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A LOCAL AREA NETWORK AND INFORMATION MANAGEMENT SYSTEM
FOR A SUBMARINE OVERHAUL FACILITY

by

Jeffrey D. Bushmire

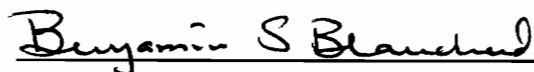
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APPROVED:



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System Engineering

(ABSTRACT)

A preliminary design of a local area network for a submarine overhaul facility is developed using System Engineering concepts. SOFLAN, the Submarine Overhaul Facility Local Area Network, is necessary to provide more timely and accurate information to submarine overhaul managers in order to decrease the overhaul time period and become more competitive.

The network is a microcomputer based system following the Ethernet and IEEE 802.3 standards with a server-client architecture. SOFLAN serves thirty-five users at various offices and overhaul facilities throughout the shipyard. The network provides a medium to transmit information between and across various organizations. Applications resident on the network include a database management system, file transfer, word processing and electronic mail.

SOFLAN replaces the existing manual systems currently in use at the shipyard. The system life cycle is twelve years from development to phase-out with a cost over the entire life cycle of approximately two million dollars.

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CHAPTER 1

INTRODUCTION

1.1 - Overview

The overhaul of the nations nuclear submarine fleet is becoming increasingly competitive. Privately owned shipyards are now competing with naval shipyards for work. The government is turning to its own facilities is because private yards have not performed up to standards. Overhauls are taking longer, especially in the nuclear power plant area. An overhaul that previously took eighteen months to complete is now taking over twenty-four months. There are several reasons for the increase in the overhaul period:

- Morale in the shipyard is low due to recent layoffs incurred by the reduction in work,
- Navy crews are inadequate for the overhaul resulting in a crew that is over-worked and thus unresponsive,
- Components not scheduled for overhaul are found inadequate,
- Stricter controls by government support agencies on the overhaul process,
- The inability to effectively track and retrieve information pertaining to the overhaul status of systems and components,
- Delays in transporting critical documents throughout the shipyard by mail.

The shipyard only has direct control over two of these problems; the inability to obtain effective information regarding the status of the overhaul and the delays caused by transporting documents by mail.

Currently, the development and tracking of the documents that drive the overhaul process takes too much time. Information provided by the current system is incomplete and inaccurate causing further delays. If the privately owned shipyards are to remain competitive for a portion of the decreasing defense budget then action must be taken to reduce the time of a submarine overhaul, especially in the areas of document control and determining the status of work-in-progress.

1.2 - The Current System

One of the private shipyards that overhauls and refuels the U.S. Navy's nuclear submarines uses a manual system for reporting and tracking work on shipboard equipment and for the management and control of procedures. In order to maintain strict controls on the overhaul of the nuclear power plant and support systems, work permits and discrepancy reports are used. A discrepancy report is written by a quality inspector when a component does not meet certain specifications such as size, cleanliness, or operability. When the discrepancy report is resolved, i.e., a method to fix the problem is determined, a work permit is issued. A work permit allows tradesmen to work on the

component in accordance with the resolution to the discrepancy report.

Besides allowing the work of discrepancy report resolutions, a work permit is also used to control the work of components that are normally overhauled or replaced. Two to three thousand work permits are generated during a single overhaul of which approximately one-half are associated with discrepancy reports. When six ships are in overhaul, over 20,000 discrepancy reports and work permits are in need of control. This does not include the documents from ships that have completed overhaul that could supply historical data.

The current method of handling discrepancy reports and work permits is manual. A discrepancy report is first generated by a quality inspector. A clerk then hand-carries the discrepancy report to engineering where a technical engineer researches the problem and provides a technical investigation to the discrepancy or problem. The technical investigation is again hand-carried back to the waterfront where it is distributed to the necessary parties. A work permit is then written by a test engineer to allow work to start on the discrepant component.

Average processing times from discrepancy report generation to start of work are listed in Table 1.2-1. The information in the table shows that over 27% of the processing time is attributed to transporting the discrepancy report. With 1000 discrepancy reports per ship, 1500 hours are wasted. Of this time, approximately 500 hours or 12.5 work-weeks are attributed to stagnation

Table 1.2 - 1 Average Discrepancy Report Processing Times

Discrepancy Report Generation	1 hour
Transport of Discrepancy Report	
Actual transporting of document	30 minutes
Average wait on mail run	1 hour
Technical Investigation	2 hours
Generate and Issue Work Permit	1 hour
TOTAL	5.5 hours

periods where workers are idle, waiting for the necessary paperwork to begin work.

A five member board, called the Joint Test Group (JTG), is responsible for planning, scheduling, and approving work. The members are senior personnel from the shipyard (chairman), NAVSEA 08, SUPSHIP, the reactor plant contractor (Westinghouse or General Electric), and a representative from the ship's crew, usually the Engineer. The members of the JTG are experienced in shipboard operations and overhaul procedures. Items approved for work are listed on a document called the Test Plan of the Day (TPOD). The TPOD lists items that were planned to be worked during the overhaul and those driven by discrepancy reports. Figure 1.2-1 shows the flow of information in the existing system.

An overhaul of a submarine is performed in distinct stages called major evolutions. Before a major evolution can start, certain systems must be intact and operational. One method to determine operability is by the number of work permits and discrepancy reports that are outstanding on a particular system. This information is used by the JTG to plan test evolutions and by construction supervisors to ready equipment and personnel.

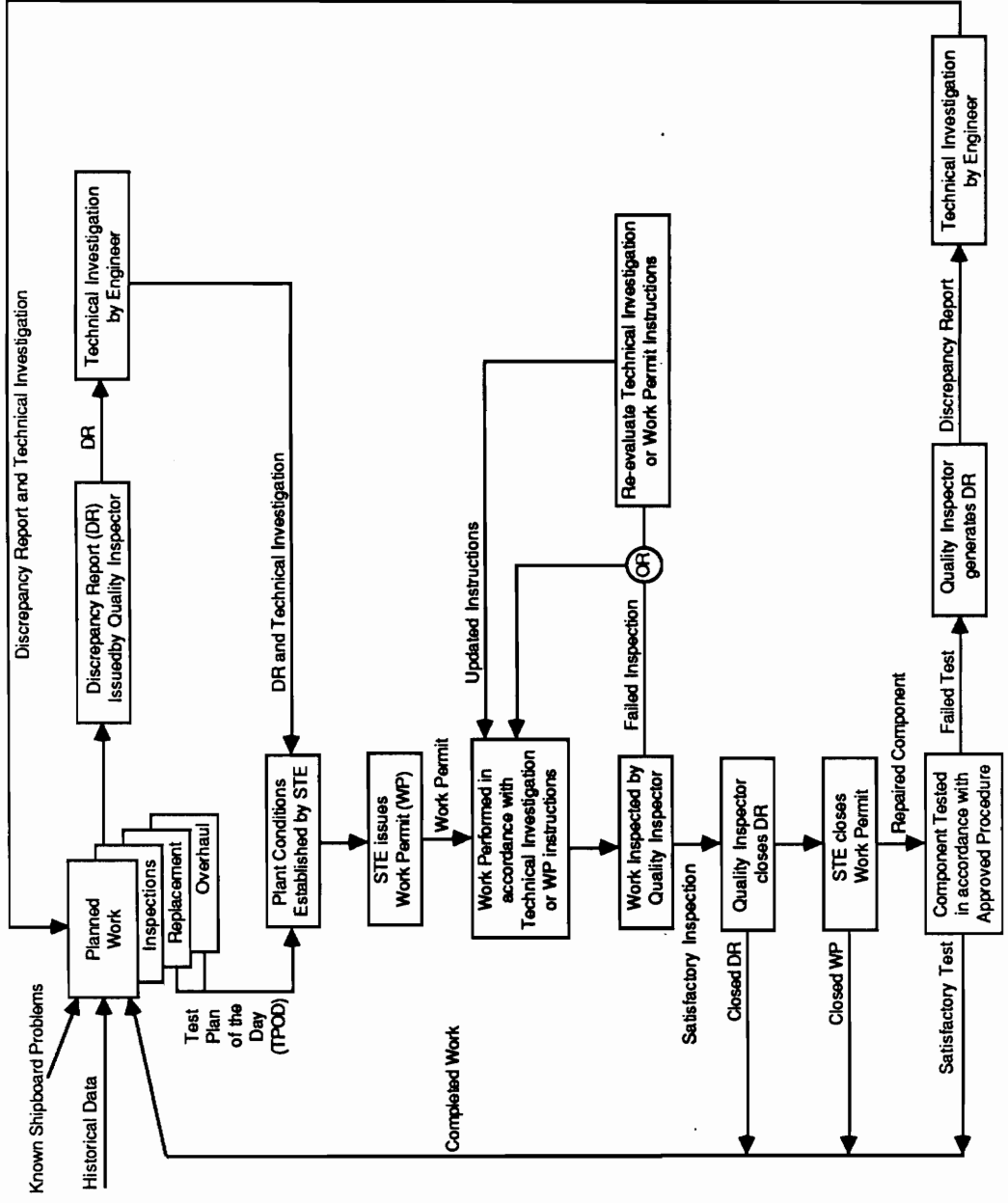


Figure 1.2 - 1 Functional Flow of Data in the Existing System

The following shortcomings are noted for the existing manual system:

- 1) Discrepancy reports and technical investigations are hand carried between various departments wasting valuable time as indicated in Table 1.2-1.
- 2) Management spends first thirty minutes of work day trying to determine what work was started on the night shifts.
- 3) Retrieving historical data on a previously worked components takes an average of one hour.
- 4) Retrieving information on past discrepancy report technical investigations averages two hours.
- 5) Determining the relationship between a discrepancy report and its associated work permit averages thirty minutes.
- 6) Management does not have information readily available to determine if scheduling milestones will be achieved.

In addition to the manual system currently used for work permits and discrepancy reports, a similar process is used for the management and control of procedures. Typewriters, instead of word processors, are used to create new procedures. The disadvantage, besides the inability to easily make corrections, is that a change made at a later date, such as adding a step, requires the entire

page be re-written or the step squeezed in along the margin or between existing steps. Changing procedures brings about the most significant problem in controlling these documents. Changes to procedures, called Test Change Notices (TCN), are handled in a manual fashion. The TCN is typed or hand written. Because of the necessary strict controls on procedures used for a nuclear submarine overhaul, all changes must be approved by the five members of the JTG or their designated alternates. The chairman initiates the TCN which is either hand carried to each member or the member must come to the chairman's office and approve it by signature. The average time to process a typical TCN is two hours of which one hour is attributed to waiting for signatures. There are 250 procedures used during the overhaul of a single ship. An average of two TCN's are written for each procedure resulting in 500 hours waiting for signatures.

1.3 - Need

An automated system is necessary to alleviate the shortcomings of the existing system. The time spent transporting discrepancy reports, retrieving information and waiting for approval of TCN's must be reduced.

A networked, microcomputer based information system that is more responsive and simple to use is required to replace the existing manual systems to increase productivity by reducing stagnant periods while waiting for

information. The following section specifies the requirements of the needed system.

1.4- System Objectives and Requirements

The objective of the system is to reduce the time transporting discrepancy reports, retrieving information and processing changes to procedures. Table 1.4-1 lists the data processing objectives and requirements of the new system.

The network will serve thirty-five users with the capability of expansion to fifty. The distance between any two users is less than one kilometer. The system will operate 24 hours per day, 350 days per year. The anticipated MTBM is 1050 hours with a MTBF of 2100 hours, a MDT of 4 hours and an operational availability (Ao) of 97%.

The average traffic throughput anticipated for the system is shown in Table 1.4-2. The peak throughput rate of the system is 166-Kbps. A growth factor of 10 has been applied to derive a peak throughput rate of 1.66-Mbps as the requirement for the system.

1.5 - Project Scope and Objectives

The purpose of this project is to provide a preliminary design of a network to

Table 1.4 - 1 Data Processing Objectives

	CURRENT	REQUIRED
Discrepancy Report Transport Time	1.5 hours	<1 minute
Test Change Notice Sign-off	1 hour	<10 minutes
Determination of Work Started on Night Shifts	30 minutes	<2 minutes
Data Retrieval of Previously Worked Components	1.5 hours	<2 minutes
Retrieval of Past Technical Investigations	2 hours	< 5 minutes
Determination of Relationship Between Discrepancy Report and Associated Work Permit	30 minutes	< 1 minute

Table 1.4 - 2 Average Traffic Throughput

	Daily (Mbits)	Hourly (Kbits)	BPS	Peak BPS
Work Permits	4.0	170	50	17408
Discrepancy Reports	9.0	384	110	39320
Procedures/TCN's	16.0	680	194	69632
Electronic Mail	3.0	128	36	13107
Data Retrievals	6.0	256	72	26214
Total	38	1618	462	165681

facilitate the retrieval and transfer of information between the organizations involved in a submarine overhaul. The development of the design follows the System Development Life Cycle (SDLC) technique presented by Blanchard (1). Figure 1.5-1 represents the evolution of system design. This project addresses, specifically, the definition of need, conceptual design, including the system operational requirements and maintenance concept, system functional analysis, including functional requirements and operational and maintenance functions, preliminary synthesis including the allocation of performance factors, design factors, effectiveness requirements and system support requirements. The system is optimized by evaluating alternatives throughout the development of the project. The project is finalized by a life cycle cost analysis and the development of a prototype of one of the software applications to be incorporated in the system. Actual design and life cycle support of the system is considered outside the project scope and should be considered only if the company accepts the preliminary design and decides to invest in the system.

