their beneficial effect to the configuration item and must be approved by the Government Change Control Board (CCB) prior to implementation (this CCB will reside internally to the project until the production/deployment phase; then the CCB of the cognizant systems command will take over). Class II changes are justified only on the basis of their benefits to the originator or the government and may be implemented as long as they will not be detrimental to the government and when the government concurs that the ECP meets this criterion. In the implementation of CM, the following recommendations are made:

1. Implement CM to the level of standardization;* do not require CM controls below that level.

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*The level of standardization, as defined in chapter VI, will include the lower level of complexity of (1) the level of (organic maintenance) repair, or (2) the level just below the level of design ownership; this will incorporate requirements for intermediate and depot level repair under government cognizance.

2. Initially implement CM controls to the level of repair until field reliability objectives have been met; then extend the level of control as necessary.

3. Defer invocation of CM controls on items under a long-term warranty until the warranty period is about to end and the government is about to take over maintenance from the warrantor.

4. Defer full spares stocking until after the product baseline is established at the level of standardization.

5. Determine the nondetrimental condition of Class II changes on the basis of both performance and total life cost.

Additional CM policy for tactical system software and ADP hardware and software subject to joint CM is covered in MIL-STD-2167A or MIL-STD-498. Project managers of systems incorporating software should be aware of the provisions of this standard.

Other references include:

MIL-STD-973

MIL-STD-1521B

QUALITY MANAGEMENT

Quality is defined as the composite of all the attributes or characteristics, including performance of an item or product (source: DoD Directive 4155.11). There are two major facets of quality management—quality assurance (QA) and quality control (QC). QA is a planned and systematic pattern of all actions necessary to provide adequate confidence that an item or product conforms to established technical requirements; QC is the collection of actions taken for the purpose of preventing production of defective materials or items (source: MIL-STD-109). Once technical requirements have been derived from operational requirements, QA becomes an unavoidable management function; however, the imposition of formal QA procedures will depend upon individual project requirements.

Categorize each technical requirement as either an attribute (it exists or it does not exist) or a characteristic (it exists in various degrees); further identify whether the requirement is critical (unacceptability is likely to, result in a hazardous or unsafe condition for individuals using, maintaining, or depending on the product or is likely to prevent performance of the tactical mission), major (unacceptability is likely to result in failure of the product for its intended purpose), or minor (unacceptability is unlikely to affect the usability of the product for its intended purpose). Minimum acceptable standards should be established for each characteristic as well as desired levels of performance. The Section 4 provisions of the system specification should fully detail the methods of inspection and test which will be implemented to assure the adequacy of the final product.

To simplify the quality management problem, decide what attributes or characteristics are products of pure design effort or subject to the vagaries of the production process. Of those which are affected by production factors, separate out the critical or highly variable attributes and characteristics. Design features and many minor requirements can be satisfactorily inspected on a one-time basis. Critical and highly variable major features should be subjected to 100% inspection; other production-affected features can be subjected to sampling inspections (see MIL-STD-105 (attributes) and MIL-STD-414 (variables)). It should be remembered that there are many components to quality—performance, reliability, and workmanship, for instance. An item can have high quality overall and still be deficient in any one area (like reliability). It is important to structure the accept/reject criteria in a manner such that an unacceptable determination in any critical or major feature results in a rejection. Do not inspect or test for features which are not requirements; inspection for cosmetic purposes only drives up costs.

The following references may be useful in imposing QA/QC requirements on contractors:

	Topic
MIL–Q–9858A	Quality Program Requirements
MIL–I–45208A	Inspection System Requirements
MIL–STD–45662A	Calibration System Requirements
MIL–STD–2168	Software QA Program Requirements
MIL–STD–252B	Workmanship Standards
MIL–STD–1535A	Supplier QA Program Requirements

Four rules of analyzing quality cost data:

1. If number of dollars spent on corrective action, quantity audits, etc., shows decrease in scrap-rework and other deviation costs > cost of quality activities: continue spending otherwise don't.

2. Publicize the results of quality cost data throughout the project.

3. Be as careful of low expenditures for quality as high.

4. Spend money where it counts. In general, if product is 80% of budget, spend most quality money there.

Checklist for Quality Cost Accounts

Quality Creation

1. Vendor control
2. Planning and implementing test; inspect and process control procedure
3. Design review
4. Training and education
5. Review of material handling and packaging

Quality Maintenance

1. Calibration and repair of TE
2. Field testing of products
3. Procedures audit
4. Failure analysis
5. Data maintenance
6. Audit of corrective action

Internal Quality

1. Scrap
2. Rework
3. 100% sorting of suspected material
4. Material review board activities
5. Production facilities downtime due to re-setups
6. Extra vendor advice

External Quality

1. Field complaints
2. Customer allowance for rejections
3. Product service and repairs

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APPENDIX A: TELCAM ENVIRONMENTAL STUDY

Under the present system of hardware acquisition, all equipments which are designated for Navy shipboard use are supposed to be subjected to the analyses and testing rigors specified in MIL-STD-2036. A review of the requirements of MIL-STD-2036 in relation to measured shipboard data indicates that savings in time and money can be gained by reducing environmental analyses and requirements testing. Before proceeding further, it should be stated and emphasized that this study does not apply to critical equipment (critical equipments being those without which the ship cannot operate or perform its mission). Any reduction of environmental requirements should be based upon the elimination or modification of those tests and analysis requirements pertaining to shipboard conditions deemed to be abnormal; that is, conditions occurring very rarely or never having occurred to date to an operational Navy ship. Examples of such conditions would be a nearby underwater blast, nuclear air blast, and simultaneous high temperature and high relative humidity. The sections of MIL-STD-2036 describing environmental tests and analyses were reviewed to determine (1) which would be classed as abnormal occurrences not applicable to noncritical equipments and which could be modified to more closely represent the expected or known shipboard conditions, and (2) which appear adequate in their present form. Those which appear adequate and those which could be modified would necessarily be applicable to all equipments to assure satisfactory operation aboard ship. The environmental tests and analyses describing shipboard conditions occurring very rarely or never having occurred to date to an operational Navy ship are nuclear air blast analysis and shock tests so designed as to simulate shock created by a nearby underwater blast. This shock test is specified in MIL-S-901. MIL-STD-2036 provides for MIL-S-901 Grade B (safety) testing for noncritical equipments.

One type of shock occurring aboard ships that is not addressed in MIL-STD-2036 is shock created by the muzzle blast from a ship's own guns impinging on external bulkheads. The severity of this type shock is dependent upon the distance from the gun muzzle to a bulkhead and the distance from this bulkhead at which equipment is mounted. In the past, attempts have been made to analytically qualify equipment to this type shock with little or no success. At times individual equipment specifications will require installation aboard ships in a specified area with equipment performance being monitored during gunfire exercises.

Certain tests and analyses describe conditions which can be expected to occur frequently aboard Navy ships and should be applied to all equipments. These are wind speed analysis and icing, noise, and enclosure tests. Airborne and structureborne noise and enclosure tests should be applied to all sheltered equipments. These tests and analyses are appropriate in their present form and should be applied to all equipments as specified.

MIL-STD-2036 requires all equipments to be inclination tested. This test should be required only for equipments deemed to be position sensitive (equipments whose proper operation is dependent upon fluid levels, position-sensitive switches, etc.), since this test is a slow rocking motion to which most equipments are insensitive.

Vibration, temperature, and relative humidity are conditions which exist aboard ship. MIL-STD-2036 requires all equipments to be vibration tested as specified in MIL-STD-167. Temperature and relative humidity tests are specified in MIL-STD-2036. Since these conditions constantly exist, it is mandatory that all equipments, both critical and noncritical, be capable of satisfactory operation over an extended period of time while being exposed to them. Therefore, vibrational envelopes were established for various classes of Navy ships, and worldwide extreme temperature and relative humidity conditions were identified.

As a first step toward establishing environmental vibration envelopes for various classes of Navy ships, literature on hand was reviewed. This encompassed 48 annual vibration survey reports from the Boston, Long Beach, Norfolk, Pearl Harbor, Philadelphia, Portsmouth, Puget Sound, San Francisco Bay, and Charleston Naval Shipyards which covered the period from 1961 to 1973. From these reports vibration data from more than 160 ships of the DD, DDG, DLG, DL, DE, DEC, CVS, CVA, CVAN, LPH, LST, MSO, PG, and SSN types were selected. NOSC reports 1577 and 1701 which are accumulations of vibration data measured by NELC personnel aboard various Navy ships, and Naval Ship Research and Development Center (NSRDC) Reports 2338 and 2338A were also reviewed. Only vibration data for spaces containing or in close proximity to electronic equipment were selected, and these electronic equipment spaces were in the ship's superstructure. Since literature surveys show the most severe vibration conditions occur in a ship's stern, the vibration data selected do not represent the worst-case conditions occurring aboard ship. This survey also indicates that the shock and vibration environment existing on a ship's mast is minimal, and these data were not used.

