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STUDY OF AN ACCREDITATION POLICY FOR NAVY EMBEDDED COMPUTERS.(U)
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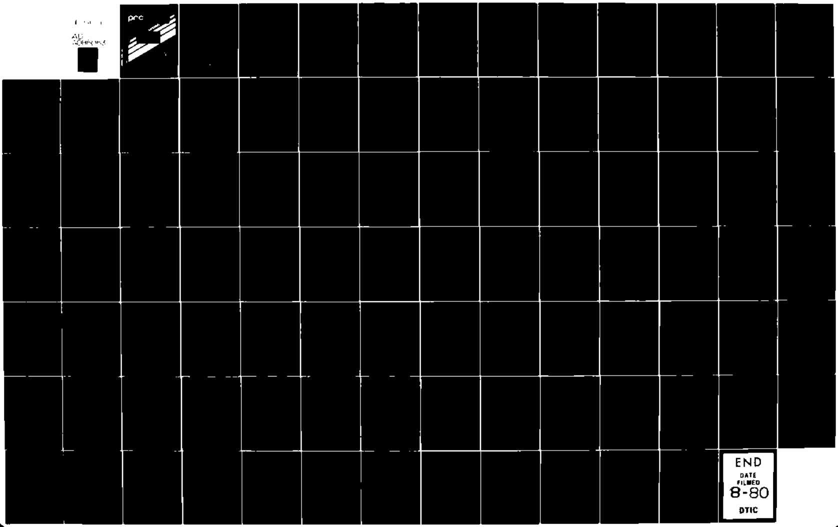

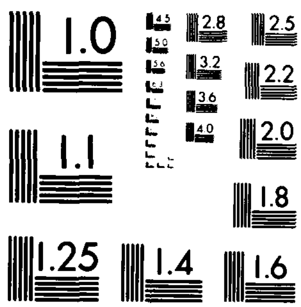
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for

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APRIL 1980

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Prepared for
Secretary of the Navy
Office of the Assistant Secretary for Research, Engineering and Systems
Washington, DC 20350

Prepared Under
Contract N00014-79-C-0862
PRC-R2518

PRC INFORMATION SCIENCES COMPANY

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FOREWARD

This report on the study of an Accreditation Policy for embedded computers proposes a methodology for an implementation of the policy. The objective of the report is to critically evaluate the concept of accreditation and to specify a procurement philosophy that will improve the Navy's ability to field militarily effective tactical systems at the lowest cost to the Navy. The concept of accreditation, as set forth by the Navy, involves creating a competitive environment for the procurement of embedded computers by acquiring multiple computers for various ranges of performance.

PRC/ISC's approach to the study was to view the goals of the Navy's Accreditation Policy and the related technological problems from a predominantly management perspective. Implicit in this approach is the belief that an overall framework for addressing the complex and interdependent technological issues must be defined before the details of each of the technological issues can be considered. Thus, an appreciation for the overall problem should be gained before attention is centered on distinct segments of the problem.

In addition, the report asserts that an effective policy must balance the goals of all the participants--agents of the Navy and vendors. Only in that way will a relationship be established that will allow the Navy to take advantage of ongoing technological advances in the computer industry.

The proposed policy is based on the following premises:

- The Navy should fund parallel, full-scale Engineering Development (FSED) efforts to obtain multiple accredited computers. An FSED effort would involve the militarization of proven technology rather than the development of new technology under an R&D program. Manufacture of production units would take place only as a result of a Program Manager's decision to purchase one of the accredited computers.

- Creation of a competitive environment for the proposal, FSED and purchase activities is expected to result in reduced costs to the Navy and improved computer performance. The resulting improved technology could be exploited (perhaps by revising approaches to operation and maintenance activities) to reduce logistics and maintenance costs.

The Navy would communicate its critical concerns to vendors to provide guidance for design decisions instead of dictating explicit specifications for meeting all of those concerns.

The proposed policy makes two assumptions:

- If competition in the form of multiple accredited computers can be promoted, then the cost of the procured technology will decline.
- The acquisition of improved technology will result in reduced maintenance costs.

While both assumptions are for the most part intuitively acceptable, they will have to be further validated by a process defined in the report using historical data and technology assessment.

The following topics are discussed in the report:

- Goals of the policy.
- Considerations in attracting multiple vendors to participate in the policy and, thereby, promoting competition.
- Significance of Instruction Set Architecture standardization.

- Characteristics of and a way to manage the list of accredited computers.
- The role of life cycle costs in comparing comparable computers.
- The relationship between accreditation and current Navy acquisition procedures.
- The impact of technology trends on maintenance costs.
- The responsibilities of a program manager in selecting an accredited computer for use in a tactical system.
- Trade-offs involved in technology selection.

SECTION 1. INTRODUCTION

1.1 Purpose.

This report presents the analysis and conclusions of PRC/ISC's study of the Navy's proposal for a policy for accreditation for embedded computers. The concept of accreditation, as advanced by the Navy, can be summarized as the reliance on the availability of competing computers in each of various performance ranges. These computers would then provide each Program Manager with competing alternatives that could be used in designing a system with a resultant reduction in the total life cycle costs for the system. The Accreditation Policy is viewed as an effort to relieve some of the problems currently experienced by the Navy in the acquisition, use and support of embedded computers.

1.2 Statement of the Problem.

The deficiencies and costliness of the Navy's shipboard data processing environment are well known to anyone associated with a shipboard system[1,2]. The state of that environment is discussed in the Final Report of the Navy Embedded Computer Review Panel, October 1978[3]. That report notes several issues that constrain the effectiveness of the Navy's systems:

- Standardization inhibits the acquisition of new technology (which provides improved capability and reliability) and limits competition among vendors for the development of Navy computers.
- Many systems must be operated and maintained at sea with a maintenance and logistics support capability which is reliant on limited personnel resources.

In addition, the Navy report notes that the projected use of embedded systems will increase while the availability of trained personnel needed to maintain them will decline. Finally, it is generally agreed that performance gains would accrue if greater use could be made of the ever improving technology in the commercial world. Because the Navy's computer technology does not undergo periodic upgrade, operational requirements predate technology instead of exploiting extant state-of-the-art technology. Therefore, the system development cycle is lengthened by the time necessary to define and produce the required technology. Consequently, the technology is no longer optimal by the time it is perfected. Worse still, ventures into new technology and the development of needed tactical systems are often discouraged by the cited technology lag.

In view of the improved military effectiveness that would be obtained if these problems were resolved, this report attempts to proceed toward that goal by defining a feasible policy for the improved management of Navy computers. This policy will establish a balance among the needs of the Navy, practices of commercial vendors and technology trends.

1.3 Scope of Accreditation Policy Study.

The following considerations are addressed to assure a policy that is consistent and workable from a management perspective:

- The prospective business relationship between the Navy and commercial vendors.
- Practical acquisition of commercial technology by the Navy.
- Handling of the Navy's logistics and maintenance requirements within the context of the expected improved technology at its disposal.

This study will define the basic premises of a workable, effective Accreditation Policy. The level of detail provided is intended to ensure that all essential issues are addressed, though perhaps not resolved since additional data from the Navy and vendors is required to validate the policy concept. In addition, no attempt was made to tie the policy to a specific scenario of Navy or computer industry directions in the future. Instead, likely trends were employed as guidelines for prospective decisions or actions.

For the purposes of the study, the phrase "embedded computers" was assumed to encompass all digital processor-based devices which are used in tactical shipboard systems as (1) aids to general purpose computing tasks, (2) controllers providing real-time direction or decision making for tactical systems and equipment and (3) programmed logic elements replacing the wired logic of hardware devices. Only the hardware domain of embedded computers was addressed within the constraints stipulated for conduct of the study.

1.4 Report Organization

This report is organized along the lines of the process by which the policy was derived:

- First the subject of the study was defined. This was achieved by (1) examining the procedures that the Navy currently uses in acquiring and utilizing computers and (2) ascertaining the ramifications of those procedures.

  Then the Navy's goals, as set forth by the principle of accreditation, were analyzed to gain another perspective on the study topic and to determine the policy's requirements.

- Then ways of achieving the goals as well as the rationale for and implications of those strategies were documented. The process of identifying suitable strategies for achieving the Navy's goals involved (1) identification of fundamental (if not axiomatic) steps in the acquisition process,

(2) examination of the factors associated with each of the acquisition steps, (3) consideration of alternative ways of performing each of the steps, and (4) specification of the preferred treatment of those activities with supporting arguments that, by implication, dismiss the alternative treatments.

- Finally, a chronology of activities necessary to implement the Accreditation Program was stated. The required actions ranged from preparations for executing the accreditation process to the actual acquisition procedures that would be performed to obtain and use an accredited computer.

SECTION 2. BACKGROUND

The procedural issues involved in the acquisition of a new computer for Navy use under current policies are documented and analyzed in this section. Emphasis is placed on the development (implementation) and operational use of a computer. The purpose of the following discussion is to identify issues that are pertinent to the Accreditation Policy; for more detail see SECNAVINST 5000.1[4] and the documents cited in its enclosure 3.

2.1 Hardware Implementation.

The processes involved in the development of a computer for the Navy are specified below.

2.1.1 Requirements Specifications.

The requirements of the computer are ascertained and documented. This involves specifying the attributes and performance requirements of the equipment in the context and environment of its expected use.

2.1.2 Selection of Contractor/Manufacturer.

A contractor/manufacturer for the computer is selected. The details of this process will vary depending on whether the selection is sole source or by competitive procurement.

2.1.3 Detailed Design.

Based on the computer's requirements specification, a detailed design is developed and documented; the wired and microprogrammed logic is specified. In addition, the operations methodology for the equipment is established. Also, a maintenance plan for the operational use of the equipment is promulgated.

2.1.4 Construction.

Initial units, probably prototypes for testing, are constructed.

2.1.5 Design Verification.

The initial units are tested to verify that the basic design has been achieved.

2.1.6 Production.

Once the design, with any necessary modifications, has been verified, the production of additional units can begin. The production units are quality-checked and tested to confirm that all standards (reliability, performance, etc.) have been met.

2.1.7 Establishment of Spares Inventory.

Spare parts are produced, stockpiled and inventoried in accordance with the logistics and management concept to support maintenance of the computers. Interfaces with the Navy logistics program are established.

2.1.8 Set Up Repair Depot.

A repair depot is set up (possibly as an offshoot of the production facility) to support depot or field repairs, trouble-shooting, etc., once the computer is in operational use.

2.1.9 Training.

Appropriate Navy grades are trained in the operation and maintenance of the system.

2.1.10 Availability for Shipboard Installation.

The equipment is declared available for projected shipboard installation dates.

2.1.11 Shipboard Installation.

The computer is installed aboard ship during shipyard periods or while at-sea by either contractor, shipyard or ship's force personnel.

2.2 Requirements Associated with Hardware Implementation.

All of the above steps have intrinsic requirements for time and costs for necessary resources (personnel, equipment, facilities, etc.) for both the contractor and the Navy.

The steps from requirements specification through production have special cost requirements due to Navy procurement practices and standards.

Training requirements involve the problem of having capable personnel available for training in light of manpower levels in the Navy. The degree of difficulty experienced in training increases as the number and complexity of computers increases.

The installation-related issues stem from the relative unavailability of the platform. The equipment must be specified far in advance of actual installation to accommodate the long lead time (three to five years) inherent in the fleet construction and overhaul cycles. Feasible installation times tend to be intermittent, infrequent and highly competitive due to the scope of Shipalt requirements. This problem is finding some relief as the size of computers and the complexity of the installation are reduced.

2.3 Impact of Standardized Computer Policies on Hardware Implementation.

From the standpoints of time, cost and procedures, the principal implementation steps are in effect eliminated for subsequent uses of a standard computer. There are, however, drawbacks that have an impact that can be assessed only qualitatively: (1) cost benefits that may be gained from competitive procurements are not realized and (2) computer design and performance will tend to stagnate in the absence of an infusion of new ideas and technology coming from both competition and new technology post-dating the original specifications.

The likelihood that equipment will be available for shipboard installations is enhanced; the only prerequisite is adequate production rather than the entire implementation process.

2.4 Operation and Maintenance.

Aspects of the operation and maintenance of an approved Navy computer are specified below.

2.4.1 Operation.

After being installed, the computer is operated as part of a system to satisfy an operational requirement.

2.4.2 Maintenance.

Activities associated with the maintenance of Navy computers are specified in the following sections.

2.4.2.1 Preventive Maintenance.

Operator or maintenance personnel perform periodic Planned Maintenance (PM) to identify problems before they become critical and to maintain the equipment in proper calibration and alignment.

2.4.2.2 Problem Identification.

In the course of operation, the computer experiences problems related to either design flaws or component failures. Diagnostic activities by the user, operator or maintenance personnel are required to pinpoint the problem. The troubleshooting may rely on diagnostic equipment or the system itself may aid in the diagnosis by actually reporting the problem.

2.4.2.3 Corrective Maintenance.

Identified problems are corrected by maintenance personnel. This can involve either parts replacement (using the spares inventory) or actual repair of the inoperative or malfunctioning part. The repairs may be performed on the organizational, intermediate or depot levels.

2.4.2.4 Spares Pipeline.

Spares used to replace parts that fail must be replenished by means of a timely and effective spares supply pipeline.

2.4.2.5 Training Pipeline.

Because maintenance or operator personnel will be rotated out of a billet accommodating the computer, there is an ongoing requirement for adequately trained replacements.

2.4.2.6 Field Changes.

Changes to the equipment may be necessary after installation to provide either design corrections or enhancements. These changes may be manufacturer-initiated although they may result from requests from the Navy.

2.5 Requirements Associated with System Usage.

Initial operation of a system is often in a situation where both the computer and its software are undergoing their first operational test. This can complicate independent evaluation of the elements of the system.

Planned Maintenance (PM) requires that properly trained personnel have appropriately scheduled access to the system.

Problem identification and correction can require widely varying skill levels and time depending on the character of the computer and the effectiveness of the available diagnostic tools. In general, these maintenance processes entail a fairly sophisticated effort requiring a good deal of training and experience. The amount of down time that can be tolerated will vary depending on the criticality of the computer and the degree to which redundancy is employed. Although highly reliable systems can reduce the frequency with which these tasks must be performed, the capability must still be in place.

Utilization of spares requires that inventory be properly monitored to facilitate timely ordering and delivery to accommodate the general inaccessibility of the ship to straightforward supply channels.

2.6 Impact of Standardized Computer Policies on System Usage.

The primary impact of standardization is in the area of maintenance for subsequent installations of a standard computer. Whereas PM requirements should tend to remain the same, few design flaws will be found after initial shakedown testing. (This does not necessarily mean that the skills required to handle design flaws are no longer needed.) Problem identification and correction may be facilitated if related experience is documented for general dissemination.