The objectives of this project are:

- 1) Learn about the design, development, and operation of local area networks and information systems,
- 2) Apply and learn Systems Engineering concepts

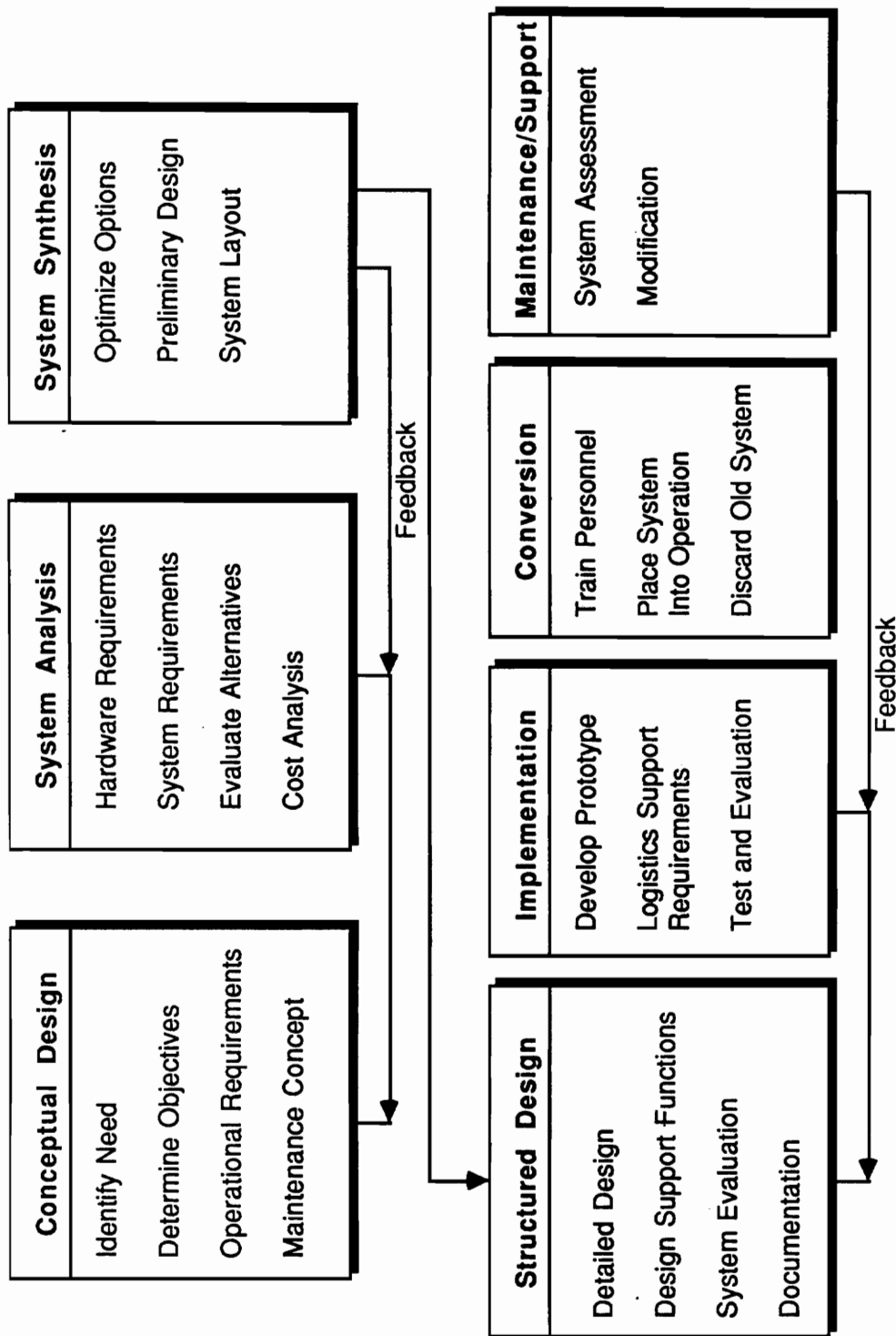


Figure 1.5 - 1 Evolution of System Development

1.6 - Assumptions

Key assumptions made to simplify the preliminary design and development of the system are :

- 1) Currently no communications equipment, such as computers, peripherals or transmission media, or communications software exists that must be considered in the design of the network.
- 2) A majority of the software used in the design is purchased over-the-counter, limiting the number of personnel required in the development.
- 3) The network employs accepted industry standards allowing the possibility of future compatibility with other networks and a better chance of compatibility among various vendors.
- 4) The peak throughput rate is 10% of the hourly throughput rate.

CHAPTER 2

CONCEPTUAL DESIGN

Conceptual design is the first step in the evolution of system design. It is comprised of a feasibility study, which covers the needs analysis, operational requirements and the system maintenance concept. These concepts lead to an initial system specification.

2.1 - The Need for Speed

The system the shipyard is using is cumbersome and unresponsive. Competition is increasing with other privately owned and government controlled shipyards. To gain a competitive advantage in the overhaul business one must differentiate from the others; be innovative [2]. A new system for handling the work-in-progress and the control of procedures is a must. These processes must be automated to save man-hours, reduce overhaul stagnation periods and allow flexibility. Overhaul managers need the capability to quickly and easily retrieve and communicate information across their organization. Preparation, updating and storage of documentation by electronic word processors and communication by electronic mail is critical in today's era of automation. Software applications are available to make these processes possible but the

users must be networked together if they are to be beneficial. Figure 2.1-1 gives a user's perspective of the network functions.

2.2 - Operational Requirements

The system operational requirements establish the technical parameters of the system. They include items such as speed, performance, quantities of equipment and personnel, location of the system, how the system will be used, effectiveness factors, and the environment in which it will operate. Each operational concept is discussed individually. Defining these parameters will lead to the definition of the system operational characteristics, the maintenance concept and the design criteria of the system. [1] One must keep in mind that when defining the operational requirements, the designer may be slightly biased. That is, the designer may have a design already in mind and would tailor the requirements to meet this design.

2.2.1 - Mission Definition

The primary mission of the system is to provide a data communications network to link the various organizations and departments involved in the overhaul of a nuclear submarine. The system should provide a database management system for the storage and retrieval of information associated with

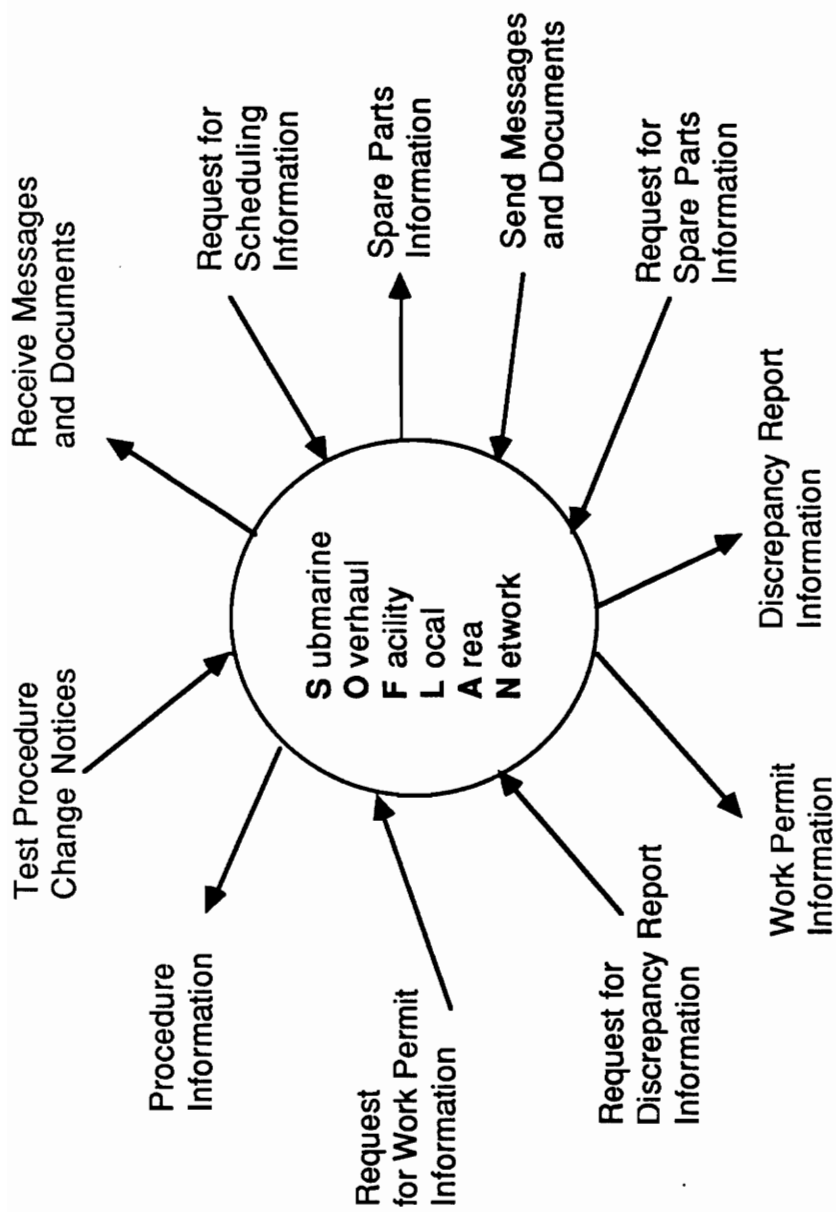


Figure 2.1 - 1 Functions of the Network: A User's Perspective

work-in-progress. Management and control of procedures must start with magnetic file storage and electronic editing capabilities. Additionally, the system should provide processes such as word processing, electronic mail, and graphics capabilities. The system must be expandable to include the future implementation of a parts inventory and sourcing system as well as a scheduling and planning utility.

2.2.2 - Performance and Physical Parameters

The performance and physical parameters define the operating characteristics of the system. [1] The parameters are defined for each individual subsystem. The subsystems include the communications network, comprising of the cabling, interface cards, and transceivers, the microcomputers and peripherals, the application software, and the operating and networking system software.

2.2.2.1 - Communications Network

As stated above, the communications network subsystem consists of the cabling, interface cards, and transceivers. The cabling must be robust enough to withstand a harsh environment. It must permit the connectivity of thirty-five

stations, expandable to fifty. The maximum distance for transmission between various buildings does not exceed one kilometer. The throughput at peak load is 1.66 Mbps. The cable must be compatible with commercially available equipment and must provide for future expandability. It should be capable of withstanding a fairly high level of interference from surrounding electrical equipment. The interface cards must be compatible with the chosen network configuration standard, i.e., Ethernet, Arcnet, IEEE 802, token ring, token bus, as well as the chosen microcomputer and the network and operating system software. The card shall have at least a 16-KByte buffer. The transceivers must also be compatible with the chosen network configuration standard, interface cards and cabling.

2.2.2.2 - Microcomputers and Peripherals

The microcomputers used in this application shall be IBM PC or PC compatible. This type of microcomputer is chosen because of industry standards and familiarity. The microcomputer shall have the following specifications:

- 16 bit, 10MHz, 286/386 CPU
- 1-MByte RAM
- 1.2-MByte internal disk drive
- VGA color monitor

- Expansion slot for network interface card
- 40-MByte internal hard drive

The peripherals for the system include dot matrix and/or laser printers. Each printer is dedicated to the workstation, therefore a print server is not required.

There is only one file server in the system. The file server manages the shared hard disk and makes sure that multiple requests do not conflict with each other. Based on the data in Table 2.2.2.2-1, a 200 Mbyte hard drive is required to store data necessary for a six-ship overhaul operation. A 40-MByte cartridge drive is required for backup purposes and is dedicated to the file server.

The file server is a 80386-based machine running at 16 MHz. The server has 4 MB of RAM to take advantage of the disk-caching capabilities of the NOVELL network operating system, a 1.2 MB floppy drive and a heavy duty power supply and cabinet capacity to support the necessary peripherals such as hard and cartridge drives.

2.2.2.3 - Application Software

Several different types of applications coexist on the system. The application software is the software the user will use to interface with the data stored in the server. The applications actually reside on the individual PC's at each station

Table 2.2.2.2 - 1 Memory Requirements

MEMORY REQUIREMENTS BREAKDOWN

Maximum Work Permit Size - 2KB
Maximum Discrepancy Report Size - 4KB
Maximum Procedure Size - 100KB
Work permits per Ship - 2000
Discrepancy Reports per Ship - 1000
Procedures per Ship - 250
Maximum Number of Ships - 6

Total Memory Size - 200MB

and not on the file server. The following applications and specifications are necessary:

Data Base Management System (DBMS) Software

The DBMS software permits the user to enter, retrieve, report, edit, browse and store data according to needs. The DBMS is a relational type to ensure flexibility and to limit redundant data storage. The software includes a procedural language for the development of programs for frequent requests, menu generation, and other program development. An interactive query language is also necessary for infrequent requests and to allow additional flexibility. This software must support approximately 20,000 records and at least 20 fields per record, including a text field. This will allow adding additional fields should the need arise. The database fields and specifications are shown in Table 2.2.2.3-1. Initially the database must support one file for discrepancy report and work permit information, however, it must be flexible and robust enough to allow expandability.

Electronic Mail Software

This software is used to send messages throughout the network and provides calendar management. The ability to send messages to other users is important since phone contacts are not always possible in the shipyard.