The vibration data were sorted by ship type and converted to displacement (inches single amplitude) vs frequency (Hz). A plot of these data was made for each class of ship (fig. A-1 through A-8) by plotting data points on multicoordinate vibration graph paper and connecting peak values with straight lines. The region under the plotted curve was then considered to be the vibration envelope; that is, any point within the curve may be a vibration condition expected aboard that type of ship; Referring to figures A-1 through A-8, the frequencies range from 1 to 45 Hz with accelerations seldom exceeding 0.2 g and displacements seldom exceeding 0.030 inch single amplitude.

See figures A-9 and A-10 for TELCAM vibration test amplitudes, figure A-11 for a MIL-STD-167 vibration test amplitude. The TELCAM vibration test amplitudes are listed in table A-1.

NOTE: The TELCAM studies were carried out under MIL-E-16400. MIL-STD-2036 provides for tailoring environmental requirements. The data in this appendix can be used in that tailoring process; however, tests of actual installation sites are encouraged to further reduce risks of environmental mis-specification.

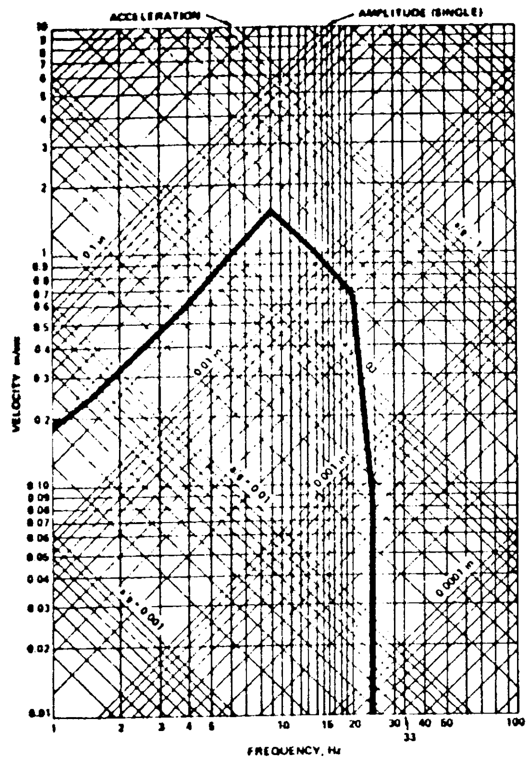

Figure A-1. CVA–CVAN TELCAM vibration limits.

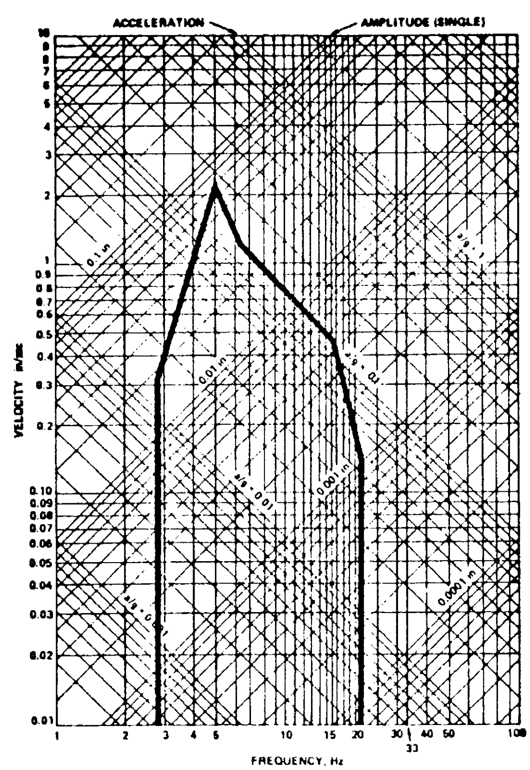

Figure A-2. DDG-DD TELCAM vibration limits.

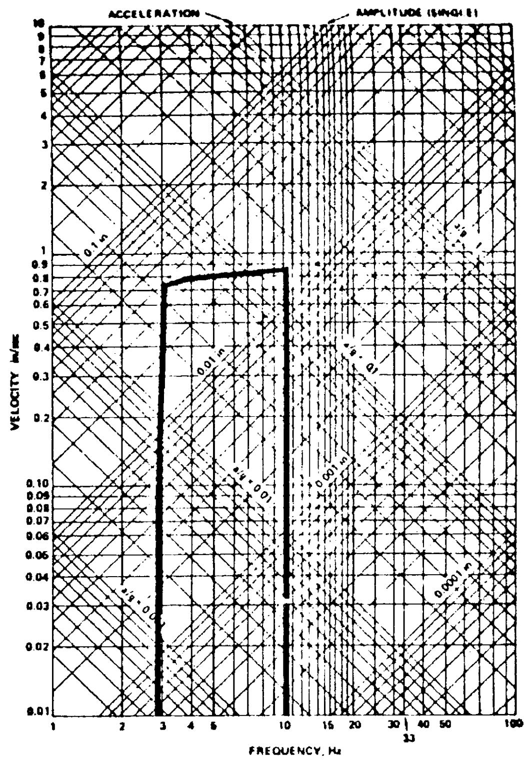

Figure A-3. DEG-DE TELCAM vibration limits.

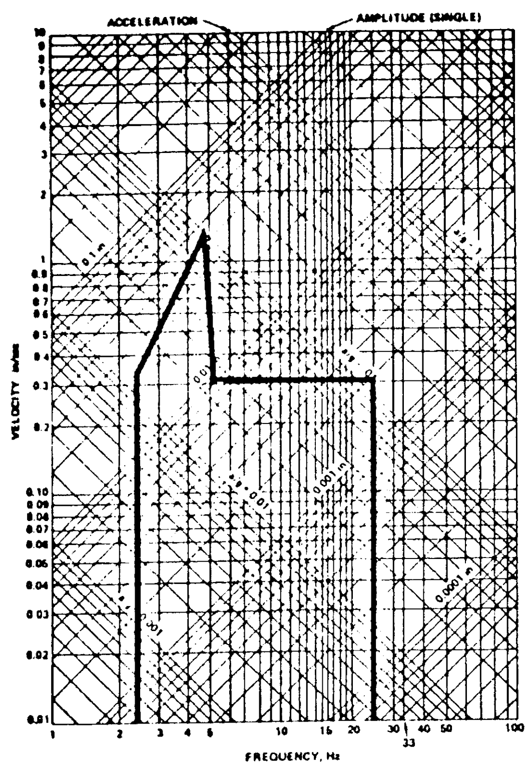

Figure A-4. DLG-DLGN TELCAM vibration limits.

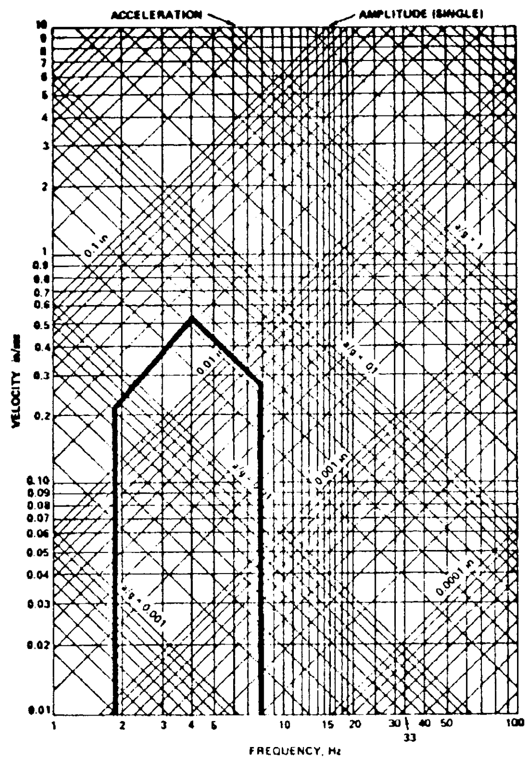

Figure A-5. LPH TELCAM vibration limits.

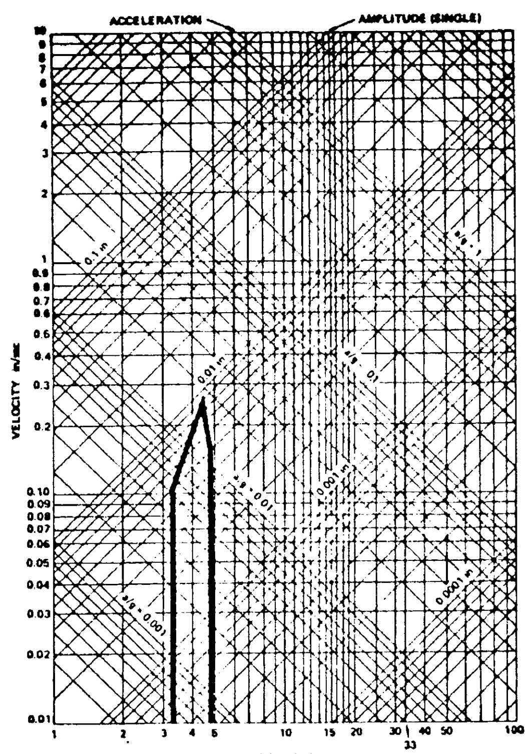

Figure A-6. LST TELCAM vibration limits.