The Navy's ability to maintain the spares pipeline is made simpler due to the economies of scale experienced with a small set of standardized computers. In addition, having a pool of maintenance personnel trained in a limited set of computers provides for greater flexibility in the use of the personnel thereby simplifying staffing.

The need for field changes related to design corrections will tend to diminish as reductions in the number of design flaws are found. However, the number of enhancement changes will most likely increase with more numerous and varied uses of the computer.

SECTION 3. POLICY FOUNDATION

The essential elements of the Accreditation Policy will be established in this section. They will be based on an analysis of the factors and issues involved in achieving the Navy's goals.

3.1 Policy Goals.

In general terms, the Accreditation Policy must provide an effective response to the Navy's overall requirement to develop militarily effective systems within total cost and budgetary constraints. Therefore, the policy must reduce direct and indirect costs in light of the inherent trade-offs and constraints related to technological, procedural and real world issues. Thus, the fundamental goals of the policy include:

- Increasing cost, design and performance competition.
- Providing ongoing access to newer technology for improved performance.
- Obtaining computers that will allow for the development of an improved maintenance plan to reduce the cost of shipboard maintenance.
- Ensuring that existing and future standard Instruction Set Architectures (ISAs) will be supported (presumably through emulation).

3.2 Factors Associated with the Accreditation Policy.

Obviously, the goals stated above are complex, interdependent and even contradictory. Therefore, any effective treatment of the issues associated with the goals must be comprehensive. To that end, the goals will be viewed as objectives that must be met by strategies that take into account the objectives themselves as well as all factors which derive from the objectives.

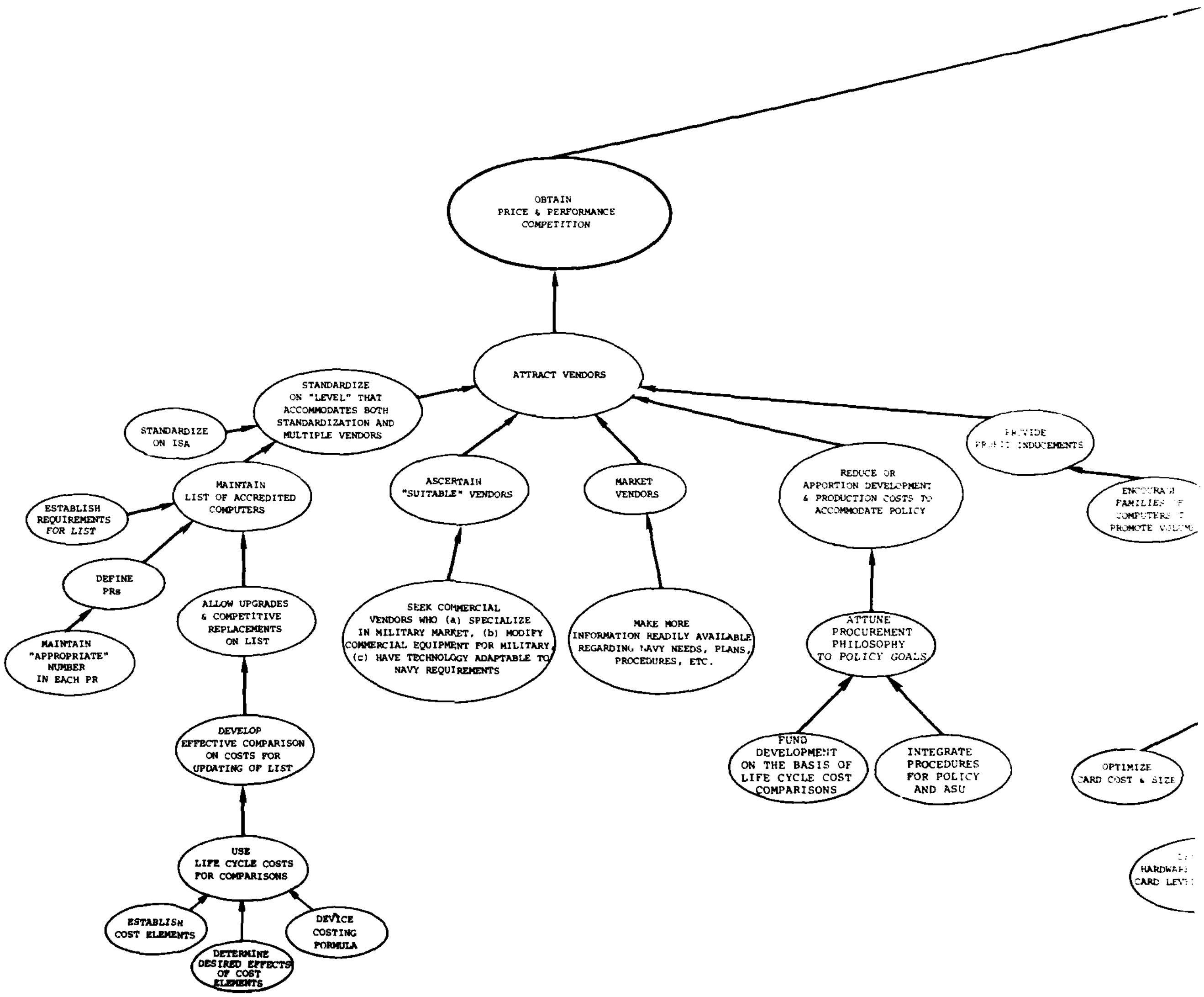
While the stated strategies are based mostly on subjective judgments, technological realities and trends are also given consideration.

To provide a starting point for the treatment of the objectives and to ensure that solutions for the diverse requirements are logically consistent, the following basic premises will be assumed:

- Computers to be used in shipboard systems will be selected from a list of accredited computers. The accreditation criteria will encompass various engineering and performance parameters. The list will be partitioned into multiple Performance Ranges (PRs), each defining a bounded range of computational performance. Each PR will ideally contain more than one computer. Because computational performance (as a function of such parameters as instruction execution time and data transfer rates) is more often than not the initial criteria for computer selection, PRs will serve as the basic reference frame for the grouping and classification of accredited computers.
- Capabilities of commercial computers and vendors will be exploited (with any needed modifications) to satisfy Navy requirements. Proposals for development of computers for accreditation will be sought from multiple vendors to create a competitive environment.
- Development of accredited computers for use in the Navy environment will not involve R&D for new logic technology, but rather will involve the packaging (or militarization) of proven technology.

- The level of standardization in computers will be on the Instruction Set Architecture (ISA). ISA is the representation of a computer employed by a programmer for (a) the manipulation of data, (b) the movement of data among registers, memory and the external world (I/O devices, etc.) and (c) the management of programming logic flow.
- Management of the Accreditation Program, including development of the Accreditation Policy, will be the responsibility of the Policy Administrator. The Policy Administrator, in effect, acts as the liaison between vendors, who develop embedded computers, and program managers who use them in shipboard systems.
- The accreditation process will entail (a) environmental stress testing to determine if applicable standards have been met, (b) benchmark testing to confirm the satisfaction of design constraints (e.g., execution of the standard ISA and adherence to interface requirements) and (c) computation and evaluation of the computer's life cycle costs from Full Scale Engineering Development (FSED) through Operation and Maintenance (O&M).
- Several approaches to maintenance problems will be promulgated including the use of system diagnostics, appropriate maintenance tasking and improved hardware design.
- Alterations to or reorganization of procurement procedures and practices will be pursued as a way to make computers more readily available at lower cost.

Figure 1 provides a concise listing of strategies for the Accreditation Policy. In the chart, the basic goals are noted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"SUITABLE" VENDORS
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IN MILITARY MARKET, (b) MODIFY
COMMERCIAL EQUIPMENT FOR MILITARY,
(c) HAVE TECHNOLOGY ADAPTABLE TO
NAVY REQUIREMENTS
MARKET
VENDORS
MAKE MORE
INFORMATION READILY AVAILABLE
REGARDING NAVY NEEDS, PLANS,
PROCEDURES, ETC.
REDUCE OR
APPORTION DEVELOPMENT
& PRODUCTION COSTS TO
ACCOMMODATE POLICY
ATTUNE
PROCUREMENT
PHILOSOPHY
TO POLICY GOALS
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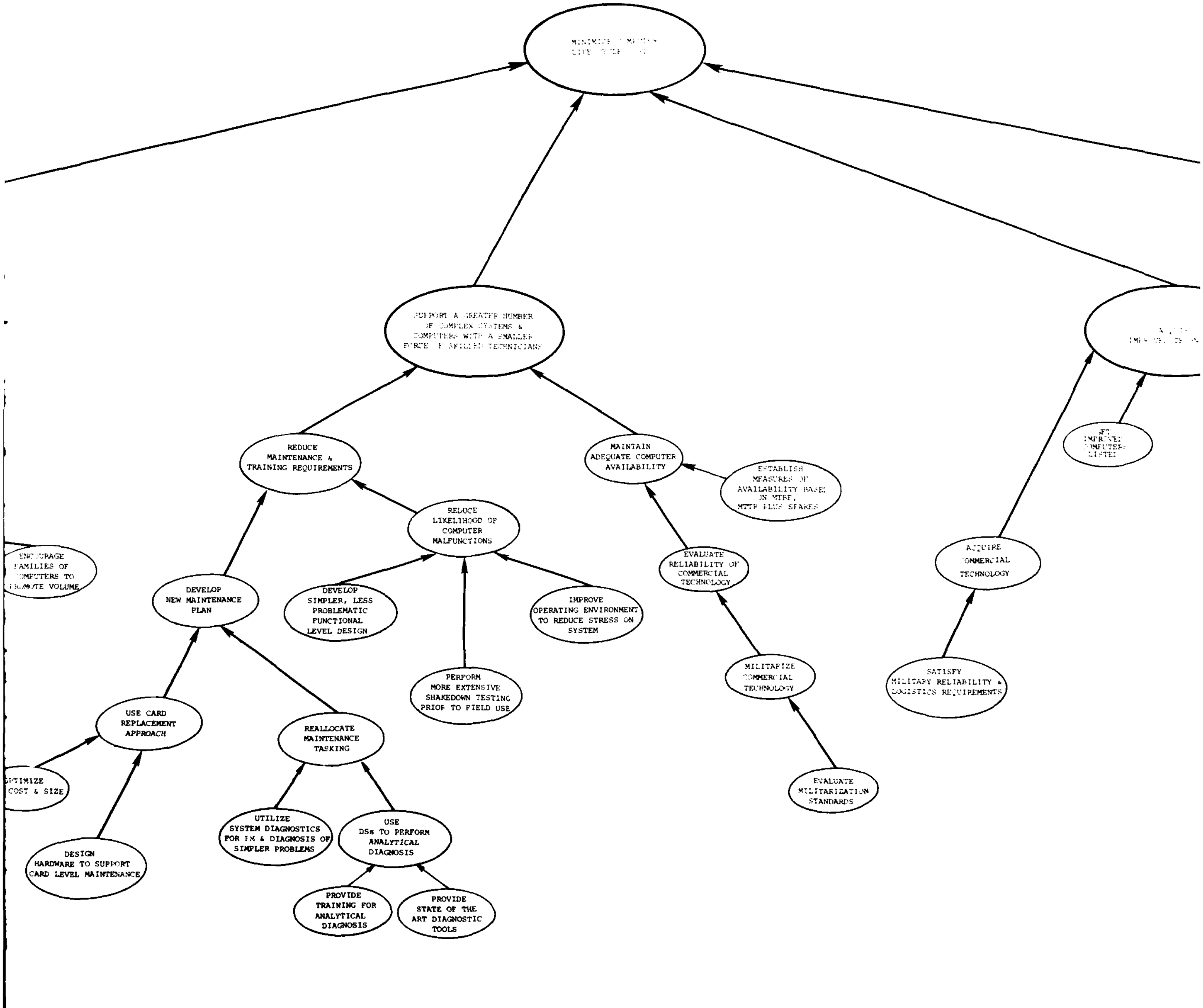
SUPPORT A GREATER NUMBER OF COMPLEX SYSTEMS & COMPUTERS WITH A SMALLER FORCE OF SKILLED TECHNICIANS
REDUCE MAINTENANCE & TRAINING REQUIREMENTS
MAINTAIN ADEQUATE COMPUTER AVAILABILITY
ESTABLISH MEASURES OF AVAILABILITY BASED ON MTBF, MTTR PLUS SPARES
REDUCE LIKELIHOOD OF COMPUTER MALFUNCTIONS
FAMILIES OF
DEVELOP NEW MAINTENANCE PLAN
DEVELOP SIMPLER, LESS PROBLEMATIC FUNCTIONAL LEVEL DESIGN
IMPROVE OPERATING ENVIRONMENT TO REDUCE STRESS ON SYSTEM
PERFORM MORE EXTENSIVE SHAKEDOWN TESTING PRIOR TO FIELD USE
EVALUATE RELIABILITY OF COMMERCIAL TECHNOLOGY
MILITARIZE COMMERCIAL TECHNOLOGY
EVALUATE MILITARIZATION STANDARDS
ACQUIRE COMMERCIAL TECHNOLOGY
SATISFY MILITARY RELIABILITY & LOGISTICS REQUIREMENTS
USE CARD REPLACEMENT APPROACH
COST & SIZE
DESIGN HARDWARE TO SUPPORT CARD LEVEL MAINTENANCE
REALLOCATE MAINTENANCE TASKING
UTILIZE SYSTEM DIAGNOSTICS FOR FM & DIAGNOSIS OF SIMPLER PROBLEMS
USE DSs TO PERFORM ANALYTICAL DIAGNOSIS
PROVIDE TRAINING FOR ANALYTICAL DIAGNOSIS
PROVIDE STATE OF THE ART DIAGNOSTIC TOOLS