Table 2.2.2.3 - 1 Database Definition

FIELD NAME	TYPE	LENGTH	DESCRIPTION
DR_NUMBER	NUMERIC	5	Discrepancy Report Number
SHIP	NUMERIC	3	Ship Number
SYSTEM	CHARACTER	2	System Designator
COMPONENT	NUMERIC	3	Component Number
DRAWING	CHARACTER	9	Drawing Number
MILESTONE	CHARACTER	11	Completion Milestone
DR_ISS_DATE	DATE	8	Discrepancy Report Issue Date
INSPECTOR	CHARACTER	11	Inspector Social Security Number
DR_CLOS_DATE	DATE	8	Discrepancy Report Closure Date
WORK_PERMIT	NUMERIC	4	Work Permit Number
WP_ISS_DATE	DATE	8	Work Permit Issue Date
WP_CLOS_DATE	DATE	8	Work Permit Closure Date
STE_ISS_WP	CHARACTER	20	Shift Test Engineer Issuing Work Permit

Word Processing Software

The word processing software is used in the generation of procedures, procedure changes, and memos. A file transfer mechanism such as KERMIT is used to move text files between users. The word processor must be convertible to ASCII to allow compatibility with other word processors outside the network and to allow for file transfer using KERMIT. An industry standard application such as Word Perfect or Microsoft Word is chosen because of user familiarity.

2.2.2.4 - Operating System Software

There are two types of software for operating systems; the PC operating system and the network operating system (NOS) software. The PC operating system software takes requests from the application software running on the computer and translates them into actions for the printer, disc drives, video display or other peripherals. For this application, the PC operating system software is MS-DOS.

The network operating software takes requests for services from several different applications and allocates the network's resources. The network operating system implements the transport and network protocols in main memory. The networking software resides in the server station but also requires that many important modules are resident in all the stations in the network. The

network operating system software must be compatible with the microcomputer and its operating system, the applications being run, and the network interface card.

NetWare, a product of NOVELL is the network operating system being considered for this project since it supports both Ethernet and token ring arrangements. NetWare requires a 80286 or 80386-based server with a minimum of 512K RAM. Workstation requirements are 192K RAM and DOS 2.0 or later. Netware also provides administration functions such as error reporting, accounting information and user information as well as security functions such as password control. The workstation and server configuration for both hardware and software is shown in Figure 2.2.2.4-1 [11].

2.2.3 - Deployment and Distribution

The next phase in defining the operational requirements is deciding the location, quantity and distribution of equipment, software and personnel necessary to operate and the system. The equipment is located throughout the various organizations that support the overhaul. The system is developed based on a maximum of six submarines in overhaul at one time. A total of 35 nodes are required for a fully operational system. The entire network is located within the shipyard gates. Table 2.2.3-1 lists the distribution of the equipment and personnel used in the network.

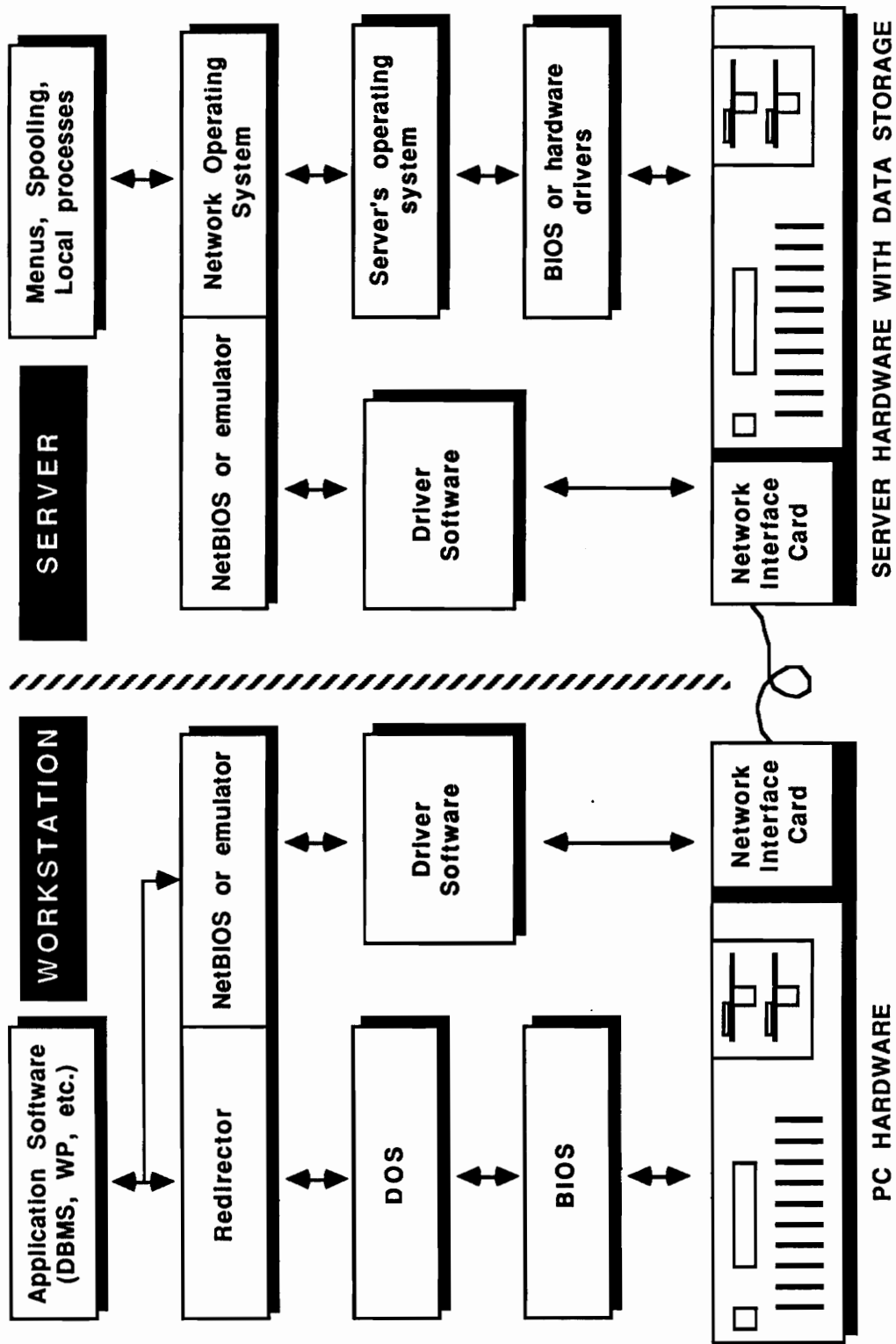


Figure 2.2.2.4 - 1 Network Hardware and Software Interaction

Table 2.2.3 - 1 Equipment and Personnel Distribution

USER	LOCATION	STATIONS	LASER	PRINTER	DOT MATRIX
Administrator	Bldg 4633	1	1		1
JTG 616	Bldg 4633	1	1		1
JTG 628	Bldg 4633	1	1		1
JTG 629	Bldg 4633	1			1
JTG 654	Bldg 4633	1			1
JTG 655	Bldg 4633	1			1
JTG 656	Bldg 4633	1			1
STE 616	Pier 6	1			1
STE 628	Pier 6	1			1
STE 629	Pier 6	1			1
STE 654	Dry Dock 4	1			1
STE 655	Dry Dock 3	1			1
STE 656	Pier 6	1			1
Electrical Eng.	Bldg 86	3	1		3
Mechanical Eng.	Bldg 86	3	1		3
NAVSEA 08	Bldg 547	2			2
SUPSHIP	Bldg 547	2			2
Westinghouse	Bldg 547	1			1
General Electric	Bldg 547	1			1
Quality Inspection	Bldg 4633	2			2
Quality Inspection	Dry Dock 3	1			1
Quality Inspection	Dry Dock 4	1			1
U.S. Navy 616	Navy Barge 1	1			1
U.S. Navy 628	Navy Barge 1	1			1
U.S. Navy 629	Navy Barge 1	1			1
U.S. Navy 654	Navy Barge 2	1			1
U.S. Navy 655	Navy Barge 2	1			1
U.S. Navy 656	Navy Barge 2	1			1
TOTALS		35	5		35

2.2.4 - Utilization

The overhaul of a nuclear submarine is a 24 hour a day, 365 days per year operation. It is not feasible to begin a testing segment that requires stationing dozens of operators, starting the reactor plant and then shutting down for the weekend or evening. Because of these requirements, the supporting network and information system must also be available at all times with the exception of scheduled maintenance and data backup periods. It is anticipated that the network will run 350 days per year at 24 hours per day. Peak usage is during the day when the majority of the management personnel are present. It is anticipated that peak usage will be 20%. During the off hours such as nights, weekends and holidays the system is operated on a limited basis by the on-duty Shift Test Engineer and support crew.

2.2.5 - Environmental Concerns

Located on the mid-Atlantic coast, the shipyard experiences all types of weather conditions with temperatures ranging from sub-zero to greater than 100 degrees. The humidity in the region is very high especially in the summer months. The cable is the only part of the network subjected to these varying conditions with the exception of the humidity, which is everywhere. The

microcomputers and peripherals are located inside office buildings or in pier-side trailers. The environment in these trailers is not clean or dust free although air-conditioning exists. Several electrical power sources such as diesel and motor generators, transformers, and high power lines located throughout the yard will subject the network to electrical interference. Some interference may be attributed to the operation of nuclear reactors around the network.

2.2.6 - Effectiveness Factors

Effectiveness factors specify the availability, reliability, dependability and maintainability of the network and components. They determine how well the system will operate, its level of efficiency and effectiveness. Of all the system parameters to define these are the most abstract and difficult. Only through experience and data collection can these factors be determined. For example, it is difficult to determine how often a system will break-down until it is actually operational and data can be collected. These parameters can then only be estimated. However requirements must be set forth and the system designed to accomplish these goals.

Table 2.2.6-1 lists the effectiveness factors for the system. Total hours of operation is based on 24 hours per day for 350 days per year. A failure is defined as a situation where the network is totally unusable. It is required that the number of failures not exceed four for a year. The mean time between

Table 2.2.6 - 1 Effectiveness Factors

Effectiveness Factors	
Total Hours of Operation per year	8400
Number of Failures per year	4
Failure Rate	0.00047
Mean Time Between Failures (MTBF)	2100
Maximum Reliability	0.99
Mean Time Between Maintenance (MTBM)	700
Mean Maintenance Down Time (MDT)	4
Operational Availability (Ao)	0.99

failures (MTBF) is 2100 hours based on the required failure rate. The mean time between maintenance (MTBM) is the average time between all maintenance actions, preventive and corrective. The MTBM for preventive maintenance is 1050 hours. MTBM is then calculated using equation (1), resulting in a MTBM of 700 hours.

$$\text{MTBM} = \frac{1}{1/\text{MTBM}_p + 1/\text{MTBM}_c} \quad (1)$$

The Submarine Overhaul Facility Local Area Network (SOFLAN) effective life is anticipated to be ten years. After this time period, a review of the system is necessary to determine if the hardware is obsolete and if maintenance costs prohibit continued operation.

2.3 - System Maintenance Concept

The maintenance concept defines the level of support the system will receive throughout its life-cycle. It describes where maintenance will be performed, who will perform it and what is to be accomplished. The maintenance concept must support the effectiveness factors. In this report, the maintenance concept addresses three distinct levels; operational, intermediate, and depot. The responsibilities and skills of the maintenance personnel

involved and the actual degree of maintenance decreases from the operational to the depot level. The levels of maintenance are shown in Figure 2.3-1 [1].

2.3.1 - Operational Maintenance

Operational maintenance is performed at the location where the equipment is located. It is performed by a technician employed by the shipyard or by another designated person. The maintenance at this level is limited to cleaning, performance checks, and other low level scheduled and preventative maintenance. The individual will have the capability to troubleshoot the system using diagnostic software and will be able to remove or replace certain components such as network interface cards, transceivers, and microcomputers. No repair of components is accomplished at this level. This person will be trained in the operation of the network and the use of software by the vendors supplying the system. A basic understanding of computer systems such as loading software and interacting with the system is required. Figure 2.3.1-1 is a functional flow of activities at the operational level.