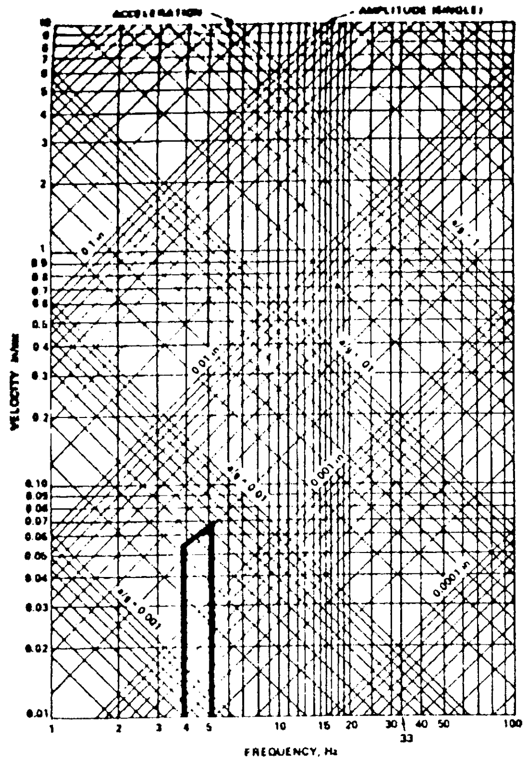

Figure A-7. MSO TELCAM vibration limits.

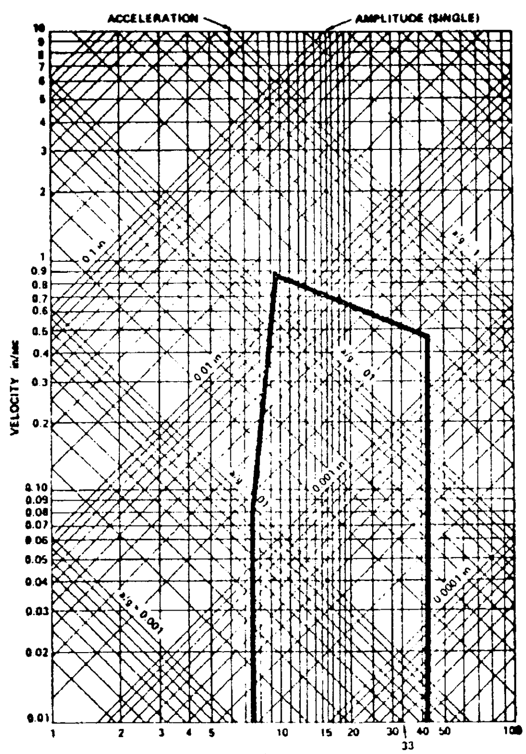

Figure A-8. PG TELCAM vibration limits.

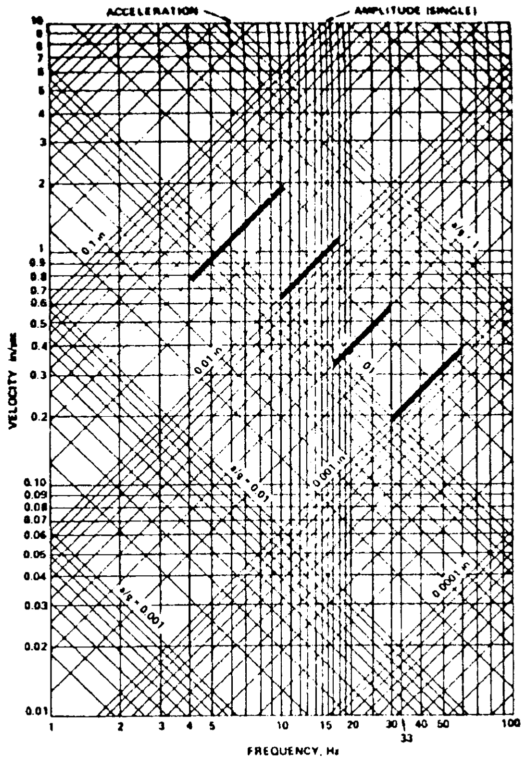

Figure A-9. TELCAM constant displacement vibration tests.

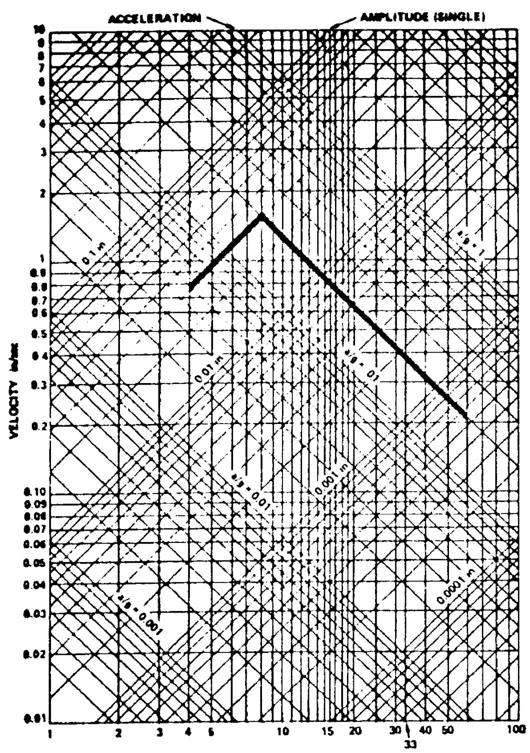

Figure A-10. TELCAM constant acceleration/constant displacement crossover vibration test.

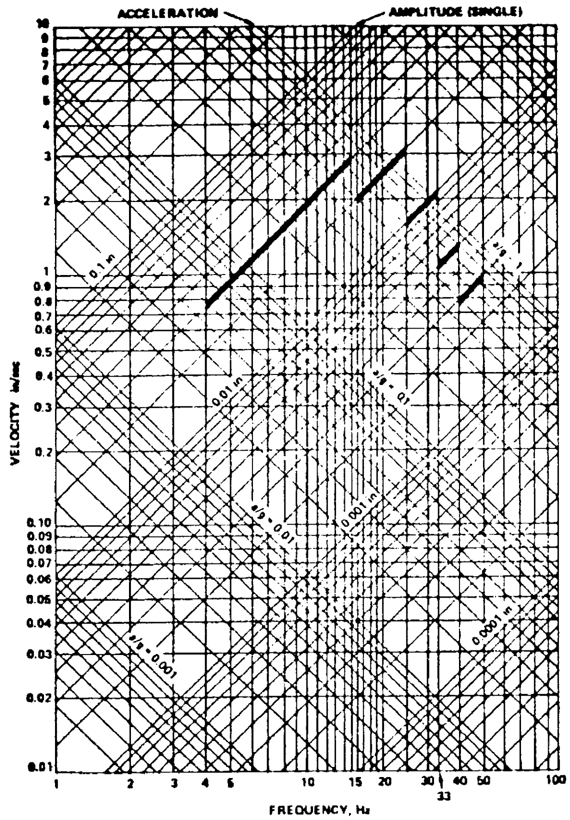

Figure A-11. MIL-STD-167 vibration tests.

Table A-1. Input amplitudes.

Use A or B, whichever is better suited to the vibration tst machine in use.

A (Constant Displacement) (see figure A-9)

Frequency Range (Hz)	Single Amplitude (inch)	g = A/G
4–10	.03 ±.003	.05–.3
10–17	.01 ±.001	.10–.3
17–30	.003± .0003	.09–.18
30–60	.001 ±.0001	.09–.38

B (Constant Acceleration) (see figure A-10)

Frequency Range (Hz)	Single Amplitude (inch)	g = A/G
4–8	.03.003	.05–.2
8–60	.001±.0001	.2±.02

The following vibration tests were developed from the vibration envelope information:

SCOPE. All communications equipment intended for shipboard use under the TELCAM concept shall be proved acceptable under the vibration tests described herein. Magnitudes of input motions and the associated frequencies are chosen to represent usual conditions existing aboard ship and do not cover the vibration environment that may exist when a ship has sustained battle damage and must continue to operate.

Users of this test are therefore encouraged to be critical in judging acceptability of the equipment under test.

BASIS OF ACCEPTABILITY. Acceptability shall be judged as under MIL-STD-167B (SHIPS), Mechanical Vibrations of Shipboard Equipment:

> Basis of acceptability. Acceptability will be contingent upon the ability of the equipment to perform its function during and after the tests specified in 5.1.3. Minor damage or distortion will be permitted during test providing such damage or distortion does not in any way impair the ability of the equipment to perform its principal functions. Because of the numerous types of equipment covered by this standard, a definite demarcation between major and minor failures cannot be specified. Therefore, such decisions must necessarily be left to the judgment of the test engineer. In general, a major failure is one which would cause malfunction of the item of equipment for a long period. Non-repetitive failures of such parts as vacuum tubes, condensers and wiring, which can be easily replaced or repaired, are generally considered minor failures. As such, the repair could be made and the test continued with no penalty to the remainder of the equipment. Sometimes the critical use of the equipment will determine the category of failure; that is, a failure of a part in a lighting circuit may be considered minor. The same failure in a reactor control circuit may be major. Thus the test engineer, or command or agency concerned, shall be responsible for specifying a major or minor failure.

In addition, large amplifications of motion created by resonant response of the equipment under test are to be considered unacceptable unless, in the opinion of the vibration test engineer, such responses do not predicate early equipment failure.