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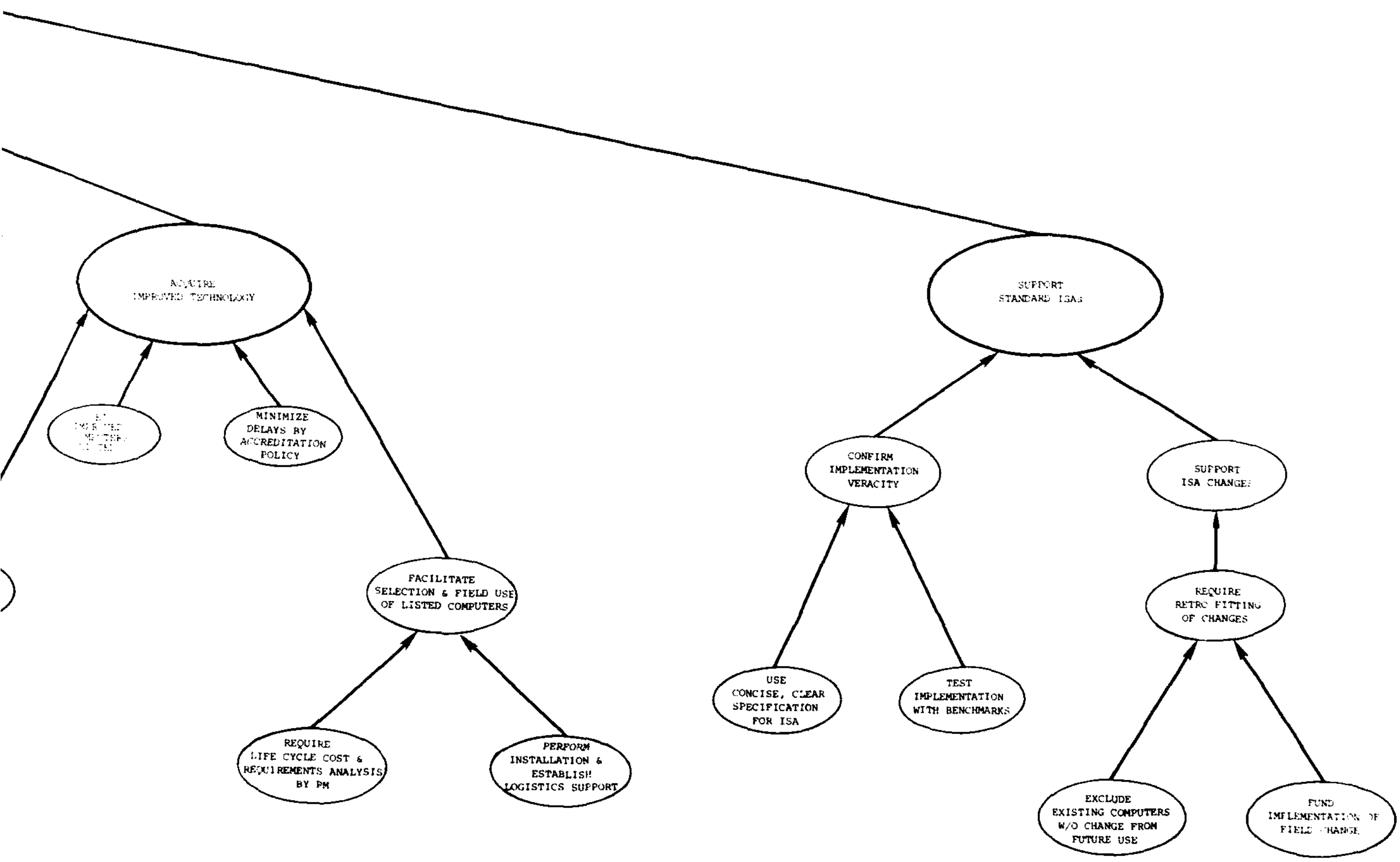

Figure 1. Analysis of Accreditation Policy Goals

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as primary requirements. From those requirements, solutions derived from the above stated basic premises are noted. It can be seen that some of the basic premises play a part in the treatment of more than one of the requirements. The issues stated in Figure 1 are treated in greater detail in the following sections.

3.2.1 Elaboration of Factors Associated With Policy Goals.

In this section, the requirements and solutions of the policy are analyzed in greater detail. The analysis follows the tree structure of Figure 1 in a left to right transversal from each mode (preorder traversal).

The examination of the proposed approach will be based on a justification of each action rather than a comparison of alternative approaches for the entire policy.

3.2.1.1 Price and Performance Competition.

The primary goal of the Navy's Accreditation Policy is to gain price and performance improvements for its embedded computers by partaking more extensively of the technology offered by commercial vendors. Benefits should accrue both from competition among vendors vying for the Navy market as well as from continuing decreases in the cost of the state-of-the-art technology of vendors. Neither of these factors, which can lead to reduced costs, are directly under the control of the Navy. In fact, the technology related price decreases may be small if the cost to upgrade commercial technology to MIL-STDS continues to be a major portion of militarized computer costs. Thus, the Accreditation Policy must promote competition as an indirect means to the desired end, while also reducing the costs upon which the Navy has a direct influence (i.e., procurement policies).

Although it is valid to assume that competition will have the desired effect on cost, it cannot be assumed that competition will materialize without some encouragement. Vendors must be attracted; the Navy must make it both procedurally easier and less expensive than heretofore for all parties to be involved in Navy business. Thus, an approach to Navy-vendor interaction must be established that will balance the goals and requirements of all involved. Characteristics of the Navy-vendor interface that should attract vendors to participate in the program are discussed in greater detail in the following subsections.

3.2.1.1.1 Level of Standardization in Embedded Computers.

Current standardization for the entire computer reduces some logistics related costs, but impedes price and performance competition. The level of standardization that is employed in Navy computers in conjunction with the Accreditation Policy will have a significant influence on the degree to which vendors can interact. The level of standardization must relate positively to the way that vendors expect to do business and the size and character of the market in which they will participate. Therefore, the standardization level must be optimal regarding its technology, its ability to satisfy Navy requirements and its compatibility with the directions of the vendors, including the structuring of their product line. The ISA standardization decided upon by the Navy meets these qualifications and as well:

- Allows for injection of new technology on the most dynamic levels (processor logic and architecture) while giving the vendor the flexibility to achieve an overall optimum design.

- Allows a vendor to design and build a complete computer rather than individual or isolated components, thereby, providing a reasonable product base.
- Provides a level of standardization that should reduce software development costs and risks by creating a well defined baseline.
- Establishes a single point for vendor interface instead of multiple interfaces that would result from card level standardization.
- Allows the Navy to perform a functional level review of computer design rather than more detailed reviews that would be required if card level standardization were employed.

Standardization on an ISA does not encourage utilization of Plug Compatible Modules (PCMs) as much as card level standardization. It might, however, be feasible to exploit PCMs when either upgrades are not available from the originating vendor or the originating vendor is amenable.

Accredited embedded computers will be required to execute the standard ISA either directly (as the native ISA of the computer) or via emulation. The feasibility of emulation allows the Navy to require support for multiple ISAs e.g., UYK-7, UYK-20 and a new "universal" ISA. Emulation also improves the chances that vendors with commercially oriented microprogrammed native ISAs for their computers will still be able to implement Navy ISAs on the same computer.

ISA standardization is justifiable since it provides upward compatibility during the transition from the current standard computer philosophy to the accreditation philosophy. However, a change to High Order Language (HOL) standardization in the future will be compatible with DODI 5000.1 and required to absorb advances in technology that will inevitably necessitate a break with current architectures. Also, HOL standardization will eliminate compliance with an ISA as a factor that might discourage vendor participation in the policy. As the "hardware" cost of supporting ISAs approaches or exceeds the cost of redoing any remaining systems implemented in machine dependent ISAs, standardization on HOL should be undertaken.

3.2.1.1.2 Methodology for the List of Accredited Computers.

The principal management mechanism for embedded computers approved for shipboard use will be the list of accredited computers. The list will identify the computers that, by virtue of their adherence to Navy specifications and standards for operation and performance, are available for use by Program Managers.

The concept of a list of accredited computers must take several factors into consideration. First, the listed computers will, in general, be viewed and treated as entities unto themselves rather than as complete systems. Second, the makeup of the list will be intended to achieve the most cost-effective set of computers possible; computers will be added to the list and listed computers will be replaced by improved computers from the same vendors (upgrades). However, the policy is not likely to guarantee that the listed computers are universally on the leading edge of technology trends, but it can improve the chances that the computers will keep pace with these trends.

The listed computers will be subject to guidelines for design specifications, operational and functional characteristics as well as reliability characteristics as defined by military environmental standards[5]. The computers will also be characterized by performance characteristics (MTTR, MTBF, size, etc.) that will not be subject to rigid standards.

All of these requirements will have the effect of creating engineering commonality within the list. This commonality will correspond roughly to the current standardization approach to Navy computers, but to a lesser degree.

The list of accredited computers will be partitioned into multiple Performance Ranges (PRs) defining bounded ranges of computational capability. The specification of the characteristics of PRs is an essential factor in the classification of accredited computers. There are several techniques that can be used to define PRs: heuristic classification, classification of instruction execution time, word size, etc. and classification based on performance of functional tasks.

- Heuristic classification would involve using the orderings and groupings of computers generally employed by the computer industry. Those classifications are typically based on an intuitive assessment of computer characteristics (word, size, etc.) that, over time, change and blur the accepted classifications. For example, the classification mini-computer spawned super-mini as technology advanced. However, the use of widely used classifications would tend to align the Navy with the computer industry and provide consistency of terminology.
- Formulae which compute overall performance on the basis of instruction execution time, word size, memory addressibility and data transfer rates are sometimes used to compare computers.

The same comparative information can be used to classify computers. The spectrum of performance that could result from the calculation could be broken down into classes (PRs) that each computer could be mapped onto.

However, minimal success has been achieved with the use of formulae since the significance of performance parameters vary by application and because differences in computer design make measurement of the parameters difficult[6]. This approach is further complicated by the fact that there are few if any guidelines available for defining the boundaries of the capability classes.

- A third way of defining PRs can employ benchmarks representative of Navy data processing tasks. The tasks performed in Navy tactical systems, of course, utilize the same atomic computational operations as business or scientific applications. However, response time requirements, data volumes and application types (e.g., signal processing and weapons control) place a more strenuous performance burden on embedded computers. Therefore, benchmarks at a level somewhere between atomic operations (individual instructions) and system level applications (C^3, etc.) could be used to measure expected performance of Navy tasks.

  The computational characteristics of Navy tasks can be defined by a mix of three performance parameters: thousands of operations per second (KOPs), data transfer rates over I/O channels and ability to respond to interrupts. These three parameters appear in varying mixes in such applications as command and control, data management, communications, and guidance and control. Available computer memory is not included as one of the primary parameters defining computational performance since each computer can generally be configured with a fairly wide range of memory sizes. Undoubtedly other parameters could be justified, but the use of the three least arguable parameters will be used to illustrate a way of defining the PRs.

Each PR would be defined on the basis of a mix of the three performance parameters with each parameter having either a medium or high level of performance. Thus, eight PRs would be defined. The range of high or medium performance would have to be defined on the basis of perceived Navy requirements. Each of the eight PRs would be defined by a range of permissible performance for each of the three performance parameters. Benchmark software for each of the three performance parameters would be executed on an accredited computer to determine the PR that it would be assigned to.

By defining PRs on the basis of the three stated computational performance parameters, the shortcomings of the two aforementioned techniques are avoided; definitions of PRs are tied to Navy tasks rather than subjective industry terminology and, thereby, vary only as a function of the proglem domain; the temptation to attempt to establish a single value definition of performance is avoided.

Each PR would be populated by at least two computers. Each accredited computer would be defined by computational performance (based on values of the computational performance parameters) and life cycle costs as a function of unit price and performance characteristics (MTBF, MTTR, etc.). The presence of multiple, slightly dissimilar computers would create competition in the RFP and FSED stages and, as well, would lead to competitive selections of accredited computers by program managers. Similarly, multiple computers per PR would provide alternative choices if a vendor could not meet production requirements of a particular program.

However, there are several reasons for limiting the number of accredited computers per PR to three or four: the competitive gains from multiple accredited computers are not likely to be as great for four or more computers; the portion of the market represented by a PR that a vendor is likely to get declines as the number of computers in a PR increase, thereby, reducing profit attractions.

One might assume that a single set of engineering standards and design constraints would be used for all PRs within the list. While universal standards will provide some benefits e.g., use of the standard ISA, minimization of the multiplicity of training programs, other costs could be reduced if subsets of engineering standards were established.

For example, segmenting the standards into compatible classes (based on differences in capabilities and uses) could allow for reduction of engineering requirements and simplification of procurement procedures for classes having less rigorous requirements. The segmentation could be achieved either with multiple lists or by grouping PRs within a single list. In the case of multiple lists, functional characteristics of digital devices (computational, data storage, control, interfacing/ data transfer) could be used as the criteria for specifying the different lists. With a single list, capability would be the primary factor used in delineating PRs. Thus, computers could be categorized by capability within functions.

The accreditation of a computer would not necessarily result in the manufacture of production models. Instead, production models would be built only in response to a purchase order from a Program Manager. Therefore, an accredited computer might never go into production and, accordingly, never be used in a tactical system.

It must, of course, be possible for the composition of the list of accredited computers to change. Allowing these changes will avoid locking out new vendors and the resulting reduction in competition. Also, changes in the list will allow new technology to be acquired.

A strategy will be required for controlling the addition of computers to the list. By definition, the variability of computational performance within a particular PR will be somewhat limited. Therefore, a computer seeking to be listed which had a level of computational capability coinciding with the i^{th} PR would be compared only with the computers in that PR.

Thus, computational performance would not be a measure for comparison but rather a guide for determining which subset of listed computers would be compared. Accordingly, the evaluation of a candidate computer for accreditation would have to be based on another quantitative measure, such as life cycle costs, in addition to validation of its adherence to the stipulated accreditation criteria. The characteristics of comparisons on life cycle costs are discussed in the following sections.

3.2.1.1.2.1 Life Cycle Cost Considerations for Accredited Computers.

Computers of similar computational performance (i.e., of the same PR) will be compared on the basis of life cycle costs. Total life cycle costs will be computed for each candidate for the list. The computation will encompass costs for development and production as well as operations, maintenance and support for the computer. O&M costs will be computed as a function of such performance characteristics as MTTR, training, etc. Once costs were computed they would be compared to the costs for already listed computers. A decision as to whether a candidate computer should be accredited would be made on the basis of the life cycle cost comparison as well as the results of accreditation testing.

In general, the criteria for the life cycle cost comparison should serve to drive down the cost of each successive addition to the list. Thus, the decision would be made to list a candidate computer only if its costs compared favorably to those of listed computers.

The life cycle cost analysis will require that all cost elements be identified and quantified[7,8,9]. The cost elements of a computer's life cycle are listed in Table 1 in the approximate order in which they arise. Costs incurred by the use of Navy resources to perform a task, as well as costs reimbursed to the vendor, are listed. The cost elements from proposal review through completion of qualification testing are grouped as a Full Scale Engineering Development (FSED) effort. The cost elements from purchase through field changes relate to the Operation and Maintenance (O&M) phase of the computer's life cycle.

Table 1. Computer Life Cycle Cost Elements

Vendor Responsibility	Navy Responsibility
	• Proposal review
• General design	
• Detailed design	
• Design documentation development	
• Prototype development & checkout	
• Development of technical manuals	• Review of technical manuals
• Development of operator documentation	• Review of operator documentation
• Development of maintenance procedures (Maintenance Requirements Cards)	• Review of maintenance procedures
• Development of Integrated Logistics Support Plan (ILSP)	• Review of ILSP
• Production of Engineering Development model	
	• Accreditation & qualification testing of Engineering Development model
	• Purchase of production models
	• Acceptance testing of production models
• Depot set-up	
	• Spares inventory purchase and administration
	• Purchase of maintenance support tools
	• Maintenance personnel training
	• PM
	• Organization level maintenance & repairs
	• Intermediate level repairs
	• Depot level repairs
	• Field changes

3.2.1.1.2.1.1 Evaluation of Life Cycle Costs.

Both Policy Administrators and Program Managers would perform life cycle cost analyses. The Policy Administrator would actually engage in two analyses. The first would be performed as part of the evaluation of a proposal for a candidate for accreditation. The second analysis would evaluate a computer's suitability for accreditation once its development was completed. Because of the Policy Administrator's role in overseeing the global and long term costs to the Navy for all computers, his evaluation of life cycle costs must provide a consistent assessment of different computers over the long term.