2.3.2 - Intermediate Maintenance

Intermediate maintenance is performed by a field representative of the

CRITERIA	OPERATIONAL MAINTENANCE	INTERMEDIATE MAINTENANCE	DEPOT MAINTENANCE
Done where?	At the shipyard	At the shipyard or in mobile units.	At a remote facility owned by the producer of the equipment
Done by whom?	By a technician employed by the shipyard or by a service representative located at the shipyard	By a service technician employed by the vendor assigned to a mobile unit.	Diagnostics and analysis performed by a highly-skilled technician. Actual repairs by a skilled worker.
Type of work accomplished?	Component replacement Visual inspection Cleaning Troubleshooting Minor adjustments Operational Checkout	Major servicing System Checkout Component Replacement Component Repair Major adjustments and calibrations Overload from the operational level	Detailed component repair Complicated adjustments Detailed calibration Overhaul of components Supply support Overload from the intermediate level

Figure 2.3 - 1 Maintenance Levels [1]

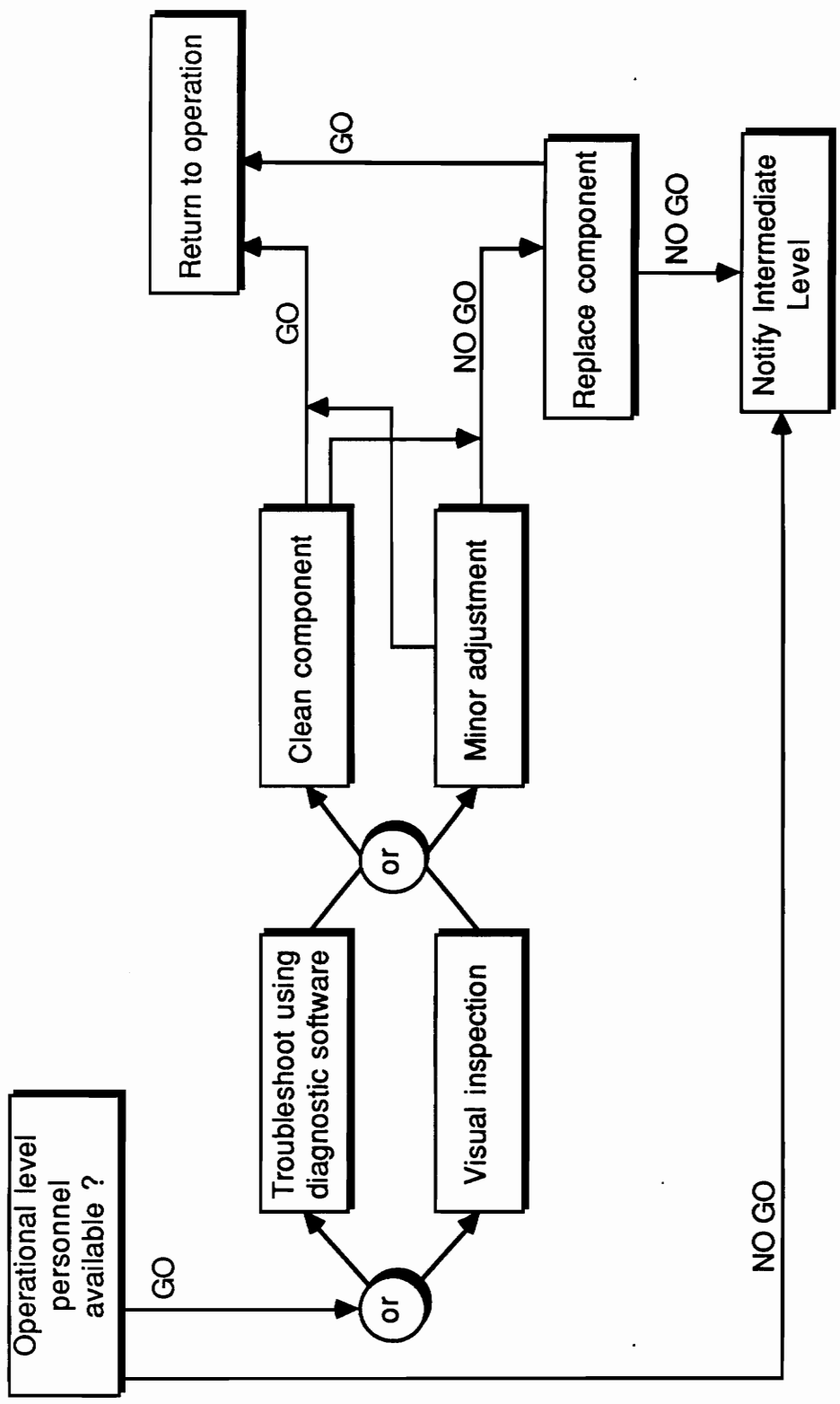


Figure 2.3.1 -1 Functional Flow of Operational Maintenance Level

vendor or supplier working under a service contract or agreement. Personnel at this level are trained and equipped to analyze and repair most components of the system. The individuals are not located at the shipyard but travel between operational sites. They will carry the tools and diagnostic equipment and software necessary for repair or replacement of most system components down to but not including the circuit board level. These technicians have an understanding of network installation and operation and have the capability to add additional nodes into the system as necessary. Intermediate level personnel handle any work overload from the operational level. They are also available as an information source to the operational maintenance personnel by telephone mail or by direct communications when on location. Figure 2.3.2-1 shows the functions at the intermediate level.

2.3.3 - Depot Maintenance

Depot maintenance addresses the highest level of maintenance. The personnel are both skilled and un-skilled workers. The maintenance performed on the components at this level involves troubleshooting and diagnostics by a highly skilled technician and then the repair is made by lower skilled worker. Maintenance at the depot level is performed at facilities away from the site. The faulty components are shipped here by the operational or intermediate

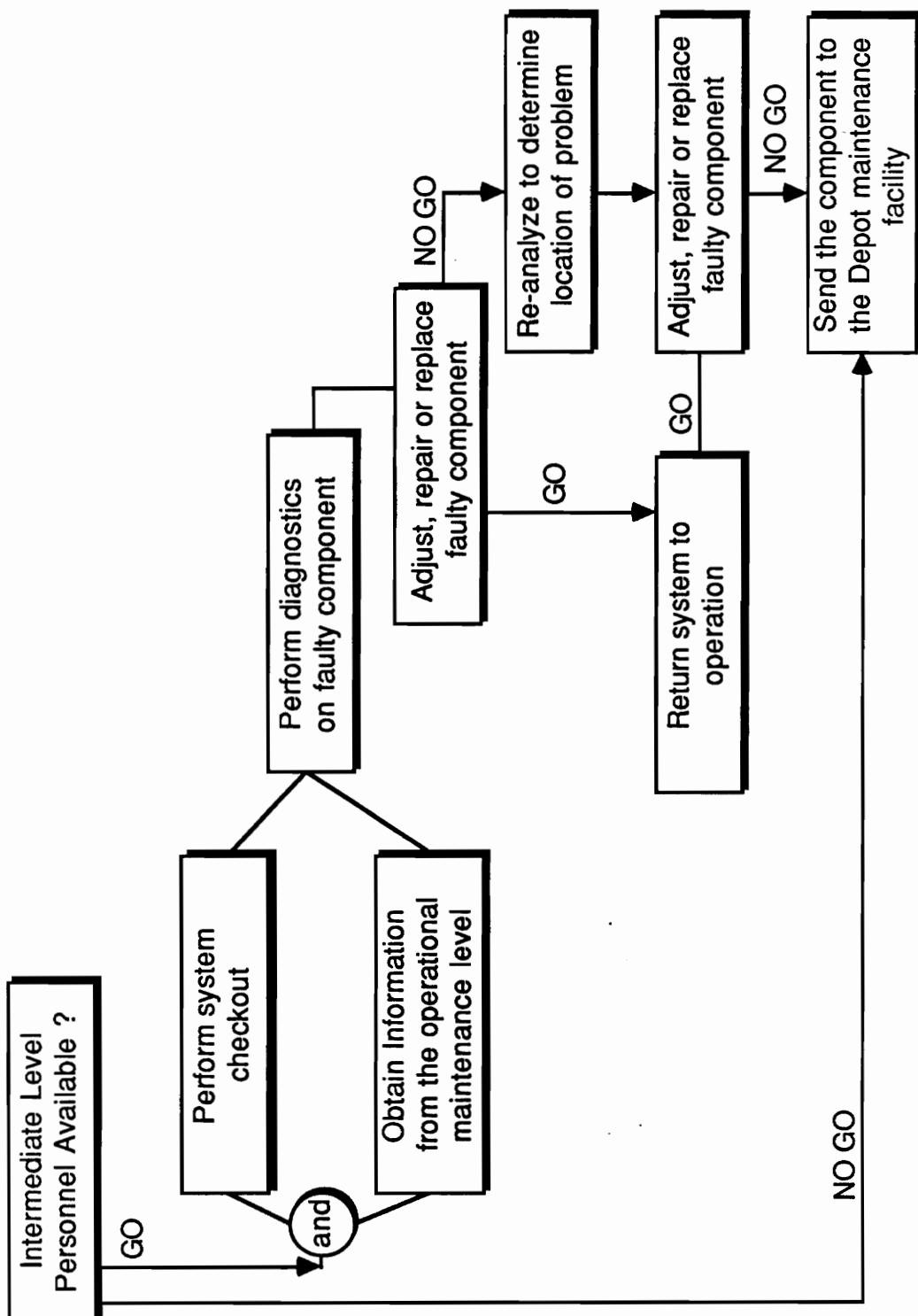


Figure 2.3.2 - 1 Functional Flow of Intermediate Maintenance Level

maintenance people or they are delivered by the intermediate maintenance personnel. The depot level facility houses all the equipment, tools, personnel and documentation necessary to repair or replace any component in the system. An inventory of replacement parts is kept on hand to limit system down time. The personnel here also manage the work overload from the intermediate level. The depot level serves as an information source, primarily to the intermediate maintenance level personnel but also serves the operational level. A functional flow of the depot level activities is shown in Figure 2.3.3 -1.

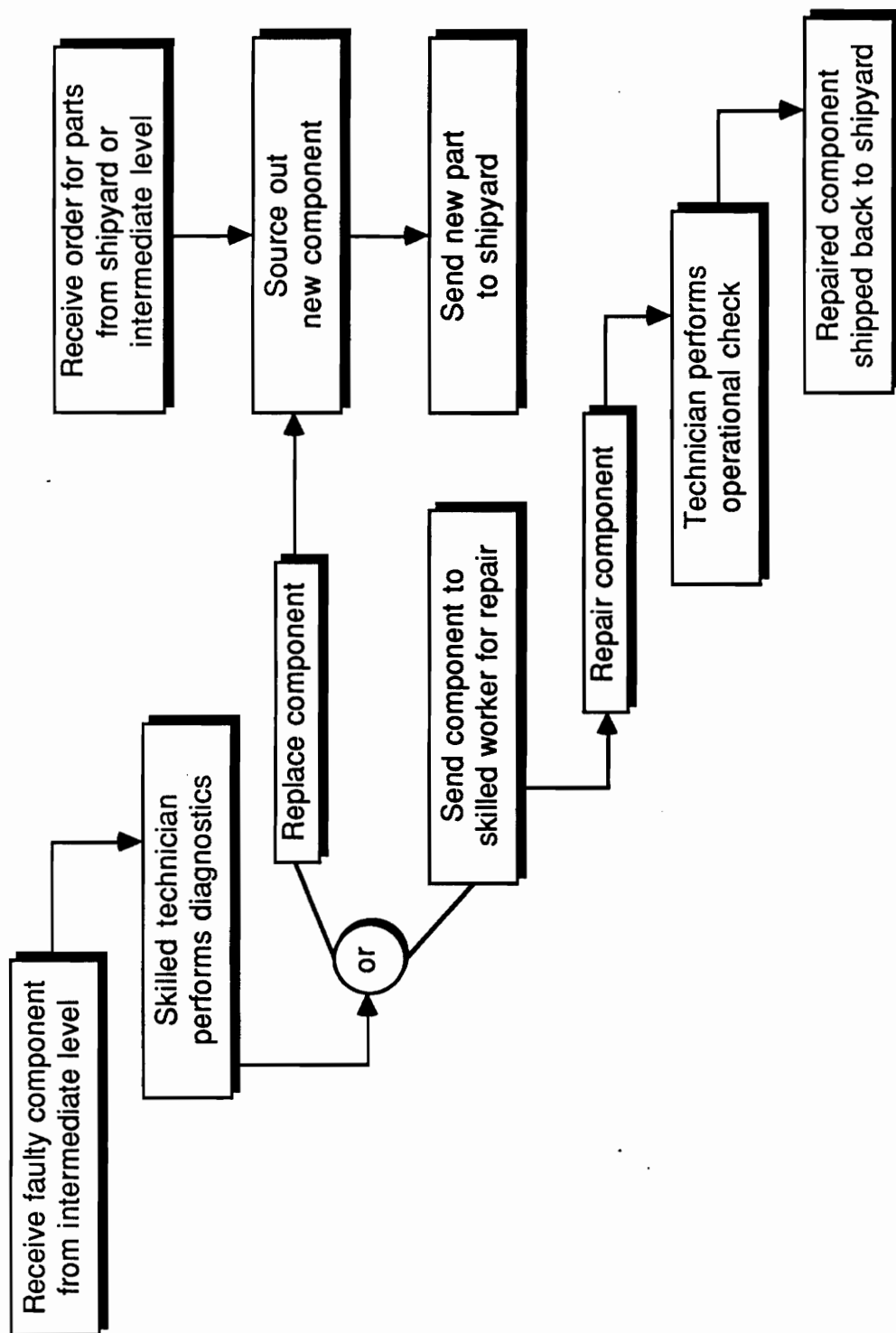


Figure 2.3.3 - 1 Functional Flow of Depot Maintenance Level

CHAPTER 3

SYSTEM ANALYSIS AND DESIGN

System analysis provides a basis for design requirements at each level of the system. The analysis leads to detailed design requirements for the system. This process includes an optimization of alternatives leading to a system synthesis.

The analysis of the shipyard local area network will cover:

- Standards such as the OSI model and IEEE 802,
- Signaling methods,
- Transmission media,
- Network topologies and
- Access methods to the medium.

A model of the approach used in the analysis is shown in Figure 3-1.