INTENT OF TESTS. Vibration tests specified herein are intended to locate resonances of the equipment under test, and to impose a 2-hour endurance test at those frequencies and amplitudes.

TESTING MACHINES. Any vibration testing machine capable of providing sinusoidal motion, of the frequency and amplitudes specified, to the points of attachment of the equipment under test may be used. Means shall be provided for controlling the direction of vibration of the testing machine and for adjusting and measuring its frequencies and amplitude of vibration to keep them within prescribed limits. If the lower frequency limit of 4 Hz specified cannot be reached, the available machine may be used upon approval of the command or agency concerned provided the natural frequencies of the equipment in translational and rocking modes of vibration do not lie below the lowest frequency of the available testing machine. This may sometimes be determined by properly controlled transient excitation, such as bumping the equipment to see whether low-frequency resonances exist. In no case shall a vibration testing machine be used which has a minimum frequency greater than 10 Hz.

METHODS OF ATTACHMENT. For all vibration tests, the equipment shall be secured to the vibration machine in the same manner in which it will be secured on shipboard. If alternative mountings of the equipment are possible and contemplated, a complete TELCAM test shall be conducted in each alternative mounting configuration.

FIXTURES. When fixtures must be used in attaching equipment to the vibration machine (for instance, when the equipment requires bulkhead or overhead support), the fixtures used shall be sufficiently rigid to ensure that motion at the points of attachment of the equipment is essentially the same as motion of the main machine platform.

PORTABLE EQUIPMENT. Equipment which is not intended for permanent attachment on shipboard shall be attached to the vibration testing machine in a manner representative of that in which it will be stored on board ship. In many cases, this will require that the equipment be restrained on the vibration testing machine by means of suitable small woven straps or line.

ORIENTATION FOR VIBRATION TEST. Equipment shall be installed on vibration testing machines in such manner that the direction of vibration will be in turn along each of the three rectilinear orientation axes of the equipment as installed on shipboard — vertical, athwartship, and fore and aft. On a horizontal vibration testing machine, the equipment may be turned 90 degrees in the horizontal plane in order to vibrate it in each of the two horizontal orientations. At no time shall the equipment be installed in any other way than its normal position. Because no particular orientation of portable equipment can be considered normal, orientation of portable equipment for vibration testing shall be left to the discretion of test engineer.

RESILIENT MOUNTINGS. Equipment which is to be installed on resilient mounts on board ship shall be installed on those mounts for vibration testing. Resilient mountings integral to the equipment (intended to protect sensitive devices within the equipment) shall be left in place.

VIBRATION TESTS. Each of the tests specified herein shall be conducted separately in each of three principal axes of the equipment under test. Each type of test (exploratory vibration, variable frequency, and endurance, below) shall be completed in all three axes before proceeding to the next type of vibration test. During the tests, the equipment shall be secured to the test machine and oriented as specified in METHODS OF ATTACHMENT and FIXTURES, above. The equipment shall be energized and performing its normal functions. Appropriate test equipment shall be applied to the equipment under test to reveal vibration-caused electrical malfunctions which are not manifested in mechanical responses. Unless otherwise directed, the test shall be discontinued if major failure occurs, and the entire vibration test series repeated following repair or correction of deficiencies. An entirely new test specimen may be substituted for the retest, but the substitution must be noted in the test report furnished. (See TEST REPORT, below.)

EXPLORATORY VIBRATION TEST. To determine the presence of possibly harmful resonances in the equipment under test, vibration in the frequency range from 4 Hz to the lowest attainable frequency not to exceed 10 Hz) to 60 Hz shall be applied. Amplitude of input vibration shall be only great enough to determine resonant responses of the equipment under test and to obtain an approximation of the amplification factor. In no case shall input amplitudes exceed those specified for the VARIABLE FREQUENCY TEST, below. The frequency range is to be swept from low to high frequency at a rate not greater than 4 Hz per minute nor less than 1 Hz per minute. Resonant frequencies and approximate amplification factors shall be noted. If believed necessary by the test engineer, resonances noted during the scan shall be reestablished, peaked, and held briefly to permit adequate documentation. Resonances, how they were manifest, their frequencies ($\pm$0.5 Hz), and their approximate amplification factors shall be included in the test report. (See TEST REPORT, below.)

VARIABLE FREQUENCY TEST. The equipment under test shall be subjected to vibration between 4 Hz (or the lowest attainable frequency not to exceed 10 Hz) and 60 Hz with input amplitudes as shown in table A-1. Vibration input shall be at discrete integral frequencies ($\pm$0.5 Hz), and each frequency shall be maintained for a period of 5 minutes. Peak responses of the equipment under test are likely to occur at nonintegral frequencies. Mechanical nonlinearity of the equipment under test will cause a shift in the frequency of maximum response as documented in EXPLORATORY VIBRATION TEST, above. Therefore, as frequency changes are made, the test engineer shall carefully observe the equipment under test and peak any response, even though it may occur at a nonintegral frequency, hold the response long enough to obtain documentation, and then move on to the next integral frequency.

ENDURANCE TEST. The equipment under test shall be vibrated for a period of 2 hours at each of the resonances noted in VARIABLE FREQUENCY TEST, with input amplitudes as specified in table A-1. In the event no resonances have been noted, the equipment shall be vibrated for 2 hours at 60 Hz.

TEST REPORT. The test report to be furnished the command or agency concerned by the testing laboratory shall include detailed descriptions of any damage or malfunctioning incurred and at what stage in the tests it occurred. When possible, photographs of physical damage shall be included. Recommendations are desired as to what corrective measure, if any, should be taken. It shall also include other pertinent information, such as the overall dimensions of the equipment, its weight, approximate location of the center of gravity, a sketch or photograph of the methods used in mounting it on the test machines, a listing of resonances, frequencies at which resonances occurred, and their approximate amplification factors.

A temperature/relative humidity profile was developed for TELCAM much like the TELCAM vibration profile. Data that had previously been collected from instrumented shipboard surveys and weather reports had been plotted as temperature vs relative humidity and were compared with MIL-E-16400 requirements as shown in figure A-12. The bounds of the natural occurrences plotted became the TELCAM limits. Referring to figure A-13, an easily applied test can be described by a temperature/relative humidity trapezoid with corner points at 68 degrees F with 95-percent relative humidity, 95 degrees F with 95-percent relative humidity, 122 degrees F with 65-percent relative humidity, and 68 degrees F with 65-percent relative humidity. This test is conducted by making five complete cycles around the trapezoid starting and finishing at 95 degrees F and 95-percent relative humidity. Each test condition is maintained for 5 hours with 1 hour allowed for the transition between points, thereby making each cycle 24 hours long. This test differs from MIL-E-16400 requirements in that it does not require the simultaneous high-temperature/high-relative humidity condition of 122 degrees F with 95-percent relative humidity. This condition does not exist naturally. The lower temperatures and transitions simulate conditions existing aboard ship when air conditioning equipment fails and a communications compartment must be opened to ambient temperature and relative humidity levels.

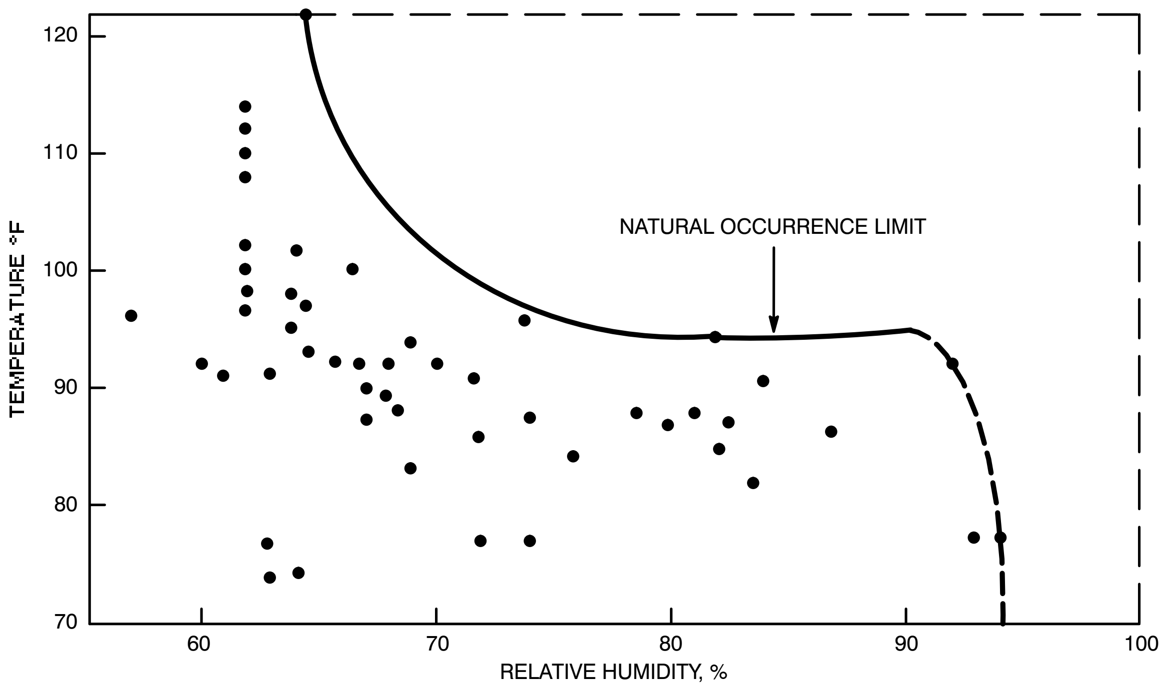

Figure A-12. Actual MIL–E–16400 temperature/relative humidity test.