On the other hand, the Program Manager's life cycle cost analysis would be based more on the planned use of the computer in a specific application or system. Thus, more exact values for purchase quantity and price and expected useful life span would be used in the analysis.

The life cycle cost analyses performed by both the Policy Administrator and the Program Manager would employ the same cost formulas and values for Navy costs.

The cost elements must be analyzed to assess both their potential and the desired impact on the computer's life cycle costs and the Navy's goals in computer acquisitions. Thus, formulas for each cost element must be set up to reflect the true cost of each element to the Navy and by so doing define targets for optimization by vendors participating in the policy.

The goals of the Accreditation Policy are actually manifestations of costs that the Navy endeavors to reduce or better control. Therefore, the life cycle cost formulas for each cost element must reflect those cost implications. The cost formulas defined in MIL-STD-1390B[10] provide a complete and detailed accounting of the cost elements related to O&M. They would have to be complemented with cost formulas for FSED and purchase activities.

3.2.1.1.3 Potential Vendors.

In its attempt to attract vendors, the Navy must recognize that not all vendors are equally compatible with Navy needs. The entire spectrum of vendors will be sought as participants in the accreditation policy. Even so, it can be surmised that the following types of vendors will be more likely to participate:

- Vendors willing to modify their own or others' products to satisfy Navy requirements. (The development of militarized versions of DEC and Data General commercial computers, respectively by Norden and Rolm, are examples of this situation. Note that this procedure usually results in price increases of a factor of three or more which is the inherent price of militarization.)
- Vendors who are seeking to maximize their potential market by striving for adaptable technology (e.g., via emulation) and who are, therefore, more likely to have the capability to accommodate the Navy's requirements.
- Vendors who, on a company or division level, see the Navy as a viable market and are willing and able to develop complete and specialized computer to meet the Navy's needs.

3.2.1.1.4 Encouraging Vendor Participation.

Many Navy procurements are the result of unsolicited ideas, products or systems from vendors or contractors. The list of accredited computers will rely almost exclusively on such unsolicited offerings. Therefore, the Navy must take steps to ensure that such offerings are forthcoming. It must "market" or encourage vendors in the sense of removing implicit impediments, thereby making it easier for vendors to present their ideas.

The Navy can represent itself as a more receptive market by making more information available regarding its needs, plans, procedures, etc. Some vendors are often discouraged from the Navy market because of a simple lack of information. Some means to bridge this information gap (already in use in varying degrees) might include industry presentations; informational contributions to industry periodicals; explanations of procedures; and published aids for the production of required DoD documents. Several of these actions imply that a single-minded Navy program can be formulated for presentation.

3.2.1.1.5 Overview of an Acquisition Process.

The Accreditation Program's acquisition philosophy must be suited to the goals and exigencies of the policy. The acquisition process has to create an environment that promotes effective price and performance competition for Navy computers while providing profit incentives for vendors.

The acquisition process will involve (a) the issuance of a competitive RFP for candidate computers for accreditation, (b) funding for the parallel development of engineering models by multiple vendors and (c) evaluation of the completed candidates. The up-front funding of multiple FSED efforts results in increased costs that should be offset by the exertion of competitive forces on overall Navy costs. Navy development funding would be intended to expedite packaging of state-of-the art, proven technology for Navy use, rather than to support the development of the logic technology itself. It must be assumed that the demands of the commercial market place will lead to advances in logic technology without Navy funding of R&D.

The acquisition process would be initiated with the issuance of an RFP for candidate computers for a particular PR. The proposals would be required to specify the technology base for the computer and how the accreditation requirements would be satisfied (with supporting rationale and data). If the proposed computer seemed to be technologically promising, if there appeared to be a good likelihood of successful completion within costs, and if the computer's projected life cycle costs were competitive with those of previously accredited computers, the development effort would be approved and funded.

By providing up-front funding of FSED efforts, the Navy ensures that state-of-the-art computers are readily available for selection and use in tactical systems. Therefore, the Navy avoids the situation wherein the system development cycle is lengthened by the time needed to develop the required computer technology. In essence, the expenditure of FSED funds to perfect fully militarized computers effectively eliminates availability of up-to-date computer technology as one of the risk factors in the development of tactical systems.

Typically, funding for the FSED of candidate computers would be provided by the Policy Administrator. However, there would be no prohibition on a Program Manager funding the development of a computer for a specific program. The resultant computer would still, however, have to undergo accreditation evaluation and prove its cost-effectiveness before it could be used in a shipboard system. This arrangement would give Program Managers a little more flexibility in acquiring needed computers while providing a funding source other than the Policy Administrator's office.

Major decision points would be established during the development effort to allow for cancellation in the event of failure by the vendor to successfully meet a milestone. The Navy would, of course, have the option to continue funding despite a milestone failure if so warranted by the product's promise.

Upon completion of FSED, the computer would be evaluated with respect to its compliance with the accreditation criteria. Additionally, its life cycle costs would again be computed and compared to those of previously accredited computers. If the candidate computer passed the accreditation evaluation, it would be added to the list of accredited computers. Once listed, accredited computers would be treated as commodities available for special order.

The proposed acquisition process is tied to the characteristics of the concept of accreditation. Not surprisingly, it differs from the two most commonly used acquisition processes: (1) award of a single contract for FSED on the basis of an evaluation of competitive proposals and (2) leader-follower acquisitions. The proposed process encourages price and performance competition throughout the acquisition process whereas the single contract method encourages competition only for the proposal stage. The funding of parallel FSED efforts is the price that is paid for that additional competition.

The proposed acquisition process also involves some differences with the leader-follower process. The leader-follower procedure encourages competition for the proposal, FSED and procurement stages. As with accreditation, increased costs result from the funding of multiple FSED efforts, in this case for both the leader and follower of the teams that win the proposal effort. The implementation of a single technology by both the leader and follower can reduce O&M costs for the completed computer. However, this lack of diversity can result in less technological innovation than if both vendors worked independently. Also, long term technology stagnation can be avoided only by going through the acquisition process again in the future to take advantage of technology advances. However, if a different design is selected in a subsequent acquisition, O&M is impacted as much as it would have been if more than one design had been chosen in the initial procurement.

With the leader-follower arrangement there is less potential for price competition for a buy than with accreditation. When the leader and follower become competitors for the production phase, they are each awarded a proportion of the buy. However, unless a stipulated, preponderent proportion will be awarded to the vendor with the lowest unit price, there will not be enough incentive to encourage rigorous competition. On the other hand, the Accreditation Policy provokes fiercer competition since each complete system buy is available for bid.

The decision of which proposed computers to fund for development is a critical one in ensuring that total costs of computers decrease as a result of the Accreditation Policy; the cost-effectiveness of proposed technology must be evaluated to ensure price and performance gains from competition. One of two alternative schemes can be used in determining the efficacy of the proposed technology: a subjective evaluation or an evaluation based on periodic quantitative analysis of life cycle costs of accredited and proposed computers.

3.2.1.1.5.1 Subjective Technology Evaluation.

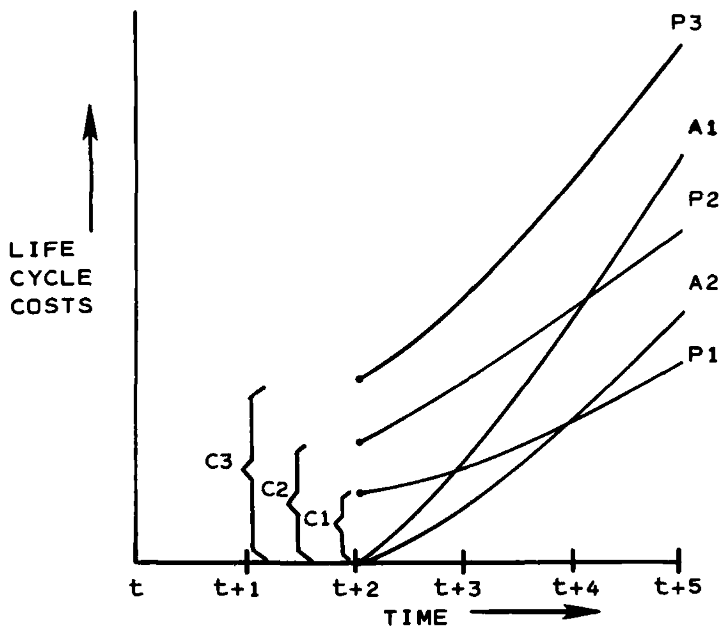
In the subjective approach to evaluating proposed technology, the proposal evaluators would use professional judgment to determine if the technology advanced the Navy's goals. The O&M costs of already accredited and proposed computers could be compared to gain a perspective on their relative cost-effectiveness. Funding would be approved for those proposed computers deemed promising. The number that would be funded would depend on the size of the available budget. Proposals would be evaluated annually to facilitate the funding decision. Every funded computer receiving accreditation would be added to the list of accredited computers.

The comparison of costs could be performed by computing the average of the O&M life cycle costs for the computers already accredited. The life-cycle costs would be computed with the aforementioned cost formulas on the basis of a "reasonably likely" purchase quantity based on past experience. The average cost (PR_{AV}) for previously accredited computers in a PR and the standard deviation of PR_{AV} (PR_{SD}) would be computed. If the life cycle costs for a candidate computer were less than, say, $PR_{AV} - PR_{SD}$, the computer would be eligible for accreditation. This method of comparison sets a ceiling on costs instead of providing a specific cost measure of technological improvement that a candidate would have to achieve. However, the removal of more costly computers from the list to maintain three to four per PR would have the effect of lowering the ceiling.

3.2.1.1.5.2 Quantitative Technology Evaluation.

The alternative approach to funding decisions involves more quantitative evaluative methods. When the RFP for candidates for accreditation is issued, newly proposed (as yet unfunded) computers as well as previously funded and accredited computers would be directly compared. The life cycle costs for both types of computers would be computed on the basis of any required development effort, O&M costs and the total projected computer buy for the period of three to four years from the accreditation evaluation (approximately two years hence). The computed life cycle costs provide a quantified but relatively heuristic basis for comparison since a single accredited computer would not, in fact, be dictated for the total projected buy. Thus, the technology of proposed computers would have to yield a sizeable enough reduction in life cycle costs to better the costs of already accredited computers whose previously funded development costs would not be included. This comparison is represented in Figure 2. To maintain three accredited computers, Computers P1 and P2 would be approved for funding. Computer P3 would not be funded and A1 would lose accreditation after t+2. Computers P1, P2 and A2 would be the available accredited computers for the period t+2 to t+5.

The number of development efforts to be funded in each RFP cycle would depend upon the number that bettered already accredited computers and would, therefore, be unpredictable. However, the goal would be to fund enough so that once those funded were accredited, there would be a mix of previously accredited and newly accredited computers totaling three or four. With this method, previously accredited computers would undergo periodic comparison with new computers and would be subject to being removed from the list.



LEGEND:

A1,A2 - ACCREDITED COMPUTERS #1 AND #2
P1,P2,P3 - PROPOSED CANDIDATE COMPUTERS #1, #2, AND #3
C1,C2,C3 - FSED COSTS FOR P1, P2 AND P3
t - TIME AT WHICH FUNDING DECISION IS MADE FOR PROJECTED BUY OF n COMPUTERS FOR PERIOD t+2 TO t+5

Figure 2. Life Cycle Cost Comparison of Accredited and Proposed Computers

Projecting the life cycle costs for a three to four year period gives the Policy Administrator a reasonable quantity base, over a period of relative technological stability, upon which to credibly minimize Navy costs. However, the listing of multiple computers will probably result in a smaller actual buy for each computer and, therefore, different cost from the projection depending on the size of each of the buys. (The continued minimization of costs in conjunction with the Program Manager's evaluation of listed computers is discussed in Section 3.2.1.3.4.)

3.2.1.1.6 <u>Reorganization of Qualifications for Operational Use.</u>

The Navy endeavors to obtain cost-effective products by using well defined procurement procedures and product standards (MIL-STDS). Some of the procedures and standards (specifically as embodied in Approval for Service Use (ASU)[11]) address computers from the dual perspective of hardware and operational effectiveness. ASU requires that several certifications be undertaken:

- The computer undergoes qualification testing to verify that it satisfies applicable MIL-STDSs.
- An Integrated Logistics Support Plan (ILSP) is generated which specifies a methodology for logistically supporting the computer.
- An Operational Test (OT&E) is performed to validate both the operational effectiveness of the computer (in and of itself as well as part of a system) and the viability of the ILSP in practice.

The Accreditation Policy can be strengthened by assigning it responsibility for certification of all of the hardware and some of the operational characteristics. This approach will allow the computer to be viewed as an entity unto itself for accreditation purposes. In addition, the apportionment of responsibility will allow as much verification as possible to be performed when the computer is listed. The performance of testing (benchmarks, etc.) during the accreditation phase can reduce both overall costs for the OT&E as well as the time elapsing between selection of the computer and its use on board a ship. These benefits are currently evidenced in standardized computers which have been approved for service use.

The vendor will have responsibility for ensuring that the computer satisfies the design constraints and engineering standards defined by the Policy Administrators as criteria for accreditation. The vendor will also be responsible for providing a practicable ILSP. Operational aspects of the ILSP will be verified as part of accreditation testing, where feasible. The ability of the computer to be used effectively as part of an operational capability (including the viability of the complete ILSP) will be verified by the system's Program Manager/Developing Agency via Developmental Test and Evaluation (DT&E) as well as during OT&E.

3.2.1.1.7 Profit Inducements.

Ultimately, vendors will be attracted to participate in the Accreditation Program by the expectation of adequate profits. The Navy's funding of the development of a candidate computer will, of course, provide some profits. Furthermore, profits would be realized for any production units purchased by Program Managers for use in shipboard systems. The magnitude of these profits will be largely a function of the number of computers sold.

By allowing only three or four accredited computers in each PR, the policy will keep the potential market share for each vendor at a level compatible with the aim of gaining competition. However, a vendor could increase his potential market size by developing a family of computers that encompassed multiple PRs and their associated expected purchase quantities. Because the same, or very similar, technology and packaging would be used for the entire family, the development costs and purchase price for each PR's computer should be lower than if only a single computer were offered by the vendor.