3.1 - Network Standards

The promise of the the local area network for the company brings about compatibility nightmares for those trying to assemble the components. For heterogeneous components this is especially true. As the use of computer communications and networks proliferates, a one-time approach to system and

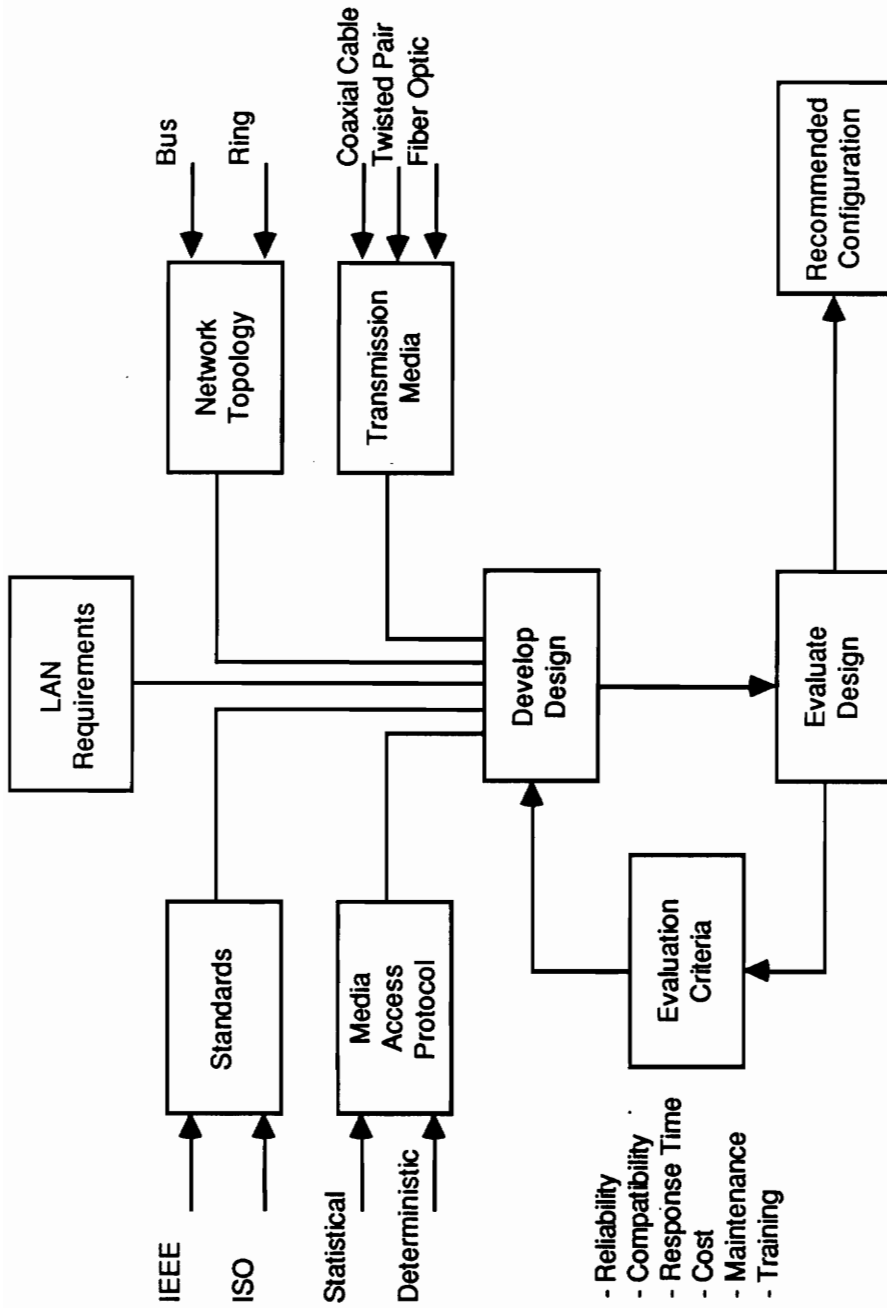


Figure 3 - 1 Local Area Network Development

software development proves to be too expensive. Communication standards have two effects:

- Vendors will feel compelled to adapt to the standards for fear of not being able to market their product.
- Customers will be in a better position to acquire products from various vendors while ensuring compatibility.

Development of a standard for the entire communications process is too complex. The problem must be broken down into manageable parts in a structure or architecture that defines the communication tasks [3].

3.1.1 - The OSI Model

The OSI (Open Systems Interconnection) model was developed by the International Organization for Standardization (ISO) in 1983. The model provides a framework for linking heterogeneous computers. Its primary goal is to decompose data communications into manageable pieces with well-defined interfaces [4]. The OSI model implements a seven layer approach to system interconnection. The OSI model and a description of the seven layers is shown in Figure 3.1.1-1. Each layer defines a peer-to-peer communication process

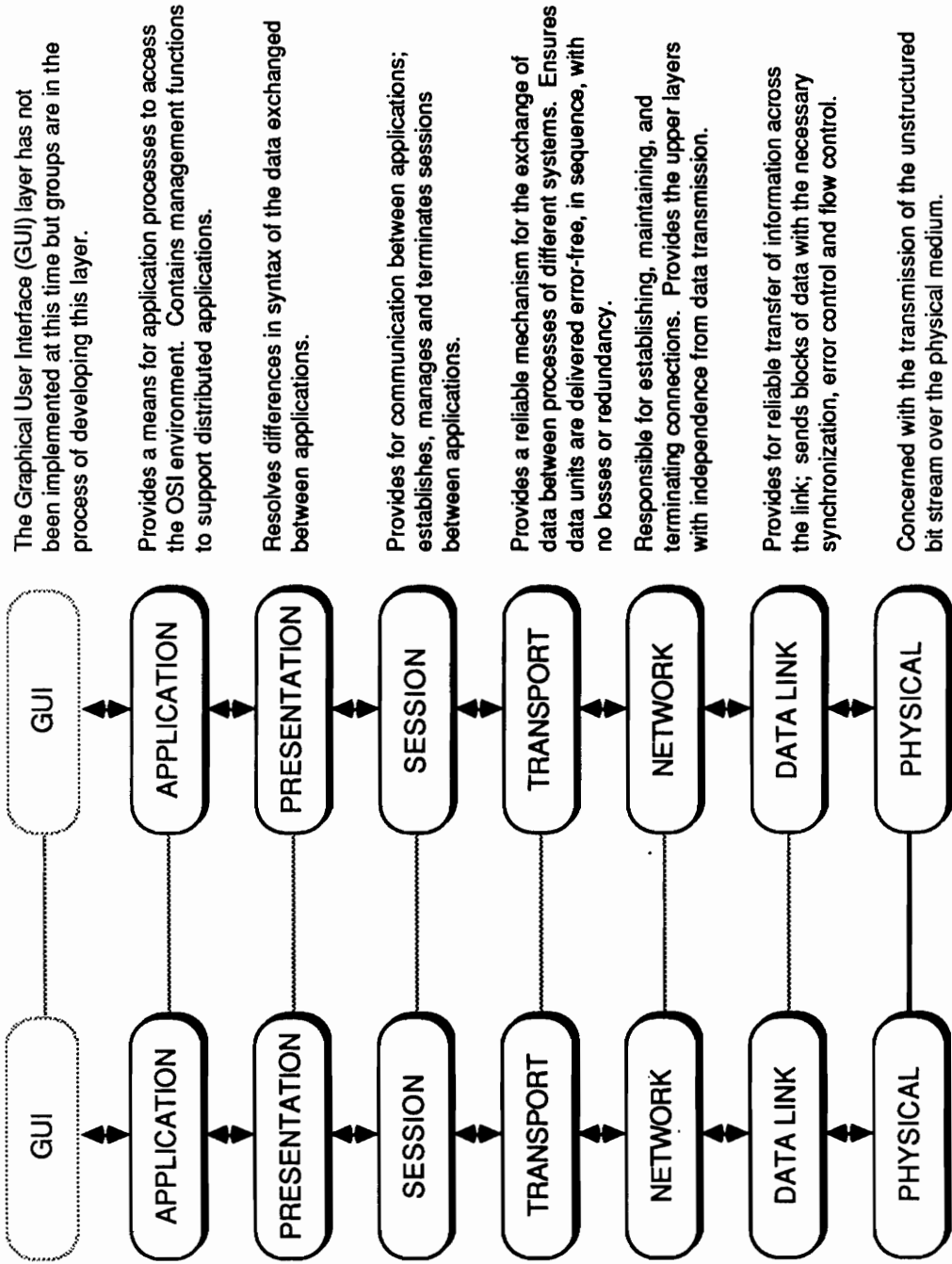


Figure 3.1.1-1 The OSI Model

between connected users. The only physical connection exists at the physical layer. All other connections are virtual through the use of software. The Graphical User Interface (GUI) layer is not a part of the OSI model at this time. It is included to show that the model is not complete and that groups are still working on refinements.

This project will deal mainly with the first two layers of the OSI model, specifically, the physical and data link layers. The other layers are discussed in general terms to provide continuity when necessary.

3.1.2 - Ethernet and IEEE 802

The Ethernet standard was published in 1980 by DEC, Intel, and Xerox. It encompasses the two lower protocol layers. The data link layer specified a contention based access method called Carrier Sensed Multiple Access with Collision Detection (CSMA/CD). The physical layer defined the medium as a shielded coaxial cable with a tree topology using baseband signaling at a data rate of 10 Mbps. The specification also defines the segment length, distance between stations, the number of stations per segment and maximum number of stations in the network.

The Institute of Electrical and Electronics Engineers (IEEE) established project 802 on network standards in 1980. These standards also deal with the

two lower protocol layers as well as an interface to the network layer. The data link layer is divided into two sublayers called medium access control (MAC) and the logical link control (LLC). The logical link control sublayer interfaces with the network layer. The IEEE Protocol model is shown in Figure 3.1.2-1 [5]. The Ethernet specification formed the basis for one element of Project 802 which developed into a series of approved standards;

- 802.2 - Logical Link Control,
- 802.3 - CSMA/CD for Baseband (almost identical to Ethernet),
- 802.4 - Token Bus and,
- 802.5 - Token Ring.

It is expected that the bulk of future LAN development work, at least in the United States, will be within the scope laid down by IEEE 802 [6]. Because of the operational requirement to adhere to an industry accepted network standard, the IEEE 802 standard is followed for the shipyard network design.

3.2 - Signaling Techniques: Baseband versus Broadband

A baseband local area network is defined as one that uses digital signaling. The digital signal are inserted on the transmission medium as voltage pulses using a type of Manchester coding. In baseband systems the entire bandwidth

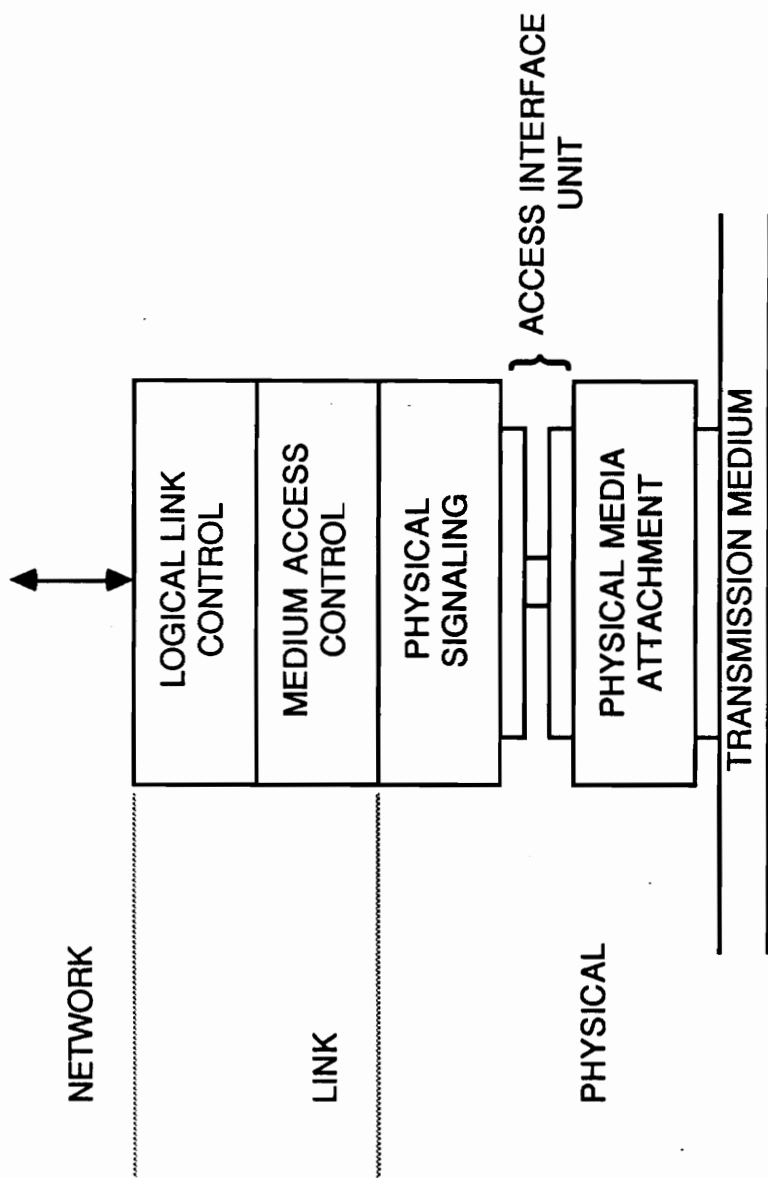


Figure 3.1.2 - 1 IEEE 802 Protocol Model

is used, thus, no frequency-division multiplexing can be implemented. Signaling in baseband systems is bi-directional; a signal inserted on the line will propagate in both directions until it is absorbed by a terminator at the end of the line. A bus topology is required because the digital signals cannot propagate easily through the taps required for a tree. Because of the attenuation of the digital signal the cable distance in a baseband configuration is limited to about one kilometer. The 50-ohm coaxial cable is normally used in this type of system although twisted pair is also a possibility.