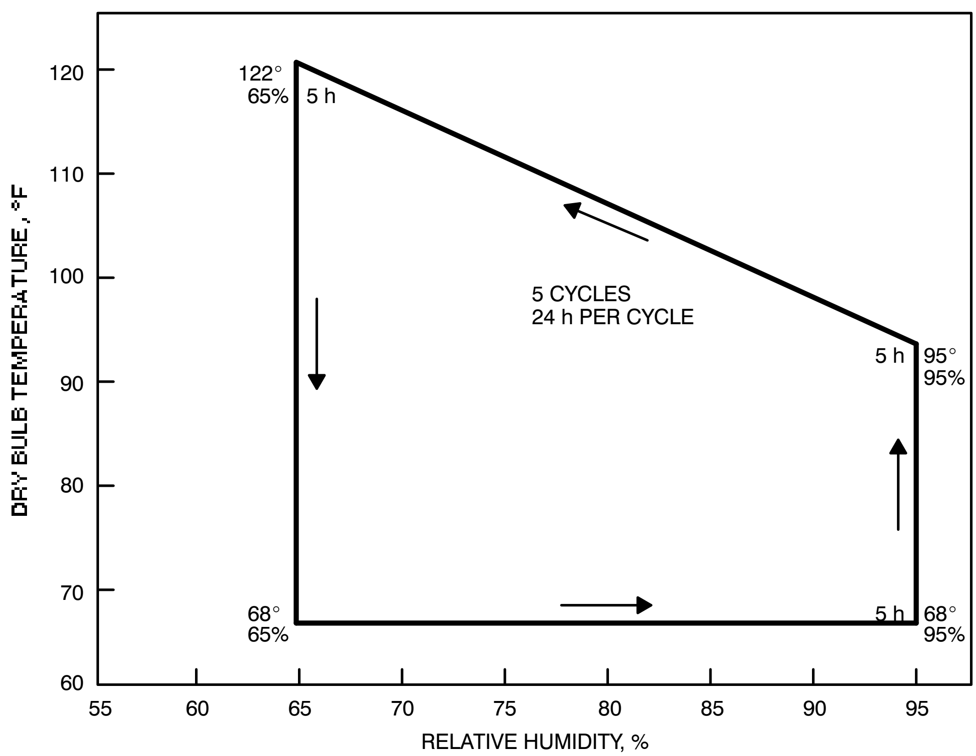

Figure A-13. TELCAM temperature/relative humidity test (revised).

Both the TELCAM-developed vibration and temperature/relative humidity tests are not as severe as their parent MIL tests. This condition resulted because the TELCAM tests were not developed to test equipment for survivability under abnormal shipboard environments, but to provide confidence the equipment will endure the usual environments. All shipboard mounted equipments are constantly exposed to the vibration and temperature/relative humidity environments during at-sea operation; therefore, testing to and determining equipment survivability under these conditions should be considered as minimum requirements. Equipment should be tested to the inclination, electrical transient, noise, and enclosure tests, as applicable, specified in MIL-E-16400 to increase the confidence level of shipboard survivability.

To date, four commercial equipments have been chosen for TELCAM vibration and/or temperature/relative humidity testing. These were a floppy disk memory unit, a digital plotter, a cassette tape recorder, and a single sideband radiotelephone. The radiotelephone has not been completely tested due to initial problems requiring correction by the manufacturer. All the equipments selected for testing under the TELCAM program are assumed to be readily available so that redundant equipment can be on hand. All tests that will be applied to these equipments represent noncombatant situations.

The floppy disk memory unit was selected for testing because it is an ideal candidate for use with shipboard minicomputers. To monitor test performance, alphabetical characters from A through P were stored on the inside track of the disk. The characters were transferred from the inside track to the outside track, printed out via teletype, and then compared with the inside track. This was done continuously during vibration testing and at the end of each temperature/relative humidity 24-hour cycle. When a discrepancy occurred, the teletype printed out DISK NOT READY.

The floppy disk memory unit was first subjected to the TELCAM vibration test. The constant displacement method was used. The only vibration-related discrepancy noted during the test was a resonance in the circuit board occurring at 51 Hz. This condition was eliminated by attaching the circuit board corners to the chassis. Two DISK NOT READY messages were printed out by the teletype during the test, but they were not repeatable, and no vibration-related reason could be found.

The TELCAM temperature/relative humidity test was conducted. The test was started at 95 degrees F and 65-percent relative humidity. As stated, the alphabetical characters were transferred from the inside track to the outside track, printed out by the teletype, and compared with the inside track at the end of each 24-hour cycle. The unit was turned off during the 24-hour cycle. When the unit was turned on, the disk required approximately 30 seconds to warm up before it would respond to the teletype control. Moisture collecting inside the unit that had to be exhausted by the unit's internal cooling fan before proper operation could be obtained was considered the cause for this 30-second delay.

To increase the confidence level that the floppy disk memory unit would survive aboard ship, the supply line voltage and frequency tests described in MIL-E-16400F section 4.5.4 were performed. No abnormal effects were apparent during the steady-state and transient tests. The teletype did print out the DISK NOT READY message during power dropout tests. This condition was deemed insignificant as it occurred only when the power dropped out exactly as its waveform crossed the neutral axis, and this would rarely occur naturally. This condition had no detrimental effect on the unit, which operated properly when the power returned to normal.

These tests performed on the floppy disk memory unit indicate that it should deliver satisfactory performance if installed aboard Navy ships.

The digital plotter was submitted for vibration testing by the Naval Undersea Center (NUC). The plan was to perform an exploratory vibration test (per MIL-STD-167) only in each of the three mutually perpendicular axes to identify resonant frequencies.

During actual testing, input levels had to be reduced when resonances were reached to avoid damaging the plotter. These reduced levels were compared with and were equal to or slightly larger than the TELCAM vibration levels. Throughout this exploratory vibration test the plotter operated properly, and at no time did the trace become discontinuous or rippled. The tracing capability of the plotter was of prime importance during the test. The plotter can be considered acceptable insofar as vibration is concerned, but before any conclusions can be reached as to the overall suitability of this plotter for shipboard use, further testing and analysis will he required.

The cassette tape recorder, which is being used in a shore-based Navy receiver, was subjected to the TELCAM temperature/relative humidity and vibration tests. Performance was measured during testing by making voice recordings and by operating playback, fast forward, and fast reverse controls.

The TELCAM temperature/relative humidity test was run for four complete cycles (96 continuous hours). Recorder performance was monitored just as the 95 degree F and 65-percent relative humidity condition was reached. The recorder was turned off during the rest of the cycle. The only abnormality noted was slight sluggishness in the reverse, or rewind, mode of operation. This sluggishness was not deemed detrimental to recorder performance, and it disappeared when the recorder was returned to room temperature.

The constant displacement with constant level crossover TELCAM vibration test (see fig. A-10) was used to test the recorder in the vertical axis. During the complete exploratory, variable frequency, and endurance tests no resonances, performance degradation, or other discrepancies were noted.

Since the recorder performed satisfactorily during TELCAM vibration testing in the vertical axis, the more severe requirements of MIL-STD-167 were applied in the remaining vibration test. Temperature/relative humidity and vibration test results indicate this recorder should operate satisfactorily aboard ship, even under abnormal vibration conditions.

The literature survey of shipboard environmental conditions is continuing. Other equipments are being investigated as possible candidates to be exposed to TELCAM-developed tests, and, where no environmental data exist, the possibility of performing at-sea measurements is being considered.

New ship classes such as the Newport class of LST, LCC, 1000 series DE, etc., should be surveyed and underway measurements made to document their environments. (See Jane's Fighting Ships.) Equipment packaging and transportation environments have not been investigated. Many instances have occurred in which equipment has been damaged during transportation due to inadequate packaging and rough handling. Time and effort should be expended to eliminate some of the inadequacies in these areas.

APPENDIX B: RECOMMENDATIONS OF GOVERNMENT STUDIES ON REDUCING COSTS OF ELECTRONIC SYSTEMS AND EQUIPMENT

DISCUSSION

A number of government studies have sought answers to the problem of reducing the costs of acquiring and using military items.[1-6] It was originally intended here to present a matrix of recommendations vs each study to provide an overview of ways and means for cost reduction. However, the most recent study to date with a published report has incorporated the results of the other studies with those of its own, and thus represents current and official thinking across the board on cutting electronic system/equipment costs. It is the "Electronics-X" study. In addition, Electronics-X is especially pertinent and significant to the TELCAM project since it addresses itself specifically to electronic systems and equipment, whereas the other studies either are of a very general, statute-oriented nature [e.g., the "Report of the Commission on Government Procurement") or focus on some one aspect of reducing costs (e.g., the design-to-cost emphasis of the "Report of the Defense Science Board Task Force on Reducing Costs of Defense System Acquisitions"). Therefore, rather than a matrix, a tabulation of Electronics-X recommendations is presented. In the few instances where other study recommendations pertinent to TELCAM are not included among Electronics-X recommendations, they are additionally listed and specially noted. This tabulation may be considered all-inclusive with respect to current government study recommendations for reducing the costs of acquiring and using electronic systems and equipment.