The use of families of computers would also make the vendor's computers more competitive with regard to the FSED or production cost factors of life cycle costs. The FSED costs for each successive member of the family could be expected to be lower because of the repeated reapplication of existing technology. If all the family members were submitted at the same time, the FSED cost for each could be estimated as the total FSED cost divided by the number of members. Production and other costs (logistics, training, etc.) could also be reduced if the larger potential market made accessible by a family line yielded a larger realized market and economies of scale.

3.2.1.2 Maintenance Support Requirements.

Analysis performed by the Navy indicates that the number of embedded computers in use will grow significantly in coming years [1]. On the other hand, studies show that the number of skilled people available to operate and maintain computer systems will not keep pace with that growth. The increased number of computers will also require that training of personnel (in either diversity or detail) be adjusted to handle the required system maintenance. The Accreditation Policy should, therefore, provide some means of accommodating these demands.

3.2.1.2.1 Reduction of Maintenance and Training Requirements.

One of the major costs of embedded computers is tied to the cost of labor intensive maintenance[12,13]. Accordingly, ways to reduce these costs are of considerable interest. However, it should not be expected that the Accreditation Policy will embody explicit requirements or procedures for reducing these costs. Rather the policy should point out the importance of reducing the cost of critical maintenance elements.

As methods and technology evolve and mature that can supplant labor intensive maintenance activities, the Navy (perhaps at the behest of the Policy Administrator) must develop a new maintenance plan (i.e., who performs maintenance and how it is performed) to reduce the cost of maintenance training and maintenance activities. An appropriate marriage of technology trends and policy goals is outlined in the following sections. The discussion below is applicable to both the Policy Administrator and the vendor since it provides a greater appreciation for critical concerns and ways in which they could be handled.

3.2.1.2.1.1 A New Maintenance Plan.

The maintenance plan can exploit a trend already extant in the computer industry, i.e., design, construction and maintenance at the card level. Accordingly, the card would be the Least/Line Replaceable Unit (LRU) for maintenance purposes.

Reliance on card level maintenance will require that computers for the Navy be designed to facilitate problem diagnosis and parts replacement at the card level.

A card taken from the spares inventory to replace a failed card can be replenished in one of two ways: (1) rotatable parts pool - the failed card can be sent to one of the maintenance unit levels, repaired and returned to the inventory at the appropriate maintenance level or (2) throwaway plan - the failed card is discarded and replaced from inventory and a newly purchased replacement card provided to the appropriate maintenance level inventory. The costs of these respective methods must be computed to identify the most cost-effective method to manage the inventory for each card.

The design of cards must be optimized so that the cards (1) entail a level of detail and complexity that is not too expensive for sparing and (2) are functionally specified so that they are conducive to the isolation of problems to a specific card. Thus, the card must be modular and functionally independent of other cards.

There are definite industry trends toward the use of software and firmware-based system diagnostics capabilities that can perform lower echelon maintenance e.g., the identification of functionally inoperative LRUs (permanent or recurring failures) via PM and problem diagnosis[14,15,16]. These tools require that the function of LRUs be well defined and modular. However, these diagnostics often still require highly skilled technicians to interpret and react to their results. Nonetheless, these capabilities should be exploited to expedite problem identification and correction. Accordingly, an even greater share of the diagnosis involved in lower echelon maintenance could be shifted to the system itself.

To carry that trend even further, less skilled operator personnel could be trained to use the system diagnostics. While this would entail additional training for this group, the increase should be minimal if the diagnostics are truly effective and easy to run. Training would be limited to operation of the diagnostics and replacement of parts identified as inoperative, as opposed to analytical troubleshooting. Thus, more highly skilled technicians can be released from lower echelon maintenance tasks, thereby, reducing the scope of tasks they have to perform. This ability of relatively low cost diagnostic aids to significantly reduce skill requirements for lower echelon maintenance may represent the greatest potential for reducing maintenance costs in light of currently experienced low MTTR (15-45 minutes).

Although diagnostics are usually computer specific, guidelines (not standards) for their capabilities and operation should be promulgated by the Navy to make them more utilitarian. Even if system diagnostics are effectual, upper echelon maintenance involving sophisticated analysis and troubleshooting will be required for field changes and for significant problems as follows:

- Errors not addressed by the system diagnostics.
- Problems related to hardware design shortcomings and experiended only under operational conditions.
- Failures prohibiting execution of the system diagnostics.

Therefore, the skills required for upper echelon maintenance must still be in place.

Personnel performing upper echelon maintenance have to be trained in analytical techniques in addition to having at least a basic familiarity with the logic diagrams of the computer. They will also benefit from documentation describing the data flow of the system, on at least a functional level, since problems are often intimately linked to the operational use of the equipment.

To further increase the productivity of upper echelon maintenance, state-of-the-art diagnostic and test equipment should be on hand. Equipment such as logic and data analyzers should be as commonly available and in use as oscilloscopes[17].

It is also feasible to reduce the training and workload for maintenance personnel by changing the type of maintenance for which they are responsible. For example, some rates (typically DSs) perform all types of maintenance from PM to troubleshooting, using logic charts and scopes. This tasking increases both the level of training that these rates must have and the magnitude of their workload. By segmenting the overall workload into lower and upper echelon tasks, available skills can be better matched to the requirements of the tasks. In conjunction with this, available and developing maintenance technology could be used to both facilitate the segmentation of the workload and complement the skills employed for the tasks, thereby reducing the associated workload. For example, lower and upper echelon tasks, respectively, could be assigned to (a) Data Processing Technicians (DPs) and Data System Technicians (DSs) or (b) DSs (or DPs) and Mobile Technical Unit (MOTU).

Decreases in the cost of computers themselves or their LRUs may become so significant that throwaway will become the predominant parts replacement method. When that point is reached, the proposed subdivision of maintenance tasking will facilitate the substitution of a comprehensive throwaway maintenance plan for most upper echelon maintenance.

3.2.1.2.1.2 <u>Reducing the Likelihood of Computer Malfunctions.</u>

The maintenance workload can be further alleviated by reducing the likelihood of computer malfunctions. One way to achieve this would be to develop simpler, less problematic, functional level design. In other words, design characteristics that are functionally complex and involve more complex hardware or logic should be avoided. An example of this in some current Navy computers is the grouping of I/O channels as chassis (rather than treating them completely independently). Use of chassis has been hypothesized as the cause of numerous intermittent or obscure hardware problems. Simplicity, perhaps at slightly higher design or production cost, should be the design goal.

Another significant factor in the amount of required maintenance for a computer is the amount of shakedown testing performed prior to field use. Navy experience has shown that computers introduced too "quickly" have experienced a high failure rate until initial production and design problems were worked out. Requiring more extensive acceptance testing prior to installation could reduce the requirement for shipboard maintenance at the time when maintenance personnel are least capable of performing it.

The age, design, etc. of today's embedded computers are the most frequently cited causes of malfunctions. However, in the shipboard environment, the stress placed on computers by means of the power source is also significant; there are frequent instances of power supply problems that are both intentional (drills requiring power curtailment, shifts between shore power and ship's own power, etc.) and inadvertent (power supply failures, brownouts, surges, etc.) that undoubtedly contribute to intermittent, delayed or immediate failures. Bringing more control and order to, at least, the intentional anomalies should lead to an overall reduction in system problems.

3.2.1.2.2 Maintaining Adequate Computer Availability.

Despite the expected imbalance in the number of computers in use and the maintenance personnel available to support them, adequate availability of the computers must be achieved. Therefore, varied means will have to be pursued to ensure adequate operational availability[18].

The reliability of militarized equipment that is generally in use is significantly lower than that for commercial computers and newer militarized computers, as well. Therefore, the increasing reliability of state-of-the-art hardware can be expected to provide a significant improvement over current Navy computers. Today's technology is more reliable by virtue of improved production techniques, more sophisticated but clearer design and efficient use of less expensive technology. Commercial computers are, however, not designed or constructed in accommodation of the Navy's engineering standards. Therefore, it will still be necessary to provide adaptions for the military environment.

The use of military reliability and environmental standards for engineering provides a significant increase in component and IC reliability. In fact, most of the standards are so stringent that mere mention of them allays most apprehension about reliability. The effectiveness of the standards, however, comes at a very high monetary price. The sense of security that is bought with these standards may result in reliability overkill and unnecessarily costly components and, ultimately, systems. The existence of varying levels of standards (e.g., MIL-STD 883 classes A, B and C with and without JAN compliance) argues for better matching of expected environmental stress conditions with adequate (not excessive) standards. The possibility of buying components or even computers suited to their expected environmental stress requirements becomes more feasible under the proposed policy; computers will be built most often in response to a particular requirement for a buy.

Measures of the operational availability of computers should not be based solely on the durability (MTBF) of the equipment. Instead, other factors should be explored to ensure required availability. The MTTR can provide a significant contribution if considered in conjunction with the proposed new maintenance plan. In that regard, the ease with which the equipment can be repaired due to the card level design and maintenance as well as the allocation of maintenance tasking and the use of good diagnostic tools can each be an indispensable complement to MTBF.

System configuration (e.g., loosely coupled or distributed architectures) can reduce the criticality of an individual computer. That would reduce the likelihood of a system failure resulting from a single computer failure. In addition, the reliability and, therefore, the operational availability of a system could be improved with the use of redundant computers. Standby redundancy (cold spares) and operating redundancy (hot spares) can be utilized to increase operational availability even though MTBF and MTTR would not necessarily be improved. Redundancy and creative system configurations may provide more cost-effective improvements in operational availability than reliance on advances in reliability and maintainability.

3.2.1.3 Acquiring Improved Technology.

Accredited computers can be expected to provide increases in computational performance and reliability as a result of the use of state-of-the-art logic technology as well as improved functional design. However, the Navy's goals will be achieved in toto, if and only if, the improved technology can be obtained for practical, in-the-field use on a timely basis. Therefore, the proposed policy must ensure that the computers themselves as well as policy procedures expedite the field use of the accredited computers.

3.2.1.3.1 Acquiring Commercial Technology.

The proposed business relationship between the Navy and commercial vendors is the first step along the path of acquiring commercial technology for use in shipboard systems. (It must be stressed that the Accreditation Policy's practical goal is the acquisition of the technology of the commercial world rather than off-the-shelf commercial computers themselves.) Additionally, steps must be taken to get the production version of the engineering development models into the fleet.

The commercial technology packaged for Navy use must, of course, be able to satisfy the Reliability and Maintainability (R&M) requirements of the shipboard environment. The increased reliability that attends technology advances is not likely to satisfy those requirements, especially as related to humidity, salt spray, EMI, etc. Therefore, the commercial technology will probably have to be repackaged or adapted to satisfy R&M requirements. The repackaging could occur on any or all of several levels: replacement of commercial grade components with MIL-STD components, redesign of card construction or redesign of card or cabinet layout.

It could be argued that continued miniaturization of digital circuitry and increasing reliance on throwaway maintenance could lead to the satisfaction of many environmental standards by means of complete encasement of circuits. However, encasing circuits in an effective "insulating" material would require the development of other technology (e.g., for dissipation of heat) comparable in sophistication to the environmental standards themselves. Therefore, environmental standards should continue to be a requirement of militarization for some time to come.

3.2.1.3.2 Getting Improved Computers Accredited.

Seldom is a device (no matter how widely it is used in the commercial world) added to the Navy's inventory until an explicit requirement for it is stated and extensively confirmed. This conservative approach helps to reduce the chance that unneeded capabilities are developed. However, it also tends to delay the operational availability of a capability. The Navy should strive to identify capabilities that have "obvious" utility and ensure that they are added to the list of accredited computers for eventual use. This approach would be similar to that of R&D in general: a reasoned investment made in development in an effort to anticipate highly probably requirements. Lagging operational availability is likely to remain a problem if the current reactive practices continue.

The most obvious point at which there is a need to anticipate requirements is with the initial set of listed computers. It may be necessary for the Navy to (a) submit an RFP to the Navy's traditional vendors to get the program underway, (b) waive some qualifications to facilitate initial development or (c) provide extraordinary funding as an incentive to, or to permit, accelerated development. Existing approved computers can, of course, be placed on the list and administered in line with the Accreditation Policy. Also, the goal should be to populate every PR with at minimum two accredited computers.

3.2.1.3.3 Minimizing Delays of the Policy.

There are numerous factors (in addition to the actual computer development cycle) that delay the introduction of a new computer into the field. Some of the delay is related to the validation of the computer's operational effectiveness. While it is not assumed that the Policy Administrators can impact operationally related issues, the delays inherent in the accreditation testing must be minimized as much as practical. Facility or personnel resources (Navy or contracted) must be made available to perform the required reviews and testing as expeditiously as possible.

3.2.1.3.4 Facilitating Selection and Field Use of Accredited Computers.

The Program Manager's selection of a listed computer for installation aboard a ship logically follows the Policy Administrator's role in guiding computers to accreditation.

The Program Manager's selection of a listed computer necessitates an evaluation of his system requirements and the available computers. The appropriate PR must first be selected based on an analysis of the proposed system's requirements. The analysis must address both computational performance and logistics characteristics. Once the requirements and PR have been matched, a life cycle cost analysis must be performed. This analysis will support an assessment of the system's total cost in comparison with other systems' costs. The Program Manager's life cycle cost analysis will employ the same O&M phase cost elements as the Policy Administrator's. However, the cost computation will be more attuned to the Program Manager's perspective with little or no concern for the computer's FSED costs and relying on an evaluation of availability in a system context rather than an evaluation for the computer standing alone.

The Program Manager would be concerned with minimizing his system's life cycle costs in the selection of an accredited computer. While his evaluation is performed from a different perspective than the Policy Administrator's (one rather than many systems), it should accomplish the same goal, minimization of Navy costs, by sub-optimization. However, the Program Manager's choice should take into consideration total system costs (including ship costs influenced by the system) that contribute to the Navy's total costs.

If, as time goes by, a particular computer is not selected because its life cycle costs are higher than others in its PR, the vendor may be encouraged to reduce the computer's purchase price to make it more competitive.

After a Program Manager selects an accredited computer, it must be installed aboard a ship. Therefore, an installation schedule must be established in accordance with dates of availability of the ship. The relative unavailability of a ship for installation can be a delaying factor in getting an operational capability introduced. There is little that the Accreditation Policy can do to improve ship availability. However, because accessibility of listed computers would be dependent only on the production process, there should be a smaller chance that a period of ship availability will be missed due to the unavailability of the computer.

When the computer is installed aboard ship, the logistics support capability must be actuated: trained technicians, supporting documentation and spare parts inventory must be available. The quantity of spares stocked can be affected by the expected new technology of accredited computers. If the replacement price of an LRU is lower than its repair cost, then more spares will be required. This situation must be monitored since (1) the high incremental cost of militarization will for some time keep parts costs high despite technology related cost reductions and (2) the cost of labor intensive maintenance is certain to rise considerably. However, the anticipated technology related improvements in reliability should reduce the overall quantity of spares required.