A familiar baseband configuration is Ethernet. The IEEE standard has established two configurations to meet the Ethernet specification. One uses a 0.4-inch diameter, 50-ohm cable. A data rate of 10 Mbps is possible with a maximum cable segment length of 500 meters. This configuration is abbreviated as 10base5. The second configurations, the 10base2, uses a thinner cable providing more flexibility but can only support a maximum cable segment length of 200 meters. The 10base2 is used as an inexpensive personal computer network. Table 3.2-1 lists the specifications of the 10base5 and 10base2 configurations [6]. If additional distance is needed a repeater can be used to extend the length of the network. The IEEE 802 standard allows four repeaters in the path between any two stations, extending the cable length to 2.5 km.

A twisted pair baseband configuration is possible but it is limited to a length

Table 3.2 - 1 IEEE Specifications for 10 Mbps
Baseband Coaxial Bus Local Networks

Parameter	10 base 5	10 base 2
Data Rate	10 Mbps	10 Mbps
Maximum Segment Length	500 m	200 m
Network Span	2500 m	1000 m
Nodes per Segment	100	30
Node Spacing	2.5 m	0.5 m
Cable Diameter	0.4 in	0.25 in

of one kilometer, a data rate of 1 Mbps and connection for about 10 devices.

Broadband systems, in LAN terminology, refers to a coaxial system using analog signaling. These systems are capable of frequency-division multiplexing (FDM). Broadband systems support various data modes at the same time since multiplexing is used. Since analog signals suffer less from attenuation than digital signals, much greater distances are possible with broadband. Broadband systems can only pass data in one direction. This is due to the fact that amplifiers are used and it is not feasible to build them to pass signals in both directions. To allow communication across the network, headends are used. These units turn the data around and send it in the other direction when it reaches the end of the line. Because of the headend, the propagation delay is increased up to a factor of two. Broadband system use CATV components including 75-ohm coaxial cable. Data rates up to 50 Mbps are achieved using a broadband system.

The pros and cons of baseband and broadband are listed in Table 3.2-2 [6]. A baseband configuration is selected for the shipyard network. The advantages of lower cost, ease of installation and simpler technology outweigh the disadvantages of limited capacity and distance. The simpler technology will aid in maintaining the system and in future expansion. The broadband systems

Table 3.2 - 2 Baseband versus Broadband

	ADVANTAGES	DISADVANTAGES
BASEBAND	<p>Cheaper Simpler technology Easy to install Bidirectional</p>	<p>Single channel Limited capacity Limited distance Grounding concerns</p>
BROADBAND	<p>High capacity Multiple traffic types More flexible configurations Large area coverage Mature CATV technology</p>	<p>Modem cost Installation and maintenance complexity Doubled propagation delay</p>

require experienced RF engineers to periodically test and align all network parameters. The limited capacity and distance is not a factor since the entire network is with the shipyard gates.

3.3 - Transmission Media Evaluation

Three types of transmission media are examined to determine which best suits the operational requirements and effectiveness factors specified in Chapter 2. The media are evaluated by transmission characteristics, connectivity, geographical scope, noise immunity and relative cost. The three types evaluated are twisted pair, coaxial cable, and fiber optic cable. It is assumed that the reader is familiar with these media, therefore, a physical description is not given. Table 3.3-1 lists the characteristics of the various media [6].

3.3.1 - Twisted Pair

Twisted pair is the most common transmission medium for both digital and analog transmission. It is located within buildings to connect the telephone system and to supply electrical power.

For analog signals, amplifiers are required every 5 to 6 kilometers. For digital signals, repeaters are used every 2 or 3 kilometers. The most common

Table 3.3 - 1 Transmission Media for Local Networks: Multipoint

Medium	Signaling Technique	Maximum Data Rate (Mbps)	Maximum Range at Maximum Data Rate (km)	Practical Number of Devices
Twisted Pair	Digital	1-2	Few	10's
Coaxial Cable (50-ohm)	Digital	10	Few	100's
Coaxial Cable (75-ohm)	Digital	50	1	10's
	Analog with FDM Single-channel Analog	20 50	10's 1	1000's 10's
Optical Fiber	Analog	100's	1	10's

use of twisted pair is voice transmission with a bandwidth of 300 to 3400 Hz, or a maximum capacity of 24 channels at 268 Hz. Digital data can be transmitted over a voice grade channel using a modem at speeds up to 9600 bps. For digital or baseband signaling, a data rate of 4-Mbps is a reasonable upper limit.

Twisted pair is used in point-to-point and multipoint applications although point-to-point usage is more common. Twisted pair is less expensive in a multipoint configuration but supports fewer stations than coaxial cable.

For networking, twisted pair is typically used within a single building or to interconnect just a few closely located buildings.

Twisted pair easily couples with electromagnetic fields and is susceptible to interference and noise. The interference can be from adjacent power lines or data line pairs. This interference can be reduced by the use of shielded twisted pair.

The cost of twisted pair is less than coax or fiber but because of its limitations, network installation costs may approach that of other media.

3.3.2 - Coaxial Cable

Coaxial cable is the most versatile media for local area networks and is becoming accepted as the standard for most applications. There are two types of coaxial cable, 75-ohm and 50-ohm. The 75-ohm cable is typical in

community antenna television (CATV) systems and can be used for both baseband and broadband signaling. The 75-ohm coaxial cable suffers more from reflections from the insertion capacitance of the taps and has a low immunity to noise.

Coaxial cable can support point-to-point and multipoint configurations. Up to 100 devices can be connected to a single segment of 50-ohm coaxial cable while broadband 75-ohm cable can support thousands of devices.

Systems using the 50-ohm cable can span a few kilometers while the 75-ohm broadband systems can span tens of kilometers. Segments can be joined using repeaters, thus allowing larger systems.

Noise immunity for coaxial cable depends on the application and the environment but is generally better than twisted pair at high frequencies.

Coaxial cable is more expensive by a factor of two or three than twisted pair and by a smaller amount than shielded twisted pair. Because of a difference in the materials and installation costs, the price of twisted pair and coaxial cable is the same [7].

3.3.3 - Fiber Optic Cable

Optical fiber has demonstrated a few gigabytes per second in the laboratory but in reality, a data rate of a few hundred megabits per second is achievable

over a range of a few kilometers. For local networks, a 850 nm LED light source is used. Other light sources include 1300 and 1500-nm but require a laser and are regarded as too expensive for this application.

Fiber optic systems are usually point-to-point configurations. Multipoint systems are in the experimental stages and are too expensive to consider. However, a segment of optical fiber can support more drops than twisted pair or coaxial cable due to a lower power loss, lower attenuation, and greater bandwidth potential [6].

The geographical scope of fiber optics is between 6 and 8 kilometers without repeaters. This characteristic permits point-to-point links between networks in different buildings.

Fiber optic cable is not affected by electromagnetic interference or noise permitting high data rates over long distances and providing excellent security.

3.3.4 - Medium Selection

The 50-ohm coaxial cable is selected as the transmission media based on the information in Table 3:3-1. Its data rate of 10 Mbps, range and practical number of devices satisfies the operational requirements. The 50-ohm coaxial cable is also compatible with the baseband configuration selected in Chapter 3.2. The cable is durable, provides sufficient noise immunity and will allow

flexibility for future expansion. The 50-ohm cable is also the cable of choice in the IEEE 802.3 specification. Twisted pair baseband is not selected because of its limited capacity over the necessary distance. Fiber optic cable is not suitable for this application due to the multipoint environment.

3.4 - Network Topologies: A View From Above

The topology used is dependent on the transmission medium chosen. For a baseband coaxial system, only a bus or ring topology is acceptable. The high data rates of the coaxial cable would overwhelm the switches of today's technology, therefore, a star configuration can not be used [6]. The bus and ring topologies for a baseband local network are shown in Figure 3.4-1.

3.4.1 - Bus Topology

With a bus topology there are no switches or repeaters. The network is simply the transmission medium. The terminals or computers connect to the medium by an interface called a transceiver. A transmission placed on the medium propagates the entire length in both directions and is available to all stations. A terminator at the end of the bus absorbs the transmission if it is not received by a station. The bus topology is considered a multipoint medium; there are two or more devices connect to and capable of transmitting on the

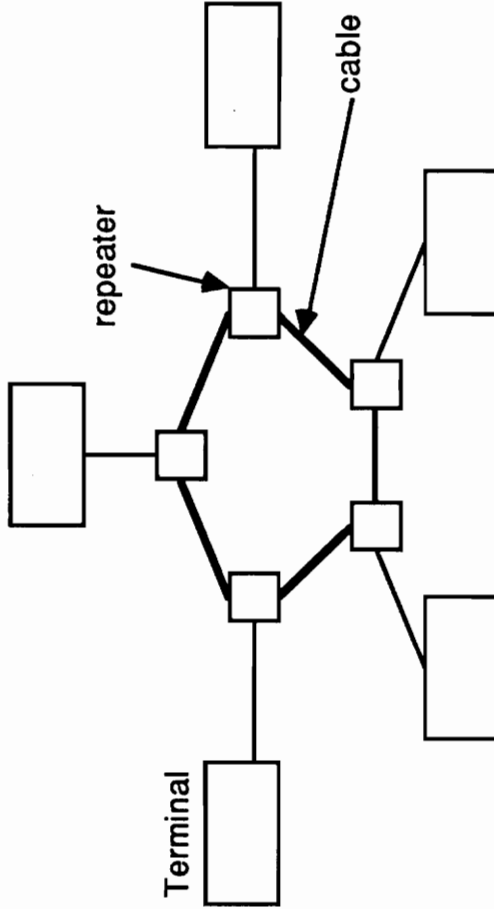
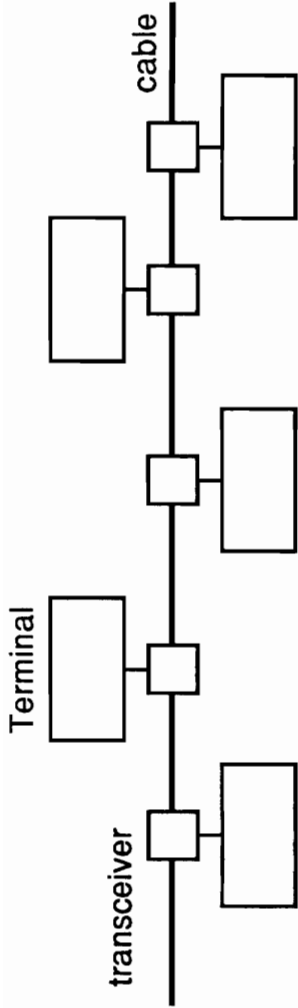


Figure 3.4 - 1 Baseband Local Network Topologies

medium. However, only one device may transmit at a time. A medium access control technique must be employed to ensure transmission in an uncontented environment. Access to the bus is either by passing a token or by sensing the carrier for transmission. A bus topology can be implemented in either a baseband or broadband systems. The bus topology is therefore a feasible alternative based on the selection of a baseband system in Chapter 3.2. The IEEE 802.3 specification implies a bus topology, further strengthening the bus as a alternative.

3.4.2 - Ring Topology

The ring topology shown in Figure 3.4-1 is comprised of repeaters connected in a point-to-point closed loop. The repeaters are unidirectional and receive the data and retransmit it without buffering. The repeater also serves as a device attachment point on the ring. Data are transmitted in packets around the ring with the destination address appended to the packet. The appropriate station will recognize its address and receive the packet. Because the ring is a continuous loop, a packet inserted on the ring will circulate indefinitely until removed. The packet can be removed by the addressed repeater or by the transmitting repeater. Packet removal by the transmitting repeater is more advantageous since it provides automatic acknowledgment and it allows

multicast addressing; one packet sent to several addresses. Access to the ring is commonly through token passing.

Because the ring uses point-to-point links, greater distances can be covered. The ring can also accommodate fiber optic links, allowing very high data rates and excellent noise immunity. Ring topologies are part of the IEEE 802 specification, making them a viable alternative.

The problem with rings are that breaks in the cable will disable the entire network as will a failed repeater. Perambulation of the ring is required when a repeater does fail and hence, access to all rooms containing repeaters and cable. Installation can be a problem, especially when adding stations. To add a station the adjacent nodes must be known and cable runs must be made between them. Determining adjacent nodes can be a problem if documentation is not kept updated. Adding new nodes will also create an irregular geometry in the ring, furthering the perambulation problem. Because of these size and maintenance problems, there is a practical limit to the number of stations that can be connected. This number, however, is in the hundreds and is not a limitation to the shipyard network.

3.4.3 - Topology Selection

The selection of the optimum topology is based on reliability, expandability, performance and satisfaction of the operational requirements. The bus

topology is chosen mainly due to its flexibility. It can accommodate the required number of users and is more easily maintained than the ring. A failure in the link will not disable the entire system in a bus network as is the case with a ring. The point-to-point advantage of the ring, allowing greater transmission distances is not necessary for this system. A bus network can also be designed using the proven technology of the Ethernet and IEEE specifications.

3.5 - Medium Access Methods

By defining the network to this point as a baseband coaxial system using a bus topology, the selections for the access protocol are limited to Carrier-Sense Multiple Access with Collision Detection and token passing on a bus. However, since 50-ohm coaxial cable is selected as the transmission medium and, the token bus access method requires 75-ohm cable, only CSMA/CD can be implemented.