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[1]*Report R-195, Institute for Defense Analyses, Science and Technology Division, Electronics-X: A Study of Military Electronics with Particular Reference to Cost and Reliability,* January 1974, prepared for Defense Advanced Research Projects Agency, DDR&E

[2]*Report of the Commission on Government Procurement*, December 1972, to the Congress of the United States

[3]*Report of the Defense Science Board Task Force on Weapon-System Simplification*, Summer of 1970, DDR&E

[4]*Report of the Defense Science Board Task Force on Avionics*, February 1973, DDR&E

[5]*Report of the Defense Science Board Task Force on Reducing Costs of Defense System Acquisitions*, March 15, 1973, DDR&E

[6]*Cost Growth in Major Weapons Systems*, March 26, 1973, report by the Comptroller General of the United States to the Committee on Armed Services, House of Representatives

RECOMMENDATIONS

COST-DATA COLLECTION AND REPORTING SYSTEMS	
1.	***A systematic effort should be undertaken to develop a step-wise implementation of a complete and uniform cost accounting system throughout DoD, with emphasis on valid input data. As a first step, a marginal cost system using sampling techniques for support-cost inputs should be implemented. The system must then evolve to cover full costs of both acquisition and support.
2.	** A central organization within OSD should be designated to organize this cost information system and to coordinate the efforts of responsible service elements.
3.	To test and exercise the system, each service major procurement command should designate certain electronic systems for review of cost reporting requirements. Appropriate steps should be taken to ensure consistency among the report outputs, complete record retrieval, and periodic validation of the reported costs. These records should be centrally located and should be made available to the cost analysis community.
RELIABILITY DATA COLLECTION AND REPORTING SYSTEMS	
4.	*** In each major producer command (AMC, Navy SYSCOMs, AFSC, AFLC), establish (or broaden) a system for competent technical reporting of reliability, availability, and maintainability (RAM) and marginal cost feed-back information from the field on selected systems and equipments, using sampling methods.
5.	** Organize a RAM Data Systems Task Force, representing the several services and chaired by OSD, to study and compare the relative cost-effectiveness of a routine maintenance data collection system (such as 3-M or AFM 66-1) with a sampled-data collection system (such as TAMMS-SDC).
6.	Establish a new RAM Information Exchange Program at the electronic equipment level in a form patterned after the Government-Industry Data Exchange Program (GIDEP).
REQUIREMENTS AND ACQUISITION DECISIONS	
*7.	*** In exploring and establishing a system requirement, give performance, physical characteristics, cost, quantity, and schedule equal status from the beginning, and perform tradeoffs among these early in the game.
8.	*** In major system developments, separate vehicle and electronic subsys-tem initial operational capabilities, where possible, and develop the electronics independently. Consolidate like subsystem or equipment requirements wherever feasible.
9.	*** Increase visibility to top-level management of potentially cost-driving developments of electronic subsystems associated with major systems, by instituting suitable review prior to each DSARC review. As appropriate, provide for a similar visibility to managers of developments of less-than-major electronic subsystems and equipments by refocusing reviews to make them analogous to DSARC reviews, but at lower management levels.
*10.	*** Give increased consideration to product improvement programs as a means of fulfilling new requirements, as opposed to instituting wholly new development programs.

* Most directly applicable to project manager/engineer day-to-day undertakings.
** High priority
*** Highest priority

*11.	*** Select technology and performance objectives for new developments conservatively (i.e., low on the cost-performance curve), except in cases where military necessity imposes an overriding need for risk-taking to achieve extremes of performance. Allow for uncertainty in establishing the corresponding system requirements.
*12.	*** Iterate requirements and acquisition decisions if performance, characteristics, cost, quantity, or schedule departs significantly from initial plans during development. Establish criteria to trigger such iteration.
13.	(From ref. 2) For major systems, start new-system acquisition programs with agency-head statements of needs and goals that have been reconciled with overall agency capabilities and resources. State program needs and goals independent of any system product. Assign responsibility for responding to statements of needs and goals to a single agency component, when the mission need is clearly the responsibility of that one component, or to two or more agency components when competition is formally recognized, with each offering alternative system solutions when the mission responsibilities overlap.
14.	(From ref. 2) Support the general fields of knowledge that are related to an agency's assigned responsibilities by funding private-sector sources and government in-house technical centers to do basic and applied research, proof-of-concept work, and exploratory subsystem development. Restrict subsystem development to less than fully designed hardware until identified as part of a system candidate to meet a specific operational need.
15.	(From ref. 2) For major systems, create alternative system candidates by (a) soliciting industry proposals for new systems, with each contractor free to propose system technical approach, subsystems, and main design features on the basis of a statement of government mission, time, cost, and operational requirements; and (b) sponsoring the most promising system candidates as selected by agency component heads, using a team of experts from inside and outside the agency component development organization as a review panel.
DESIGN TO COST	
*16.	*** Choose easily defined design-to-cost (DTC) targets such as unit produc-tion or flyaway costs (rather than, for example, the presently still ill-defined life-cycle costs; but see following subparagraph to this recommendation). Establish such targets early, permitting successive revisions during development, contractual commitment to a unit cost for low-rate initial production at the start of such production, and another contractual commitment for unit cost at the start of full-scale production for systems to be procured in quantity. Flexibility to revise cost targets should decrease, and these should be based increasingly on firm experience as the development-to-production cycle progresses.
	If the equipment is to be maintained by the supplier under long-term warranty, the design-to-cost target can be established as the sum of the production cost and total warranty cost; this sum may be considered a surrogate for life-cycle cost. But if military maintenance is contemplated, establishing life-cycle cost as a design-to-cost target is not now appropriate because of the inadequacy of current knowledge of the cost to the government of military maintenance, and of the dependence of these costs on equipment parameters.

* Most directly applicable to project manager/engineer day-to-day undertakings.
** High priority
*** Highest priority

17.	*** Establish explicit limits of deviation from "desired" performance/characteristics/cost/schedule/quantity requirements, and authorize program managers to trade off freely among these separate requirement parameters within the established limits. Establish "desired" parameters and permissible deviations such that tradeoffs are in fact possible and not subject to hidden constraints due to technical feasibility, absolute force requirements, or available budgets.
18.	*** To the extent feasible, maintain design and price competition throughout the acquisition process, especially for components and subsystems.
19.	*** In the contractor-selection process, ensure that performance and cost are considered together rather the evaluated separately.
*20.	** This study identified only one design-to-cost acquisition, namely, the Navy electronic warfare suite, that uses the approach of specifying equipment needs and requirements functionally, leaving it to the competing contractors to propose optimal development and production strategies to maximize payoff to both the government and the contractors, and including maintenance strategies among the variables. More experience with this approach should be acquired.
21.	Increase the number of design-to-cost acquisitions of electronic subsystems designated as "experimental" for observation and extraction of "lessons learned." In further experimental design-to-cost acquisitions, seek wider variation of the management variables relevant to design to cost (for example, tradeoffs among requirements, program manager's freedom to trade off, types of contracts). The services should publish "lessons learned" periodically to maximize the pool of explicitly analyzed experience available to all.
22.	** Review the contracting procedures associated with design-to-cost con-tracts, modify those that inhibit requisite design-to-cost flexibility, and incorporate the modifications in the FAR, if necessary.
DESIGN FOR IMPROVED RELIABILITY	
*23.	*** Limit the complexity of new subsystem or equipment designs (as mea-sured by criteria such as unit production cost or parts count) to a level consistent with the reliability required by a mission analysis. Require evidence of compliance as a preliminary DSARC review for electronic subsystems of major systems, and as a preliminary to sub-DSARC review for independently developed electronic subsystems.
*24.	*** Require contractually the in-plant use of a formal management methodology, such as methods using Duane-curve monitoring, to ensure reliability growth in electronic equipment and systems.
*25.	*** Use long-term contractor maintenance warranties to motivate the contractor to design for minimum life-cycle cost. (See later recommendations on warranties for further details.)
*26.	*** Specify the reliability of electronic equipments or systems to be consistent with predictions based on their anticipated complexity (or unit production cost, as a surrogate for complexity).
27.	*** Undertake redesign of selected equipments with the specific objective of improving reliability while holding performance constant.