As the number of different computers (different vendors for the same or different PRs) in use on a ship goes up, the maintenance problem is complicated; technicians must be trained to maintain different computers, and logistics support mechanisms must be expanded.

While the increase in logistics support costs for each additional type of computer is less than linear, the training situation presents a more serious problem. The training necessary for each computer can be costed by means of a cost formula. However, it is difficult to associate a cost with the fact that each technician reaches an individualized saturation point beyond which further training cannot be effectively absorbed. For example, while two technicians working together and supporting i and j computers of two different types could reasonably take on an additional number of computers of the same types, it is less likely that they could handle k computers of a third type.

If the cost of adding a new vendor's computer is incorporated into the Program Manager's life cycle cost formula, there could be a serious bias against the use of computers that are suited to provide militarily effective capabilities. Maintenance technology can be used to reduce the severity of this situation: the use of diagnostic aids can increase the number of computers that a technician can be trained to support by lowering the skill level requirements.

When a decision is made to purchase a listed computer, the vendor's ability to supply the computer on the required schedule (and at reasonable cost) must be considered. The vendor may be unable to meet the schedules because of either inadequate or inoperative production facilities. The relative unpredictability of the Navy's demand under the policy concept may, in fact, contribute to the problem. However, the purchaser would still have several alternatives: (a) the original vendor could adjust the status of his production facilities to meet the Navy's purchase requirements, (b) another vendor could be given a licensing agreement to produce the computers, or (c) another of the listed computers could be selected instead. (The existence of alternative purchase options should minimize the negative impact on purchase options if a computer's production is discontinued, for whatever reason.) The Program Manager's life cycle cost analysis would, of course, have to take into account any additional costs resulting from either of these actions.

3.2.1.4 Standard ISAs.

The standardization on the ISA level will require that existing ISAs for the standard Navy computers (UYK-20, UYK-7), as well as any new standard ISAs, be supported. It is assumed that all standard ISAs will have to be implemented on each listed computer, probably by means of either emulation or different versions of the computer's logic.

3.2.1.4.1 Verification of ISA Implementation.

The use of standard ISAs will require that the Navy confirm the veracity of each implementation. The implementation must be faithful to the ISA specifications and without implementation related side effects. To improve the likelihood of successful implementations by vendors, a clear definition of the ISA must be provided, perhaps by means of the ISP notation[19].

A suitable method by which to verify the ISA implementation would be the use of benchmark applications which, at minimum, straightforwardly exercise all elements of the ISA.

3.2.1.4.2 ISA Changes.

Although standard ISAs will be used, it is inevitable that technology advances will argue for, or even require, modifications to the specification of the ISAs. The changes can result from either Navy generated requirements or unsolicited changes advanced by vendors. For unsolicited changes, the Navy would undoubtedly evaluate them before giving them any official sanction. If the unsolicited change were rejected, it would be advisable (in the case of a completely new computer) to allow the vendor to submit the computer for inclusion in the list with the change disabled. Otherwise, vendors would be discouraged from developing enhancements to the ISA if the entire computer could be rejected.

Changes approved or promulgated by the Navy would become formal changes to the ISA and be required on all candidate computers subsequently submitted for accreditation.

To ensure consistency across all listed computers, it will not necessarily be purchased since existing users may have no changes to computers already in use. The retrofitted capability will not necessarily be required since existing users may have no use for the change. If a vendor elected not to implement the field change to be retrofitted, the affected computer would be excluded from future purchase considerations.

It would be appropriate for the Navy to guarantee reimbursement of costs for the implementation of field changes. This additional cost would deter the policy administrators from approving changes that were not cost-effective. Also, this approach would encourage vendors to implement the change on existing computers to maintain consistency among the Navy's computers.

3.2.2 Cost and Benefit Relationships of the Accreditation Policy.

Examination of the factors cited in the proposed approach to accreditation reveals, not surprisingly, that a cumulative price must be paid to achieve the desired goals. In this section, the areas where costs are incurred and the objectives that they affect are presented diagrammatically.

In Figure 3, the interrelationship of costs and benefits is summarized. Militarization costs involve those activities required to meet the design constraints of the policy. Technology costs reflect the cost of technological advances in logic and overall computer design. The costs associated with multiple FSED efforts by vendors (not always resulting in purchased computers) are represented by development cost. Management costs for the policy relate to such activities as defining the accreditation criteria, communicating policy goals and procedures, performing proposal and accreditation evaluations, and optimizing procurement procedures. Each cost type yields a benefit in one or more of the Navy's goals.

In Table 2, the positive and negative impacts of the proposed policy on the respective goals of the Navy and vendors are summarized. Also, graphic representations are provided of the expected influence of the policy on these goals.

3.2.3 Review of the Policy Concept

Two basic premises were assumed in the proposed policy: (1) competition will reduce computer purchase price while yielding improved performance for equivalent dollars and (2) acquisition of improved technology will result in reduced maintenance costs. Both premises may be acceptable on an intuative basis. However, further validation of these premises must be performed as part of the process of initiating the Accreditation Program. However, available data and past experience can be used to preliminarily support these premises.

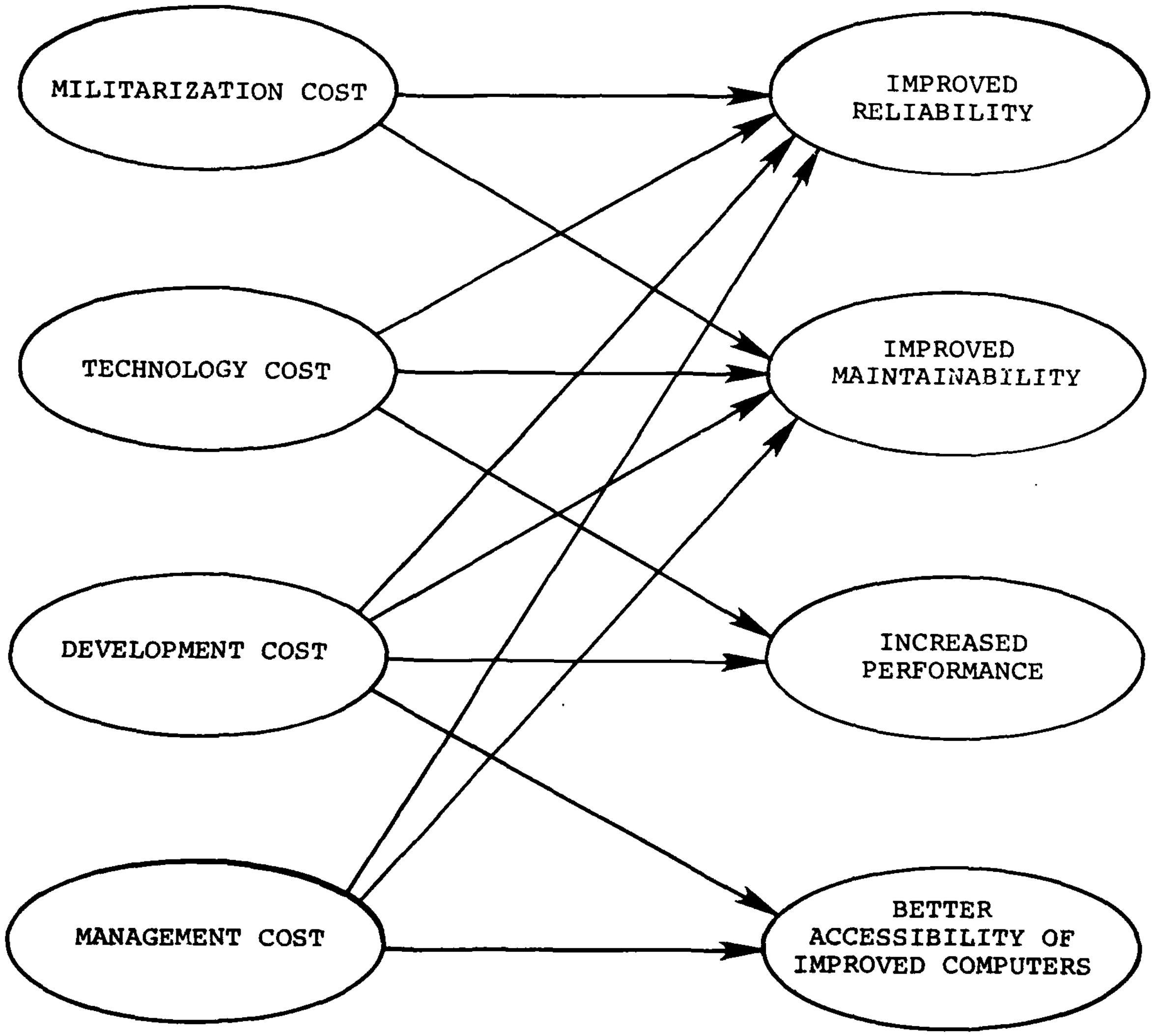
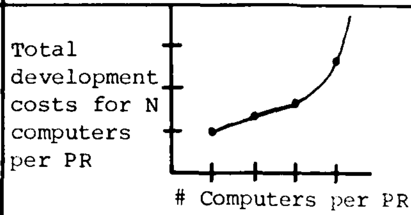
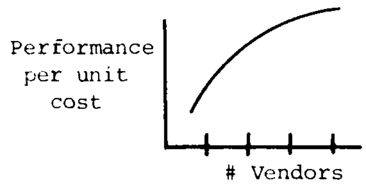
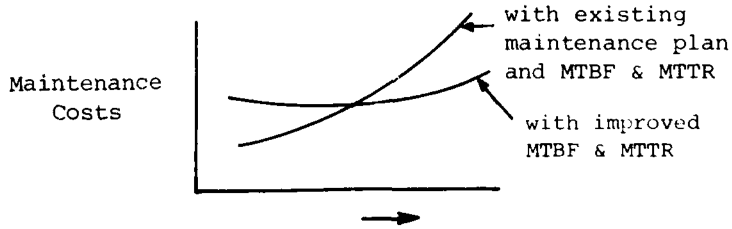
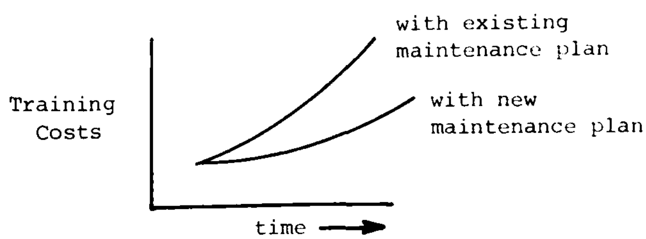
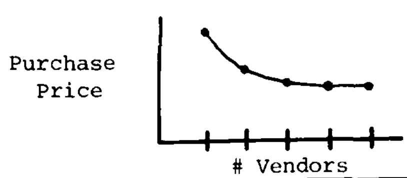


Figure 3. Cost-Benefit Relationships

		Factors Inhibiting Navy Goals	Factors Supporting Navy Goals	
Conflicts Among Issues Related to Navy Goals	Computer Development Costs	• Multiple development efforts must be funded • Upgrades to ISA must be funded	• Competition among multiple vendors will yield price and performance improvements • Improved technology will be obtained • Navy will have option to terminate unpromising development efforts • Increased performance in upward compatible computers will be gained	Tot deve cos com per
	Maintenance Costs as a Function of MTTR & MTBF	• More costly improvements in computer design needed to improve MTTR & MTBF	• Improved reliability decreases frequency of maintenance and cost of spare parts • Modular design facilitates maintenance • Use of system diagnostics reduces MTTR	
	Maintenance Training Costs	• Increased diversity of computers increases number of training programs and training time for technicians	• Use of system diagnostics reduces requirement for upper echelon training	
	Purchase Price of Computers	• Defined at time of purchase rather than at time of development	• Reduced by competition	
	Use of a Standard ISA	• Reduces number and types of viable vendors because of its uniqueness • Requires verification	• Establishes commonality among computers • Reduces software development costs	

2

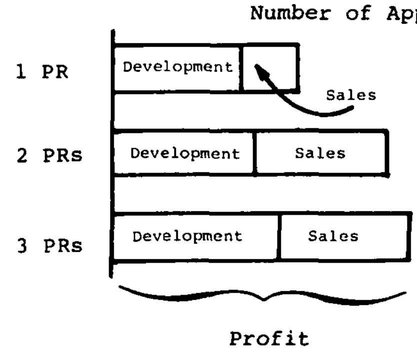
Table 2. Factors Requiring Cost-Benefit Analysis (1 of 2)

Factors Supporting Navy Goals	Representation of Net Effect of Trade-off
Competition among multiple vendors will yield price and performance improvements Improved technology will be obtained Navy will have option to terminate unpromising development efforts Increased performance in upward compatible computers will be gained	 
Improved reliability decreases frequency of maintenance and cost of spare parts Modular design facilitates maintenance Use of system diagnostics reduces MTTR	
Use of system diagnostics reduces requirement for upper echelon training	
educed by competition	
stablishes commonality among omputers educes software development costs	

		Factors Discouraging Participation	Factors Encouraging Participation
Conflicts Among Issues Related to Vendor Goals	Factors Involved in Doing Business with the Navy	• Unique expertise required to handle Navy standards and requirements • Lack of clarity about Navy goal (technological and philosophical) • Differences between characteristics of Navy and commercial markets • Suitability of product line for Navy market • Unpredictable saleability of finished computer	• Increased information on Navy goals • Increased information on procurement procedures and requirements
	Size of Market and Potential Profit	• Military market is small in comparison with commercial market • Multiple computers (i.e., vendors) per PR can reduce potential market size	• Low risk profit for development • Families of computers can increase potential market size

1

Table 2. Factors Requiring Cost-Benefit Analysis (2 of 2)

Factors Encouraging Participation	Representation of Net Effect of Trade-off
• Increased information on Navy goals • Increased information on procurement procedures and requirements	
• Low risk profit for development • Families of computers can increase potential market size	Profit Sources as a Function of Number of Applicable PRs 

The effect of competition in decreasing costs is widely touted and is evidenced in our society at large. In fact, the ramifications of competition for EDP equipment prices is readily apparent in the decline of IBM mainframe prices since plug compatible machines (PCMs) were introduced[20,21]. The development of functionally identical mainframes that were and are directly price and performance competitive forced IBM to significantly cut prices. In some cases the price reductions were not the result of technology improvements but rather marketing decisions. Similarly, the favorable price/performance ratio for small computers is undoubtedly the result of a highly competitive market as well as technological progress. Nonetheless, the Navy and commercial markets differ enough in character and requirements that the existence of competition for Navy business cannot be taken for granted. However, if competition materializes, there is every reason to believe that price gains will follow.