3.5.1 - CSMA/CD: Listen Before Speaking

Carrier-sense multiple access with collision detection for baseband is the IEEE 802.3 specification. Referring to Figure 3.5.1-1, the CSMA/CD protocol operates as follows. The medium access control (MAC) sublayer constructs the

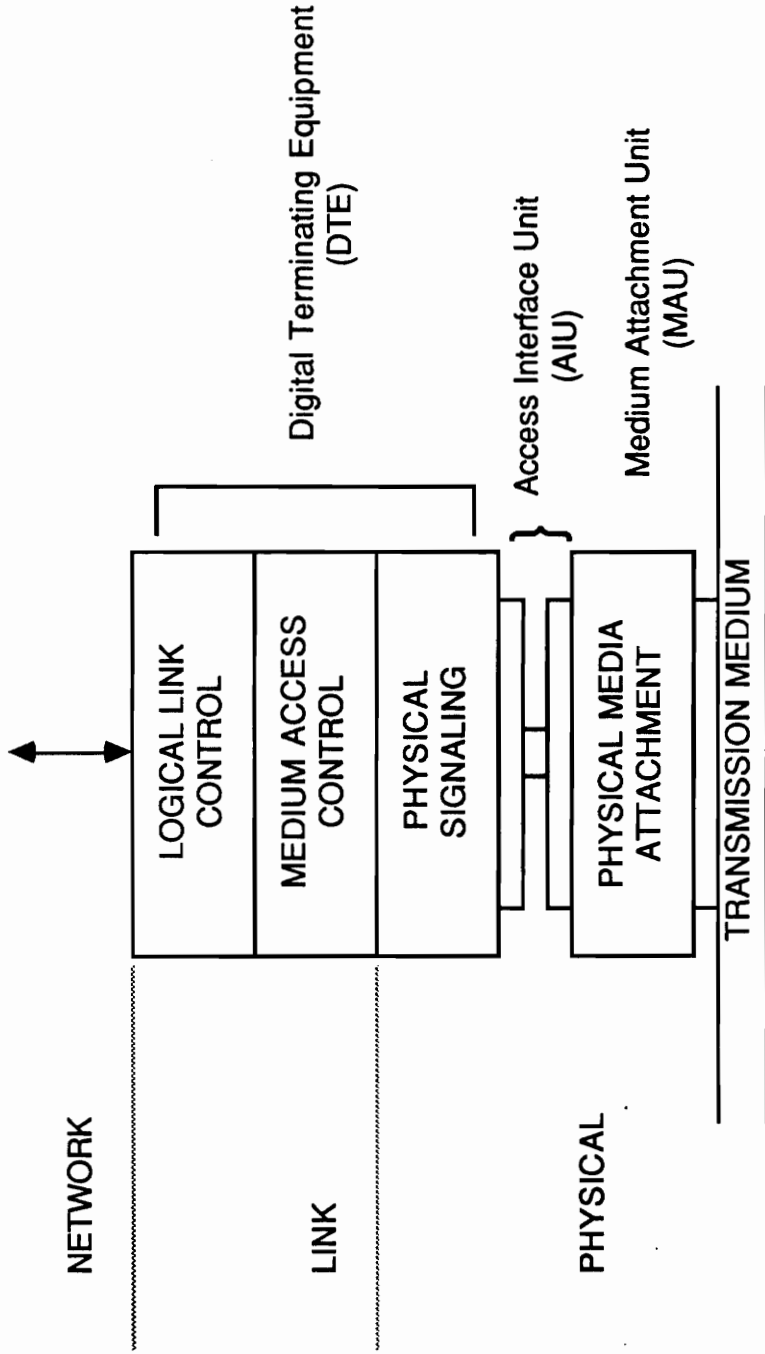


Figure 3.5.1 - 1 CSMA/CD Attachment Unit Interface

data frame from the logical link control (LLC) supplied data. The carrier-sense signal provided by the physical layer is monitored and, if there is passing traffic, then transmission is delayed. When the medium is clear, frame transmission is initiated after a brief delay to provide recovery time for other stations. A collision occurs when multiple stations attempt to transmit at the same time and their signals interfere with each other. In the event of a collision, the physical layer of the transmitting stations notices the interference on the medium and turns on the collision detect signal. This is noticed by the MAC sublayer and collision handling begins. First, a bit sequence called a jam is transmitted to ensure the duration of the collision is long enough so that it can be noticed by all transmitting stations. After the jam is sent, transmission is terminated and a retransmission is attempted after a random delay. If repeated collisions occur the random delay is doubled with each attempt. This is known as binary exponential back-off. After sixteen attempts transmission is terminated and an error condition is cited [5].

3.6 - System Synthesis

Synthesis refers to the combination and structuring of parts and elements to form a functional entity. Synthesis has been achieved when sufficient trade-offs and preliminary design have been accomplished to assure completeness of

system performance and design requirements allocated for detailed design [1].

For the shipyard network, all sub-systems alternatives have been analyzed and the most suitable have been chosen. What remains is the actual configuration of the system and a subsequent performance evaluation.

The recommended system, a 50-ohm, baseband, coaxial, bus network using CSMA/CD, adheres to the Ethernet and IEEE 802.3 specifications. The configuration for the implementation of the Ethernet architecture is shown in Figure 3.6-1 [6]. The guidelines necessary for installing Ethernet are the same as the IEEE specification for a 10base5 system shown in Table 3.2-1.

A generic baseband configuration is shown in Figure 3.6-2. Stations are connected to the coaxial cable through a transceiver. A transceiver cable, with a maximum length of 50 meters, connects the transceiver to the controller or network interface card (NIC). The NIC resides in an expansion slot in the microcomputer. The NIC communicates with the microcomputer through the use of the network operating system. The coaxial segments are limited in length to 500 meters. In order to span the necessary distance, repeaters are used to link segments.

A birds-eye view of the actual network layout is shown in Figure 3.6-3. There are 35 nodes on the network. Building 4633 houses shipyard management, and the network administrator. The 80386-based server is located in this building and is controlled by the administrator. The longest