* Most directly applicable to project manager/engineer day-to-day undertakings.
** High priority
*** Highest priority

DESIGN TO FACILITATE COMPETITION	
*28.	*** Lay the groundwork for future design and price competition through production and for ready replacement of old designs by new-generation equipment by ensuring the interchangeability of similar equipments intended for similar applications. Accomplish this by including mechanical, electrical, and environmental interface standards for each unit as part of military electronic equipment specifications.
	Require design interchangeability when production competition or design upgrading is foreseen as desirable or likely. Equipment classes that are judged ripe for initial application of interface standardization are airborne communication, navigation, identification, and weather radar; vehicular communication; and modular electronics packages for tactical missiles.
*29.	*** Modify approval processes for engineering change proposals to expedite incorporation by suppliers of internal design improvements to enhance reliability and performance or inclusion of new technology to meet competition during the procurement cycle and even after deployment, if the suppliers are called upon to maintain their equipment. But keep rigid control over interface configurations to ensure interchangeability.
30.	*** Obtain multiple developments of equipments conforming to interface specifications. Where the potential market for the equipment is large enough, encourage industry-financed development; otherwise, procure multiple developments under government contracts.
31.	*** Facilitate government testing and qualification of designs offered in compliance with the specifications, whether or not the designs were developed under government contract. Plan, prepare, and provide for retesting and requalification of modified designs submitted in production competitions subsequent to the initial competition.
*32.	*** To overcome the potential problem of spare-parts stocking and field repair of multiple equipment configurations, make use of depot repair or supplier maintenance under warranty. In the field, replace rather than repair failed replaceable units of equipment. Include warranty requirements when initiating development.
*33.	** To achieve multiple-source availability, rely on performance specifications plus environmental and interface requirements (i.e., “form, fit, function” specifications) to define equipment, rather than imposing detailed specifications on parts, processes, materials, and internal configuration.
34.	To broaden the markets for competitive suppliers, encourage the evolution of multiservice interface standards.
35.	(From ref. 2) Maintain competition between contractors exploring alterna-tive systems by (a) limiting commitments to each contractor to annual fixed-level awards, subject to annual review of their technical progress; (b) assigning agency representatives to advise competing contractors in developing requirements for each candidate system as tests and tradeoffs are made; and (c) concentrating the activities of agency development organizations, government laboratories, and technical management staffs on monitoring and evaluating contractor efforts, and on participating in those tests critical to determining whether the candidate system(s) should be continued.

* Most directly applicable to project manager/engineer day-to-day undertakings.
** High priority
*** Highest priority

36.	(From ref. 2) Limit premature major-system commitments and retain the benefit of competition. This should be accomplished by conducting competitive demonstrations of candidate systems after a determination by agency heads to do so and on these stem: (a) choosing contractors according to their relative technical progress, the remaining uncertainties, and the economic constraints; (b) providing selected contractors with the operational test conditions, mission performance criteria, and lifetime ownership cost factors to be used in the formal system evaluation and selection; (c) proceeding with final development and initial production, and with commitments to a firm date for operational use (after agency needs and goals are reaffirmed, competitive demonstration results prove that the chosen technical approach is sound, and the definition of a procurement program is practicable); and (d) strengthening each agency's cost estimating capability.
37.	(From ref. 2) Should an agency component (responsible developer) determine it should concentrate development resources on a single system rather than fund competitive system candidates, require agency head approval before proceeding. When such single system development is to be pursued, (a) establish a strong centralized program office within the agency component to take direct technical and management control of the program; (b) integrate selected technical and management contributions from in-house groups and contractors; (c) select contractors with proven management, financial, and technical capabilities, as related to the problem, and use cost-reimbursement contracts for high-technical-risk portions of the program; and (d) estimate program cost within a probable range until the major system reaches the final development phase.
38.	(From ref. 2) Withhold agency head approval and congressional commitments for full production and use of new major systems until the need has been reconfirmed and the system performance has been tested and evaluated in an environment that closely approximates expected operational conditions. Regarding T&E, (a) continue efforts to strengthen test and evaluation capabilities in the services, (b) establish an agency-wide definition of the scope of operational test and evaluation, and (c) establish in each agency component an operational T&E activity separate from its developer and user organizations.
39.	(From ref. 2) Use contracting as an important tool of system acquisition, not as a substitute for management of acquisition programs. In so doing, (a) set policy guidelines within which experienced personnel may exercise judgment in selectively applying detailed contracting regulations, (b) develop simplified contractual arrangements and clauses for use in awarding final development and production contracts for demonstrated systems tested under competitive conditions, and (c) allow contracting officials to use priced production options if critical test milestones have reduced risk to the point that the remaining development work is relatively straightforward.
40.	(From ref. 2) Within each agency and agency component, unify policy-making and monitoring responsibilities for system acquisitions, including minimization of management echelons, staff reviews, coordinating points, procedures, reporting, and paperwork within both industry and government.
PRODUCTION	
41.	*** Where the quantity to be bought is large enough, depart from the conventional approach of aggregating procurements into a single large buy intended to take advantage of "learning curves." Instead, fragment the procurements into sequential buys, inviting design and price competition on each buy by the several suppliers of qualified interchangeable equipments.
*** Highest priority	

42.	** The government must assure prospective suppliers that there will be future design and price competitions. One method of doing so is to analyze and publish future needs and a schedule of planned competitive buys.
43.	*** The government must provide assurance that new or improved designs will be given full consideration in future competitions if they meet the form, fit, and function requirements that ensure interchangeability with prior designs. This implies the need for inclusion of interface requirements in government specifications.
44.	*** The government must offer to perform and must be prepared to perform laboratory tests and evaluations of the actual hardware prototypes offered by bidders or prospective competitors in order to qualify the designs for current and future competition.
45.	When it is desirable and necessary to sustain competition, award fractions of each buy to two or three competitors in proportion to the merit of their respective designs and prices, rather than making the award on a winner-take-all basis.
REPROCUREMENT	
46.	** In selected development contracts where subsequent competitive reprocurement is anticipated, the government should provide a payment to the developer for each accepted unit produced under government contract from the developer's design by a supplier other than the developer. This payment should constitute a deferred part of the compensation for the reprocurement data package. This contracting procedure should be used by the government on a trial basis.
MAINTENANCE	
47.	*** As recommended earlier, institute a cost accounting system that will afford visibility of the maintenance process and make possible realistic cost comparisons between military and industrial maintenance.
48.	** Provide separate accounts for functions other than maintenance, such as the use of continental US maintenance billets to facilitate the rotation of military personnel not involved in maintenance, or for personnel in training from overseas and shipboard billets.
*49.	*** Establish alternative sources of maintenance, including the maximum feasible amount of contractor maintenance, to foster competition and resultant efficiency in the maintenance process and to ensure the proper utilization of scarce military personnel in the present zero-draft environment.
*50.	** Intensify efforts to reduce field maintenance by shifting complex tasks from the organizational and intermediate levels to the depots, taking due account of increased turnaround time and transportation problems.
MAINTENANCE TRAINING	
51.	*** Develop fully proceduralized job performance aids for use in routine maintenance of new weapon systems and for selected tasks in high-maintenance portions of existing systems.
52.	*** Selectively, on a trial basis, reorient the training sequence for electronic technicians so as to provide first the specific training they require to perform maintenance tasks by using procedurialized aids during their initial enlistments.
53.	Increase research on job performance aids and on job-oriented training to enable the utilization of personnel of lower ability levels and to enhance learning on the job. Apply the results in selected training programs.
* Most directly applicable to project manager/engineer day-to-day undertakings. ** High priority *** Highest priority	

WARRANTIES	
*54.	*** Extend the application of long-term contractor maintenance warranties to military electronics procurements.
*55.	*** Make known the intention to contract for maintenance warranties on production equipment at the time development is initiated, so that the contractor will design to minimize total costs of production and warranty maintenance.
56.	*** Establish a warranty review group within OSD to monitor results of trial applications, to determine desirable warranty contractual formats, and to refine the categories of equipments to which warranties are most applicable and for which warranties are most effective.
57,	*** Initially, apply long-term contractor maintenance warranties to equipments whose failed units can be replaced in the field and conveniently returned to the contractor's plant or base for repair, or to which the contractor can have ready access for field repair, such as airborne communications, navigation, and identification equipment; modular radars; vehicular communication sets; complex manpack equipment such LORAN C/D; forward-looking infrared (FLIR) systems; and domestic, communication, data processing, and radar installations.
DESIGN EVOLUTION AND CONFIGURATION MANAGEMENT	
58.	*** The recently promulgated DoD regulation on configuration management (NAVMATINST 4130.1A, for the Navy) should be adopted with the following modifications: (a) specifically permit consideration of changes that are of benefit to the contractor and not detrimental to the government; (b) establish two product baselines, the first (tentative) one at the end of full-scale development, and the second (final) one when the design has been adequately stabilized; and (c) permit internal equipment changes that do not affect form, fit (compatibility and interfaces), function, price, or delivery to be classified Class II (defined in the regulation) in order to facilitate the change approval process until the "final" product baseline is invoked by the government.
59.	*** The government should defer invocation of the final product baseline, as applicable to electronic equipment, until field reliability objectives have been achieved, or, in the case of equipment under contract maintenance warranty, until the warranty period is about to end and the government is about to take over maintenance from the warrantor.
*60.	*** The government should defer full spares stocking until after the final product baseline is invoked.
PROJECT MANAGEMENT	
61.	*** Use the multiprogram project office ("basket" SPO) structure for all independent electronic subsystem developments where a number of related or similar developments can be grouped under one perpetual project manager (PM) to provide a PM of higher rank and greater authority, better project office personnel, more responsive support from functional groups, and more tradeoff flexibility.
62.	*** Provide multiprogram project offices with sufficient flexibility in the use of available R&D funds to allow the necessary tradeoffs by the PM in the development, operational test and evaluation, and low-rate initial production phases.
63.	** Arrange for the project manager or prospective project manager to participate in drafting the operational requirements before developing specifications for subsystems under his jurisdiction.