Acquisition of state-of-the-art-technology can be expected to reduce maintenance costs. The improved technology will provide gains in MTBF and MTTR as well as reductions in costs for spare parts. These gains can be estimated by comparing Navy and commercial maintenance costs as related to hardware costs. Data provided by Naval Underwater Systems Center[22] indicates that the cost of consumed spare parts per year is $3,000-$8,000 for a UYK-20. The cost of a DS per year per computer is $15,000-$30,000. If the low end values are totaled for a $55,000 UYK-20, the yearly maintenance cost ($18,000) is approximately one third of the purchase price. For the UYK-7, maintenance costs amount to a little less than 10% of the $275,000 purchase price. Industry experience[12], however, indicates that maintenance costs amount to 7% to 15% of hardware costs. While industry maintenance costs are affected by market situations (and expected to rise) and militarized hardware costs are higher than those for industry, there is a substantial potential for savings by the Navy in maintenance costs.

SECTION 4. IMPLEMENTATION OF THE ACCREDITATION PROGRAM

In this section, the recommended actions and responsibilities of the participants in the Accreditation Program proposed by PRC/ISC are specified. These topics were initially identified during the analysis of the factors associated with the proposed policy. A chronology of activities is presented that extends from the preparations for instituting the program through the actual policy procedures and the participants who perform them. First the responsibilities of the policy administrator in initiating the program are discussed. Then the actual policy procedures are specified.

4.1 Preparations for the Accreditation Program.

There is a considerable amount of data collection and planning that must be performed before the accreditation of computers can begin. The requisite actions are specified in this section. Most of these activities will be performed in parallel, culminating in a methodology for the Accreditation Program. These activities are summarized in Figure 4 which provides a feasible timetable for the initiation and execution of the Program.

The methodology of the Accreditation Program must be stated to provide guidance to all of its participants regarding its goals and how they can be achieved. The planned relationship between the Navy and vendors must be stated and must stress the importance of the policy in providing benefits to both the Navy and vendors. The three essential elements of this relationship are the expected competition among vendors, the funding of computer development by the Navy and the treatment of accredited computers as commodities to be purchased by Program Managers.

The methodology should not be formulated in a vacuum, i.e., with only the Navy's input. Comments as well as original ideas should be solicited from vendors (perhaps through an attitudes

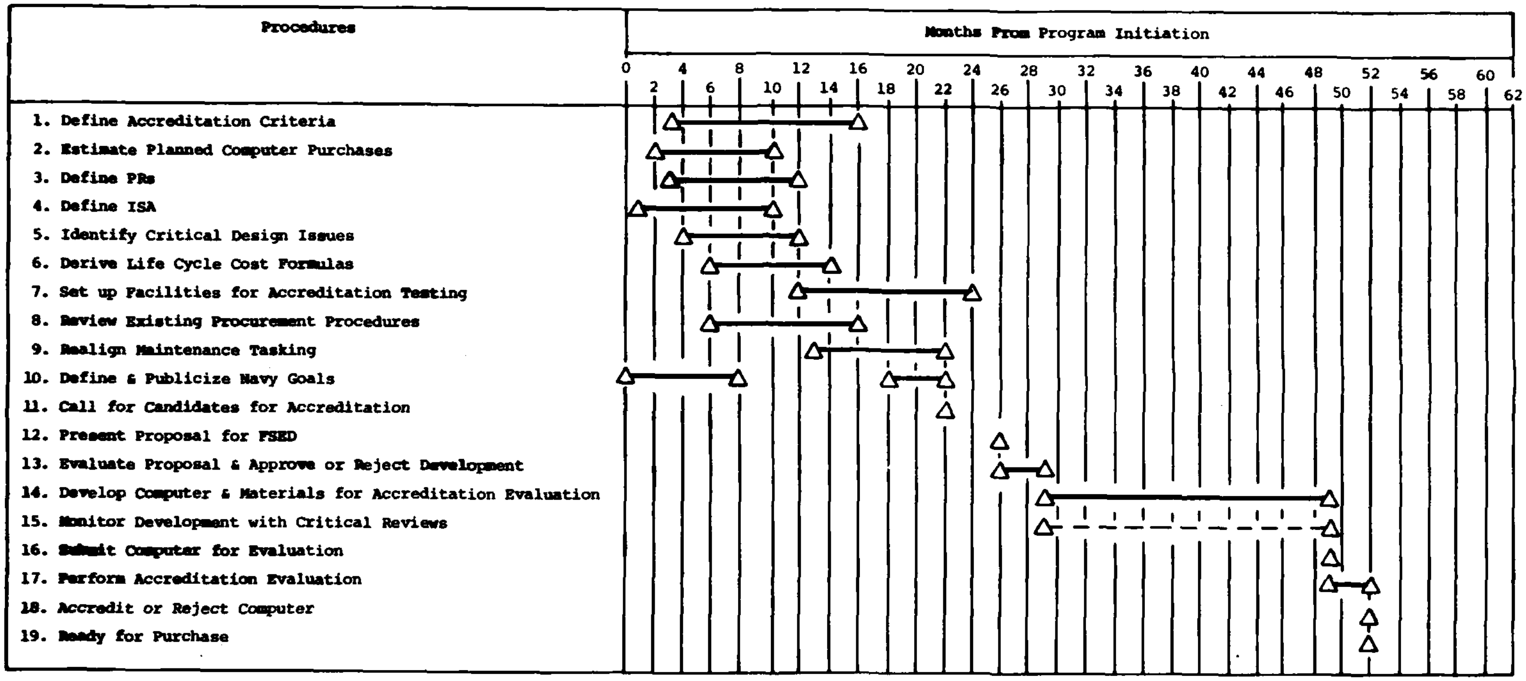


Figure 4. Tentative Timetable for Initiation of Accreditation Policy

survey) to guarantee a well balanced, complete and effective methodology. Conferences or panel discussions should be held with a wide spectrum of Navy and vendor participants.

The Navy will have to collect and evaluate data that is pertinent to its goals as encompassed by the Accreditation Policy. This information will be necessary to support the process described in the following sections for defining the policy. The types and sources of the needed information are outlined in Table 3.

The collected data will be essential to the validation of the Accreditation Policy concept, in addition to providing a data base for policy details. The validation could be performed either in conjunction with a decision as to whether or not the program should be undertaken or as part of the first call for candidates for accreditation. While validating the concept prior to initiating the program is the more prudent technique, it must be recognized that any vendor supplied data carries no commitment and may be influenced by marketing goals rather than technical plans.

4.1.1 Define Accreditation Criteria (Policy Administrator).

The criteria used in judging the suitability of a candidate computer for addition to the list of accredited computers must be formulated. These criteria will define the ground rules for vendor efforts and allow the Navy to formalize the technical basis for its computers. As proposed, the evaluation criteria would encompass three areas:

- Design Constraints - These guidelines define characteristics of a computer which will facilitate its effective use in tactical systems.

  The formulation of performance bounds for PRs will give some guidance for the uses that the Navy envisions for its computers. The definition of PRs will also provide a set of guidelines for the classifications for computers (see Section 4.1.3).

Table 3. Data Required for Policy Formulation

Data Source	Date Type and Purpose
Navy	• Projected quantity of required embedded computers: to define Navy requirements for embedded computers and to quantify the potential market available to vendors. • Projected tactical application requirements: to support requirements analysis and definition of the domain of required computers as represented by PRs. • Maintenance personnel projections (requirements and availability): to determine staffing levels and to estimate level of assistance required of technology. • O&M costs: as input for life cycle cost formulas and trade-off analyses. • ISA specification: to establish accreditation criteria. • Electrical and functional computer interface requirements: to establish accreditation criteria. • R&M data for ASUed computers: to provide a basis of comparison for vendor estimates for accredited computers.
Vendors	• R&M data for current and future technology: for comparison with ASUed computers to assess reductions in maintenance costs. • Impact of diagnostic aids: to assess influence on required skill levels and MTTR to validate compatibility of proposed new maintenance tasking and diagnostic technology.

Compliance with the standard ISA(s) will facilitate software portability between systems in addition to defining a set of baseline characteristics against which computers can be assessed. (If the computer cannot accurately execute the standard ISA, it will not be accredited.) Definition of the ISA is discussed in Section 4.1.4.

The electronic interfaces for computers are other design constraints which impact the Navy's use of the embedded computers. Implementation of standard interfaces (such as NTDS, RS232 and 188C) will facilitate the use of a computer with other systems and devices.

The specification of functional standards for front panels and the man/machine interface will make it easier for operations and maintenance personnel to read and understand the state of the computer at any point in time.

- Environmental Standards - Environmental standards will provide a basis for determining the ability of a candidate computer to operate under the environmental stresses imposed on embedded computers. The planned uses of the computers should guide the specification of applicable MIL-SPECs and MIL-STDs as accreditation criteria. This will necessitate a critical evaluation of the utility and cost-effectiveness of existing standards based on an analysis of historical data on reliability, experienced environmental conditions and resulting costs.

- Life Cycle Costs - A candidate computer's life cycle costs will be used to estimate the total cost of the computer to the Navy. Life cycle cost formulas will be used which incorporate all of the cost elements associated with the life cycle of a computer. The computed life cycle costs will be compared with those of listed computers to support an evaluation of the candidate's cost-effectiveness and return on investment as represented by reduced life cycle costs.

4.1.2 Estimate Planned Computer Purchases (Policy Administrator).

Several aspects of the policy require that the Navy analyze its projected computer requirements to establish an estimate of the number and type of computers that will be procured over time. This information will allow the Navy to gain a better perspective on its anticipated requirements and costs while providing input to trade-off analyses. The procurement projections will also be useful to vendors in their efforts to gauge their costs and production requirements.

These projections can best be ascertained by canvassing Program Managers and planning agencies cognizant of system implementation plans the budgetary considerations. Periodic reviews of the projections should be performed to provide timely input to procurement plans and the trade-off analyses by both the Navy and vendors.

4.1.3 Define Performance Ranges (Policy Administrator).

PRs play an essential role in categorizing the Navy's computational requirements in addition to providing a basis for comparison of computers. Accordingly, each PR will define a bounded range of computational performance as defined by three computational performance parameters: thousands of operations per second (KOPS), composite data transfer rate over external I/O interfaces and interrupt response time. Each of eight distinct PRs will be defined by the three parameters, each having a medium or high level of performance for each PR.

The minimum value for the levels of each parameter will have to be defined on the basis of requirements for performance specified for planned systems. Current and expected technology will have to be assessed to determine the feasibility of the requirements.

Then the planned systems should be mapped onto the PRs to determine if the mapping argues for fewer or more PRs. More PRs can be established by refining the medium and high levels into additional levels. Similarly, PRs can be consolidated by providing for a single level of performance for a particular parameter.

The specification of PRs categorizes the Navy's computers and, in turn, establishes the prospective market size for each PR. Because market size will be a factor influencing the degree of vendor participation in the policy, the definition of PRs must also take into account the effect on the potential market size for vendors.

4.1.4 Define ISA (Policy Administrator).

A dictated constraint of the Accreditation Policy study was that a standard ISA would be executed on all accredited computers. The definition of the ISA would serve as a specification of one component of the design constraints. Whether an existing (i.e., UYK-20 or UYK-7) and/or new ISA were used, it would have to be defined concisely and precisely to facilitate accurate implementation and verification. Specification of the ISA using an effective and widely accepted notation such as ISP would be a means to this end.

The characteristics of the ISA would have to be defined in conjunction with an evaluation of desired and required capabilities as well as the current state of technology. The ISA would have to be functionally complete and responsive to the requirements of the Navy's applications.

A configuration management board would be required to provide ongoing expertise in the ISA. The board would respond to vendor questions about the ISA and handle Navy or vendor initiated Engineering Change Proposals (ECPs) for the ISA.

4.1.5 Identify Critical Design Issues (Policy Administrator).

In Section 3.2.2, trade-offs involved in the specification of both the policy methodology and cost formulas were outlined in the discussion of factors affecting Navy and vendor goals. While most of these issues are of obvious interest to the Navy, the policy should not attempt to establish explicit or rigid requirements (in the form of accreditation criteria) that vendors must meet. Instead, the Navy should communicate to vendors its perception of the issues and the level of attention that should be given those issues. It must be expected that the vendors will then utilize that guidance to meet the Navy's goals and thereby enhance their competitive position.

Some of the trade-offs involve the attitudes of vendors more so than Navy concerns. Therefore, the Navy will have to gain an appreciation for vendor attitudes and expectations. Accordingly, the Navy will better understand the factors affecting vendor actions.

The critical design issues that must be examined are listed below:

- **What is the relationship between expenditures for improved technology (MTBF, MTTR, card level, LRU, and diagnostic aids) and maintenance costs (labor, parts and training)?**

- How will competition among vendors influence FSED costs and computer purchase price?
- How will projected market size and FSED phase profits impact vendors' inclination to participate in the Accreditation Program?
- What influence will constraints of the Navy environment (technological and procedural) have on the tendency of a vendor to participate in the Accreditation Program?

This report has provided speculative answers to these questions. Nonetheless, these issues must be kept in the forefront of the program to ensure that they receive the visibility that is warranted by their importance.

4.1.6 Derive Life Cycle Cost Formulas (Policy Administrator).

The computation of life cycle costs entails the use of cost formulas that incorporate expected costs to the Navy. The cost formulas provide visibility for costs that are not clearly or explicitly billed to the Navy. The formulas are also important in highlighting costs that the Navy considers critical and that should be considered by vendors when making cost/performance trade-offs in their design. The cost formulas can be used to implement or enforce trade-offs by establishing bounds for particular cost elements. Thus, if trade-off analyses indicate that a specific range of costs for an element must be achieved to balance costs and performance, this fact can be clearly stated in the specification of the cost formulas.

The life cycle cost formulas will be used in the evaluation of a vendor proposal for a candidate computer, in the accreditation evaluation for a completed computer, and in determining the cost-effectiveness of a computer in a particular system or application. In each of these instances, the intent of the formula is the same--to define costs for evaluation; yet the specification of costs in each instance may vary as more exact cost data is obtained.

Derivation of cost formulas can be accomplished only through exhaustive listing of the costs involved in each phase of the computer's life cycle followed by a thorough specification of the cost items in each cost element.

Cost formulas must, of course, undergo periodic review to ensure that changes in costs are accounted for and that trade-off decisions remain valid.

4.1.7 Set up Facilities for Accreditation Testing (Policy Administrator).

Facilities and resources must be established to perform accreditation evaluations for candidate computers.

An essential tool in the accreditation testing will be benchmarks. Benchmarks for computational performance will support determination of the applicable PR against which the candidate computer should be compared. Benchmarks will also be required to verify compliance with the standard ISA by thoroughly exercising all aspects of the ISA. Benchmarks would also be used to drive the computer so that its compliance with the interface requirements could be tested. The benchmark testing could be performance at vendor facilities under Navy supervision with government furnished equipment (GFE) to alleviate problems in scheduling tests.