* Most directly applicable to project manager/engineer day-to-day undertakings.
** High priority
*** Highest priority

64.	** Make available to system project managers catalogs of available elec-tronic equipment that show current price and reliability figures as well as technical descriptions.
STANDARDIZATION AND SPECIFICATIONS	
65.	*** DoD should establish an Electronic Standards Panel having responsibil-ity and authority to act on recommendations 66 through 76, following.
66.	*** Promulgate policy requiring that the services include electrical, mechanical, and environmental interface specifications in specifications for electronic equipment.
67.	** Promulgate policy requiring that the services take steps toward assuring that new electronic equipments that are likely to replace older equipments in aircraft, ground vehicles, and other platforms will be made electrically, mechanically, and environmentally interchangeable with the older equipments, of similar types, so that the new equipments can be substituted for the old without costly installation modification.
68.	*** Promulgate policy requiring that equipments, subsystems, or systems of similar types be developed to the same interface specifications, so that they may be interchanged.
69.	** Promulgate specific interface standards for classes of equipment used by more than one service.
70.	** Establish and promulgate standards for the thermal, atmospheric, vibration, shock, mounting, shielding, and power-source environments to be provided by aircraft, ships, and vehicles in which electronic equipment is to be installed. This should include standards for benign-environment enclosures whenever they are feasible and cost-effective.
71.	** With the concurrence of and to the extent authorized by the Military Communications Electronics Board, establish and promulgate standards for the signals to be transmitted or interchanged in cooperative systems, such as communications, navigation, and identification systems.
72.	** Review service forecasts of electronic equipment needs in order to determine those types and classes to which uniform standards should be applied, and act to ensure that the standards are applied.
73.	*** Establish and promulgate DoD standards for the multiplexing and interchange of digital data among electronic equipments within ships and aircraft.
74.	** Promulgate policy designed to ensure maximum compatibility of military standards with commercial practices.
75.	** Review existing standards and specifications for parts, materials, fin-ishes, processes, and other aspects of the internal design of military electronics to determine which should be (a) strictly enforced, (b) subject to the substitution of the contractor-validated alternative, (c) regarded as advisory only, or (d) revoked. The several general design specifications used in most electronics procurements (e.g., MIL-E-16400 [resulted in MIL-STD-2036], MIL-E-5400, MIL-I-983) should receive particular early attention.
76.	** Issue up-to-date guidance on military utilization of standard commercial LSI and MSI items, with particular attention to the need for multiple sources and avoidance of military-unique designs.
** High priority *** Highest priority	

77.	** DoD Directive 4120.3 (DoD Standardization Program) can be the vehicle for the establishment of an effective electronic standards organization. In order to accomplish this, the defense Material Specifications and Standards Board should, under paragraph VII B2 of the directive, recommend the establishment of an Electronic Standards Panel (ESP) with the authority and responsibility to promulgate multiservice electronic standards and promote the cause of standardization of electronic equipments, subsystems, and systems, both single-service and multiservice. The ESP should be given the further authority to establish continuing (as opposed to ad hoc) committees, to which may be delegated segments of the authority and responsibility of the ESP. Once established, the ESP should organize to undertake formulation and promulgation of the policies recommended above.
SOFTWARE	
	To reduce costs of software in processors employing conventional general-purpose machines:
*78.	*** Complete the design of the system and the basic program structure in substantial detail before making major commitments to hardware or coding.
*79.	** Limit the aggregation of problems to be solved on a central machine; as an alternative, decentralize processing by providing peripheral special-purpose devices (either analog or digital) or separate peripheral general-purpose machines to perform specific separable functions.
*80.	** Select a processor of adequate size to permit underutilizing the com-puter; write highly modular programs; emphasize structure and overall efficiency rather than hardware efficiency alone.
*81.	** Use rigorous discipline in software development, such as the top-down structured-programming approach.
*82.	** Use a standard, well-established programming language with which pro-grammers are thoroughly familiar. Use the highest-level language appropriate to the task at hand, but avoid the unnecessary development of a unique language.
*83.	** Defer coding until the computer design is substantially complete and firm, except for that necessary to verify hardware-software design compatibility.
DIGITAL SYSTEMS ARCHITECTURE	
*84.	*** Systems-function-oriented processing hardware structures should be considered as alternatives to the conventional centralized programmable uniprocessor for use in military tactical systems.
*85.	*** The military processing problem should be clearly stated, the system design should be spelled out in detail and alternate processor architectures and designs should be compared before a hardware approach is selected.
*86.	*** A processor design for each system should be selected and developed that will minimize the combined costs of hardware and software; the allocation of functions between hardware, software, and human operators should be conscientiously worked out prior to decision.
*87.	** Standard LSI processing elements available from more than one source should be used to the maximum extent possible; development of uniquely military LSI elements should be minimized.

* Most directly applicable to project manager/engineer day-to-day undertakings.
** High priority
*** Highest priority

88.	** Military laboratories should be encouraged to investigate and develop processor architectures, including federated architectures, that fit military problems and are cost-effective. Conversely, their extensive efforts in the programming of conventional uniprocessors should be reduced to bring overall programs into better balance.
*89.	** Commercially successful processors for which software already exists should be considered for DoD applications wherever appropriate.
90.	** Formats and speeds for data interchange among sensors, actuators, processors, controls, and displays should be standardized across service lines and for as wide a variety of applications as practicable.
DATA COSTS	
*91.	Accept contractor's data format unless there is a demonstrable advantage in specifying a government format.
*92.	** Defer the ordering and delivery of contractor data until the need is firmly established.
*93.	**Delay procurement of spares provisioning, technical manuals, and maintenance handbooks until the point of design stabilization is identified and reached.
*94.	** Scrub data requirements mercilessly through the efforts of Data Require- ments Review Boards that include representation of the project manager, the user, and industry.
*95.	Where the equipment future is uncertain, buy options on reprocurement data instead of the data items themselves.
96.	(From ref. 2) Establish standards and criteria for estimating costs and bene- fits of product data requirements. The need for product data should be determined on the basis of cost-benefit analyses. Selective after-the-fact reviews should be used as the basis for eliminating unnecessary requirements.
97.	(From ref. 2) Establish government-wide criteria for management systems which are prescribed for use by contractors, including standards for determining mission-essential management data requirements.
	Following recommendations 98-101 are rewordings of previous recommendations in the context of data costs.
98.	Use competing suppliers of interchangeable equipment to reduce the need for reprocurement data.
*99.	Use contractor warranties and maintenance to reduce the need for technical and maintenance manuals and provisioning data.
*100.	Rely on competitive prototyping and test as a substitute for voluminous in-process validation data (and as a substitute for myriad detailed specifications).
*101.	As an alternative to formal and highly detailed reprocurement drawings and specifications, require less-formal drawings and encourage more informal information transfer. For reprocurement data, pay a fixed amount for the drawings plus a fixed amount for each equipment successfully delivered by the second source.
GENERAL PROCUREMENT CONSIDERATIONS	
102.	(From ref. 5) To provide an open environment in which recommended changes can take place, the hierarchy of DoD program management structures should be realigned and simplified.
* Most directly applicable to project manager/engineer day-to-day undertakings. ** High priority	

103.	(From ref. 2) Require the use of formal advertising when the number of sources, the existence of adequate specifications, and other conditions justify such use. Authorize the use of competitive negotiation methods as an acceptable and efficient alternative to formal advertising. Require that the procurement file disclose the reasons for using competitive methods other than formal advertising, in procurements over $10,000 or such other figure as may be established for small-purchase procurers. Repeal statutory provisions inconsistent with these proposed requirements.
104.	(From ref. 5) The important role of cost-plus-fixed-fee contracts should con- tinue for development and prototype contracts where effective fixed-price competition cannot be achieved without the addition of large contingency factors.
105.	(From ref. 2) The procurement of professional services should be accom- plished, so far as practicable, by using competitive proposal and negotiation procedures which take into account the competence of the proposers, the proposed concept of the end product, and the estimated cost of the project, including fee. The primary factors in the selection process should be the professional competence of those who will do the work, and the relative merits of proposals for the end product, including cost, sought by the government. The fee to be charged should not be the dominant factor in contracting for professional services.
106.	(From ref. 2) Provide through legislation that it is national policy to rely on private enterprise for needed goods and services, to the maximum extent feasible and within the framework of procurement at reasonable prices.

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This guide is intended to help the manager to scope, plan, and set up the management system for projects requiring research and development within the Department of Defense, especially the Navy. It is assumed that the manager has a background which is primarily technical and not necessarily managerial. The guide treats the acquisition cycle in chronological order and supports this perspective with specialized information on the various disciplines employed. The emphasis is on the implementation of practical methods of acquiring the best possible product for the resources available.

14. SUBJECT TERMS

Project Management	Program Management	Acquisition Management
Acquisition Research	Procurement Research	Reliability
Cost Reduction	System Effectiveness	Life-Cycle Costs
Design-to-Cost	Maintainability	Test and Evaluation
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