Facilities would be required to test compliance with environmental standards. Existing test facilities could be used to support accreditation testing or similar facilities could be established.

4.1.8 Review Existing Procurement Procedures (Policy Administrator).

The performance of some ASU testing as part of the accreditation evaluation is warranted by the two ways in which a computer must be viewed: as a device standing alone and as a component in an operational system. ASU procedures treat the computer completely within the context of an operational capability. The Accreditation Policy will divorce the computer from any system or operational context, yet subsume some of the testing and evaluation currently performed as part of ASU. There are several activities associated with the ILSP that can be performed in the accreditation evaluation: (1) analysis of the materials related to tasking, skill levels and training for the three levels of maintenance, (2) limited performance of PM and corrective maintenance for the derivation of experienced MTBF and MTTR values, (3) assessment of the spare parts plan, and (4) evaluation of MRCs and technical manuals. This evaluation will require that expertise extant in OPTEVFOR be utilized during the accreditation evaluation.

In general, a similar overall review of procurement policies and practices must be performed to (a) evaluate their relationship to the Accreditation Policy methodology, and (b) determine if the goals of the procurement policies can be accomplished better or for lower costs as part of the Accreditation Policy.

4.1.9 Realign Maintenance Testing (Policy Administrator).

The division of maintenance into lower and upper echelon tasks is an essential element in the long-term viability of the proposed Accreditation Policy. Initially, the current maintenance workload should be categorized into lower and upper echelon tasks to assess the potential benefits of system diagnostics for each.

As diagnostic tools (in concert with modular card level hardware design) become available that can reduce the level of expertise needed to perform lower echelon maintenance, personnal grades and training requirements should be better matched to the requirements of lower echelon tasks. This matchup can be exploited when the cost of the training for lower echelon maintenance is outweighed by the lower costs resulting from the reduction of the workload for personnel currently performing all types of maintenance. These trade-off decisions must be made on the basis of data gathered on the effectiveness of the diagnostic tools, the training requirements for lower and upper echelon tasks and the costs of maintenance labor.

4.1.10 Define and Publicize Navy Goals (Policy Administrator).

The Accreditation Policy has the goal of helping the Navy to obtain cost-effective systems that provide required, militarily effective capabilities. The statement of this goal in more detailed terms will be required to educate the participants in the policy. Such a statement must encompass rationale for policies, procedures and standards as well as specification of technological and capability objectives. The documentation of these issues will improve the Navy's understanding of its own direction.

All aspects of the Accreditation Policy should be communicated in publicized regional conferences and national publications to ensure the widest possible dissemination of this vital information.

4.2 Accreditation Program Procedures.

Procedures involved in the establishment of a list of accredited computers and the use of those computers are discussed below. The policy procedures are summarized in Table 4. The respective responsibilities of the Policy Administrator and the Program Manager are depicted graphically in Figure 5.

Table 4. Policy Procedures

Policy Administrator	Vendor	Program Manager
• Call for candidates for accreditation		
	• Present proposal for FSED of a candidate for accreditation	
• Evaluate proposal and approve or reject development effort		
	• Develop computer and materials for accreditation evaluation	
• Monitor development with critical reviews		
	• Submit computer for evaluation	• Evaluate accredited computer based on requirements and life cycle costs
• Perform accreditation evaluation		• Select an accredited computer for use in tactical system
• Accredit or reject computer		
	• Produce computers for shipboard use	• Purchase selected computer
		• Establish logistics capability for computer
		• Develop tactical system
		• Have tactical system approved for service use
		• Install computer for operational use

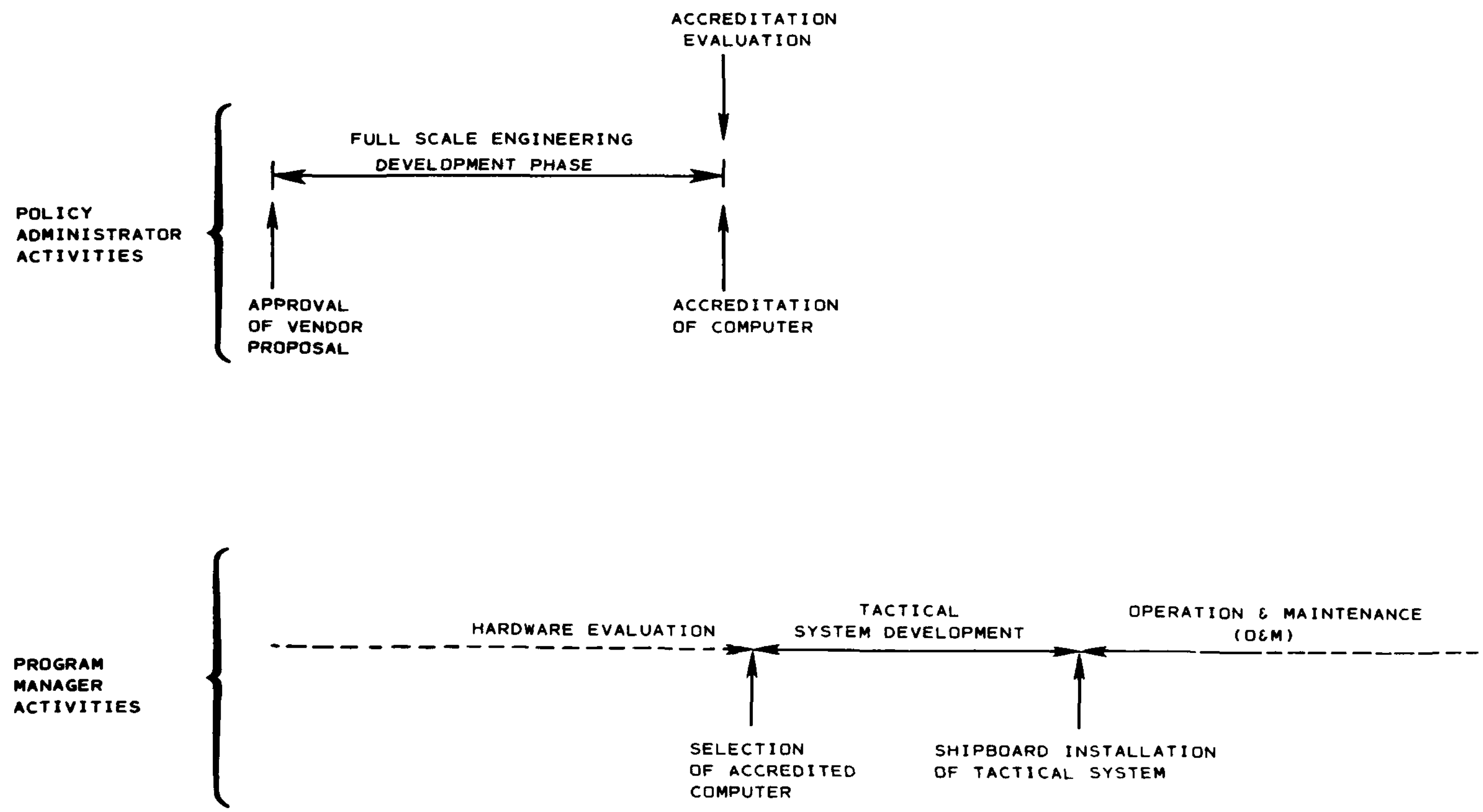


Figure 5. Responsibilities of Policy Administrator and Program Manager

4.2.1 Call for Candidates for Accreditation (Policy Administrator).

Once the requirements, procedures and methodology of the Accreditation Policy have been established, a call for candidate computers for accreditation would be made. The call for candidates should be widely publicized to increase the response from vendors. The call for candidates would, in effect, be an RFP directed to the entire computer industry.

On the initial call for candidates, special waivers or allowances might be necessary to overcome inertia and get the Accreditation Program underway. The RFP would be reissued on a periodic basis to encourage first time or ongoing participation by vendors. Existing standard Navy computers would be effectively guaranteed accreditation since they already meet the overwhelming majority of the proposed accreditation criteria and would provide a basis for comparison.

4.2.2 Present Proposal for FSED for a Candidate Computer (Policy Administrator).

Vendors would then submit a proposal for the development of a candidate computer for accreditation in a particular PR. The proposal should be responsive in providing the vendor's credentials, technology base and plans for meeting the accreditation criteria. The implementation plans would, by implication, convey the vendor's understanding of the policy, the accreditation criteria and the Navy's requirements. The timetable, resource requirements and costs of the development effort would be specified in the proposal.

4.2.3 Evaluate Proposal and Approve or Reject Development Effort (Policy Administrator).

The Policy Administrator would evaluate the vendor's proposal from four perspectives: technical feasibility, potential for technological and cost improvements to Navy computers, likelihood of successful completion within cost and likelihood of accreditation. The evaluation of these points would determine whether or not the development effort would be approved.

Suitable Navy resources would have to be available to make the necessary judgments in evaluating the proposals. The number of proposals that could be approved for funding would depend on the available budget for FSED activities. Initially, funding should be geared towards getting at least two computers into each PR.

4.2.4 Develop Computer and Materials for Accreditation Evaluation (Vendor).

If a vendor's proposal were accepted and approval given for the development of a candidate computer, the computer itself and supporting documentation would be produced. The following documentation would be required of the vendor:

- Design documentation for the computer
- Technical manuals
- Operator and maintenance procedures documents
- ILSP

In addition, more exact performance and cost data than that provided in the proposal would have to be specified for use in the life cycle cost analysis.

A set number of prototype units (three or four) would be produced to satisfy requirements for different types of accreditation testing, possibly at different locations.

4.2.5 Monitor Development with Critical Reviews (Policy Administrator).

The Navy would monitor the vendor's progress by performing scheduled critical reviews of technical and cost status. The cost reviews would guard against the incorrect application of funds or overruns. The technical reviews would permit an ongoing assessment of the chances for successful completion and accreditation. The critical reviews would provide the Navy with the opportunity to terminate or redirect development when justified by the status of the effort.

4.2.6 Submit Computer for Evaluation (Vendor).

Once the vendor had completed the development effort, the computer would be submitted to the policy administrator for an accreditation evaluation. The timetable for the evaluation would have been agreed upon as part of the proposal.

4.2.7 Perform Accreditation Evaluation (Policy Administrator).

Once a computer has been submitted, it would be evaluated according to the accreditation criteria: design constraints, environmental standards and life cycle costs. The computer's compliance with the design constraints would be tested with benchmark and operational tests. Satisfaction of environmental standards would be tested in accordance with applicable MIL-STDS.

The computer's life cycle costs would be computed using the policy's life cycle cost formulas. The computed costs would be in current dollars (to account for inflation, etc.) and compared to the costs of already listed computers in the appropriate PR. The cutoff cost would be the value that a candidate would have to better to be listed.

4.2.8 Accredit or Reject Computer (Policy Administrators).

The results of the accreditation evaluation would be used to support a decision to accredit or reject a candidate computer. If the computer received accreditation it would be added to a published list of accredited computers. Program Managers with a computer requirement would consult the list for current offerings. If the computer were rejected it would not be listed, but could be resubmitted following resolution of any deficiencies.

4.2.9 Evaluate Accredited Computers on the Basis of System Requirements and Life Cycle Costs (Program Manager).

A Program Manager with plans to develop an application or system using an embedded computer would consider only those computers on the accredited list. The Program Manager would first assess his computational performance requirements to determine the most suitable PR from which to choose. The vendors for the computers in the PR would be contacted to verify that the computer could be provided as required. If the vendor were unable to supply the computer as needed, that computer would be excluded from further consideration in the program manager's selection process.

The computers within the selected PR would be evaluated in two ways: (1) their ability to satisfy the Program Manager's requirement as represented by performance characteristics (including MTBF, MTTR, Size, etc.) and (2) the life cycle costs of the planned system with each of the listed computers. The computer deemed best (i.e., with lowest total life cycle costs) on the basis of this evaluation would be selected.

4.2.10 Purchase Listed Computer (Program Manager).

Following the comparison of his requirements with the capabilities of accredited computers in the appropriate PR, the Program Manager would initiate procurement of the selected computer in a quantity and to a schedule suited for his program. The procurement decision would be communicated to the Policy Administrator to ensure that any available information about the vendor or computer was taken into consideration. The Policy Administrator would also use this feedback to fine tune the methodology, procedures and data used throughout the policy. However, the Policy Administrator would have no mandated influence on purchase plans.

4.2.11 Produce Purchased Computers (Vendor).

The vendor for a computer selected for purchase would provide the purchaser with a purchase price and a delivery schedule. (The inability of a vendor to handle a "reasonable" purchase could result in the computer being removed from the list.)

4.2.12 Implement Logistics Support for Computer (Program Manager).

The first use of a computer would require the institution of a logistics support capability. This would involve the following activities:

- Establish and stock an Inventory Control Point (ICP).
- Establish parts list using Navy part numbers.
- Establish facilities for depot level maintenance and support.
- Institute training programs for operators and maintenance personnel.

4.2.13 Develop System with Accredited Computer (Program Manager).

The delivery schedule for purchased computers will have to include initial production units available for developing software for the planned operational capability. (The functional interchangeability of accredited computers would allow the earliest stages of software development to be performed on more readily available units of another accredited computer if necessary.)

4.2.14 Have System Approved for Service Use (Program Manager).

Although the viability of some logistics and support features of the computer would be confirmed at the time of the accreditation evaluation, others (including operational effectiveness of the system) would continue to be verifiable only in the course of OT&E for ASU. Thus, it would still be necessary for a Program Manager to gain ASU for the computer as part of his operational system (rather than for the computer itself), via a Test and Evaluation Plan instead of a Test and Evaluation Master Plan.

4.2.15 Install Computer for Operational Use (Program Manager).

The POA&M for the Program Manager's system would include a timetable for the shipboard installation of the system (and the included computer) for both OT&E and full scale shipboard use. The installation of the computer would be performed by either Technical Representatives, shipyard personnel or the ship's own force. The installation would have to be coordinated with the provision of spares and the availability of trained operators and maintenance personnel as well as supporting documentation.

SECTION 5. SUMMARY

The Accreditation Policy proposed in this report is intended to define a Navy management approach to accreditation that will lead to the acquisition of more cost-effective embedded computers.

Although the report could have proposed a strategy that tied Navy actions to a specific timetable for technological milestones, it was deemed more useful to define a comprehensive framework for dealing with vendors in order to obtain improved technology.

Several of the Navy's goals (e.g., improved reliability and maintainability of computers) are reflected in the commercial world. Therefore, it can be expected that sizeable gains will accrue to the Navy if a symbiotic relationship can be established (via the Accreditation Policy) between the Navy and vendors. The commercial marketplace has, to date, controlled the pace and direction of maturing technology. There is little reason to believe that the Navy can expect to exert any significant influence on technology trends. Instead, the policy should allow the Navy to ride the wave of technology.

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