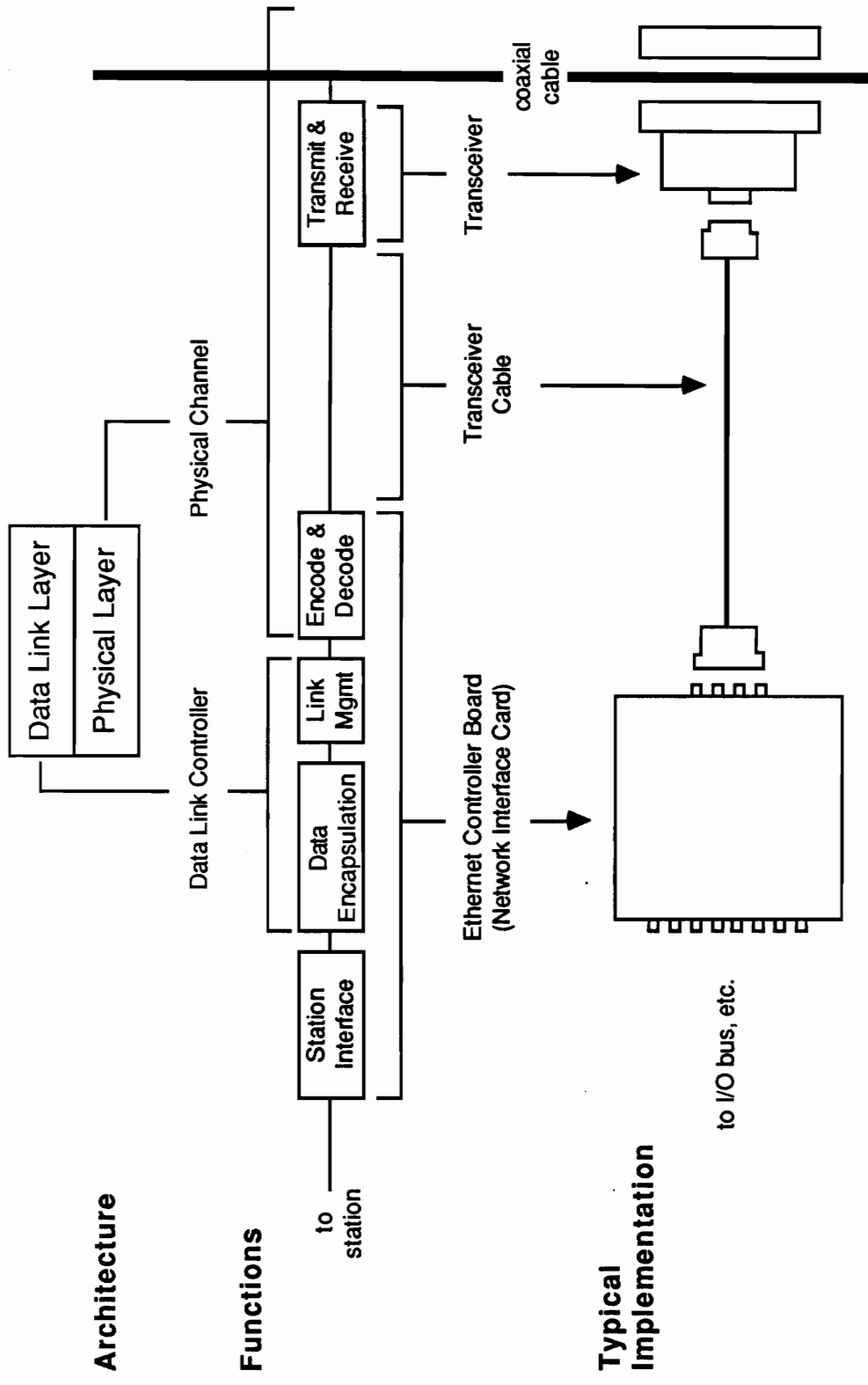


Figure 3.6 - 1 Ethernet Architecture and Implementation

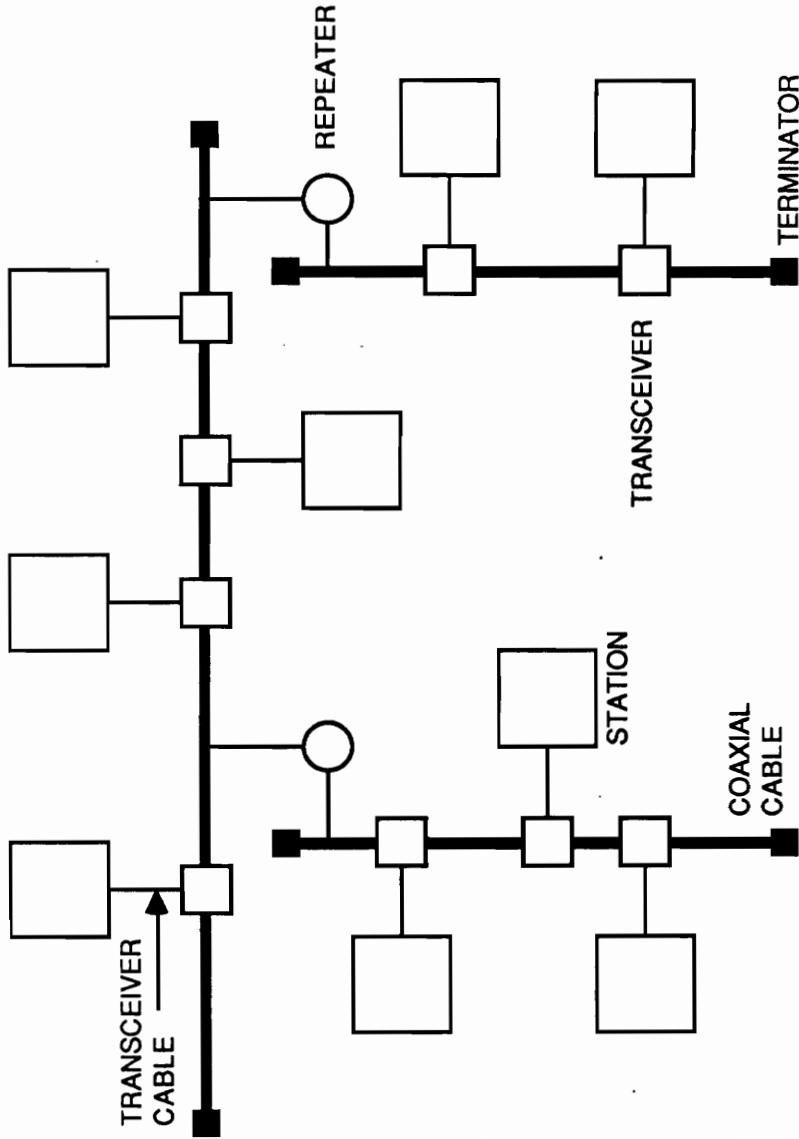


Figure 3.6 - 2 Generic Baseband Ethernet Configuration

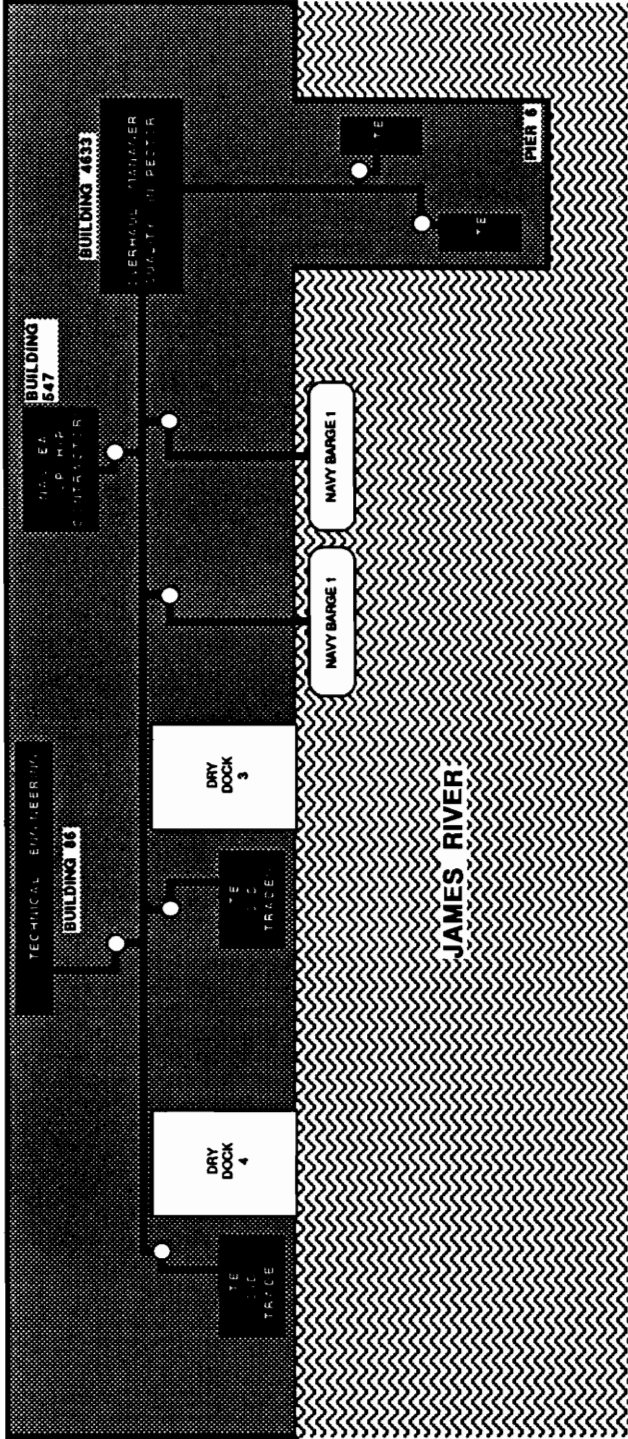


Figure 3.6 - 3 Network Layout

segment is 450 meters, spanning from Building 4633 to Dry Dock #4. Each station has a microcomputer and dedicated dot matrix printer. The technical engineering department and the overhaul managers have laser printers in order to generate high quality reports as necessary.

3.7 - Performance

Local area networks are characterized by their high data rates and low error rate. The network is constrained in performance by competition within the network for resources such as memory, data, and CPU time. Factors that contribute to the level of performance of a network are data rate, loading, access method, topology, error rate, and procedural protocols. Table 3.7-1 lists the network and memory characteristics of the system.

3.7.1 - Data Rate and Loading

The data rate for the network under consideration is 10 Mbps. However, this does not imply that a station can utilize the channel at its fullest capacity. The network runs at 10 Mbps so that the time required to send a message across the channel is as short as possible. The net data rate is determined by the access

Table 3.7 - 1 Network and Memory Characteristics**NETWORK PHYSICAL PARAMETERS**

Number of Stations - 35
Max Distance Between Stations - 1000m
Cable Type - 50-ohm coax, 0.4in. diameter
Data Rate - 10 Mbps
Maximum Segment Length - 500m

MEMORY REQUIREMENTS BREAKDOWN

Maximum Work Permit Size - 2KB
Maximum Discrepancy Report Size - 4KB
Maximum Procedure Size - 100KB
Work permits per Ship - 2000
Discrepancy Reports per Ship - 1000
Procedures per Ship - 250
Maximum Number of Ships - 6

Total Memory Size - 200MB

802.3 SPECIFICATIONS

Access Protocol - CSMA/CD
Address Size - 16 bits
Maximum Network Size - 2800 m
Maximum Stations - 1024
Minimum Packet - 64 Bytes
Maximum Packet - 1518 Bytes
Data Signaling Rate - 10 Mbps

method and the number of stations competing for network resources.

The performance of the network is influenced, from the user's point-of-view, by the number of stations actively competing for the resources. When the capacity of the resource is reached, either additional requests are blocked or there is a reduction in service to all.

The effects of loading are apparent in Figure 3.7.1-1 [7]. This is an example of a 10 Mbps LAN channel. It indicates that the available data rate is a function of the channel's total data rate divided by the number of users. The curve does not take into account the access method, overhead, or other factors. The horizontal lines indicate the limitations of the equipment connected to the channel. The channel is capable of a data throughput higher than the stations connected to it can sustain. As long as the number of users is below the point on the curve where the equipment limitations determine the throughput, the user will not notice any difference in throughput as the number of users vary. For example, if the equipment limits the data rate to 0.5 Mbps, then the throughput for three users will be the same as for twenty users. However, once the number of users increases above twenty, the available data rate and throughput decreases. The true data throughput tends to depart from the curve for a large numbers of users due to access methods, overhead and errors. Since the network has only thirty-five users, the theoretical data is assumed actual.

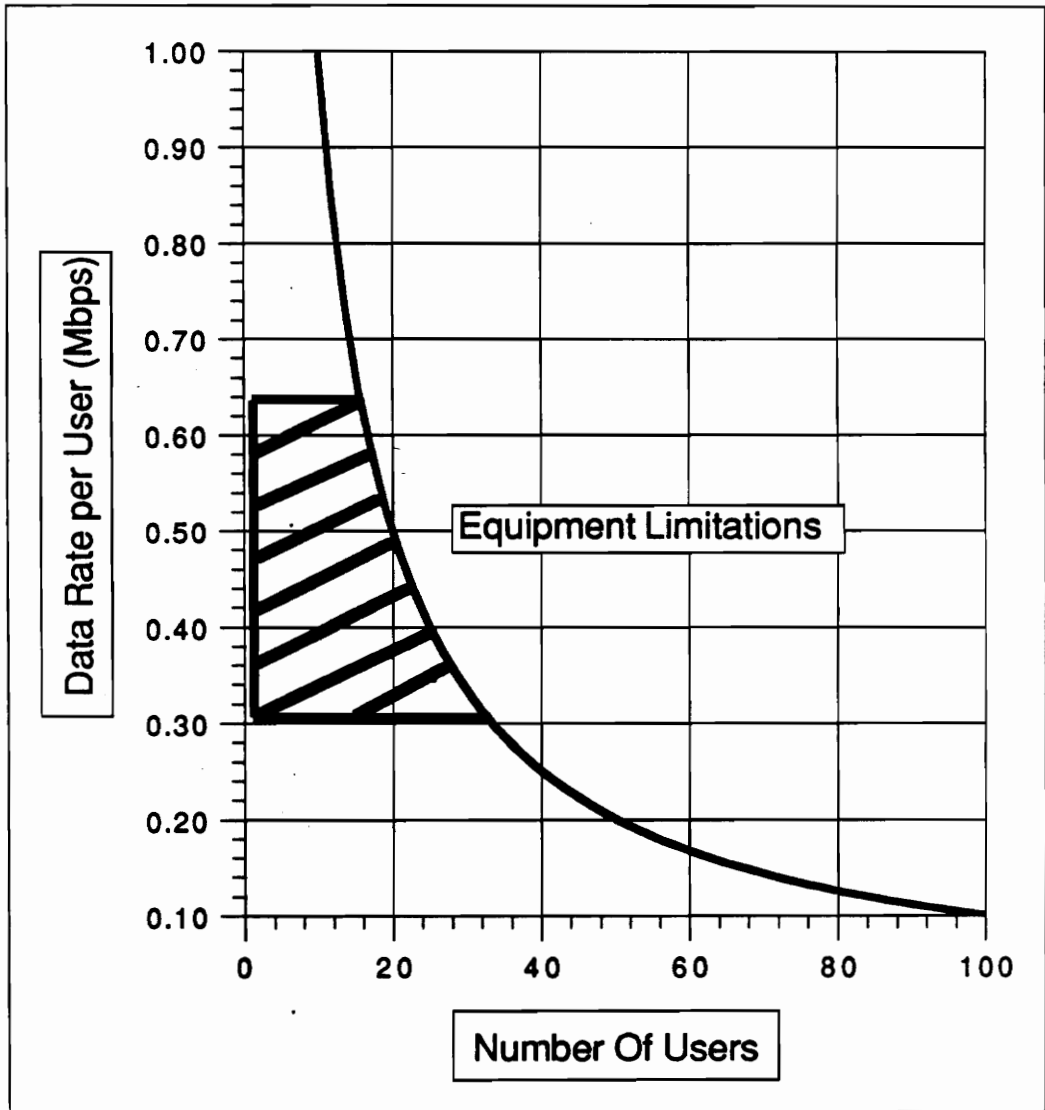


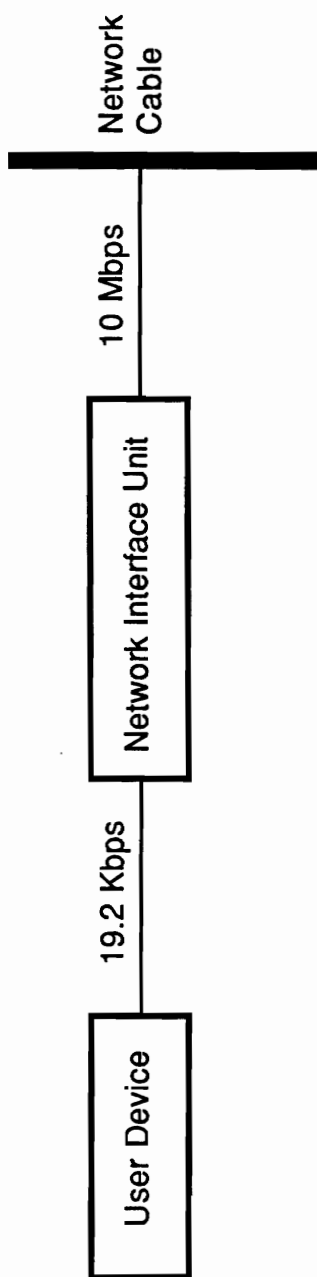
Figure 3.7.1 - 1 Throughput versus Number of Users

Table 3.7.1-1 [7] shows representative times for file transfer under light and heavy network load conditions. The total file transfer time is a function of the file size. The table lists the transfer times for a work permit, discrepancy report and procedure file. It is assumed that the files are sent in blocks of 512 bits. This is the minimum packet size under the IEEE 802.3 specification. The use of a packet of this length represents the most severe case in terms of contention. It is obvious from the table that the file transfer times are not significant. It would take a 1-Mbyte file before the transfer time exceeded the one second barrier. However, the table does allow for a comparative analysis of various file sizes.

The next step is to determine whether the network can accommodate the peak throughput rate required by the actual system. The peak throughput rate of 1.66-Mbps is based on the requirement documented in section 1.4. The IEEE 802.3 specifications listed in Table 3.7-1 are used to analyze the throughput requirements and capabilities of the system. Figure 3.7.1-2 shows the data rates between the user device, the network interface unit and the network cable. Also shown in Figure 3.7.1-2 is the frame format for CSMA/CD medium access control. The figure shows the minimum packet length of 512 bits of which 368 bits are allocated to the information field and 144 bits are allocated to the header and control fields. It is assumed that the data rate between the user device and the network interface unit (NIU) is 19.2 Kbps. The user device is

Table 3.7.1 - 1 File Transfer Times

ACTIVITY	LIGHT NETWORK LOAD	HEAVY NETWORK LOAD
Process file transfer request; set up transfer	3.0 ms	3.0 ms
First disk access	16.0 ms	16.0 ms
Assemble packet; establish circuit over network	3.0 ms	5.0 ms
Access and transmission time per packet (one block per packet)	0.5 ms	1.5 ms
Disestablish circuit	1.0 ms	2.0 ms
Total times	23.0 ms + 0.5 ms/block	26.0 ms + 1.5 ms/block
Work Permit File (2KB)	25 ms	32 ms
Discrepancy Report File (4KB)	27 ms	38 ms
Procedure File (100KB)	123 ms	326 ms



preamble	start frame delimiter	destination address	source address	length count	data	frame check sequence
size (bits)	56	8	16	16	368	32

Figure 3.7.1 - 2 Data Rates and Frame Format

only concerned with the transfer of the information field. At a data rate of 19.2 Kbps, the 368 bit information field is transmitted to the NIU at 52 $\mu\text{sec/bit}$. The NIU transmits the entire 512 bit frame at 10 Mbps or 0.1 $\mu\text{sec/bit}$. The total transmit time (T) of a message is therefore, 51.2 μsec . The maximum throughput is the inverse of the total transmit time.

$$\text{Maximum Throughput} = 1 / T = 19531 \text{ messages / second} \quad (1)$$

Since the message only contains 368 bits of information, the maximum capacity of a 10 Mbps channel is given by equation (2).

$$\text{Maximum Capacity} = 19531 \times 368 = 7.19 \text{ Mbps} \quad (2)$$

The required data rate of 1.66 Mbps is 23% of the maximum possible throughput of 7.19 Mbps. Therefore, the chosen configuration can support the required throughput rate which includes a growth factor of 10.

3.7.2 - Errors and Performance

Protocols are designed to recover from errors. The recovery takes time and requires the use of network resources. If the network is 40% utilized, about

4,000,000 bits per second are transmitted. Bit error rates for a typical Ethernet configuration is 10^{-9} . Errors occur on the average:

$$\begin{aligned}\text{Errors / sec} &= \text{bits / sec} \times \text{error / bit} \\ &= 4 \times 10^6 \times 10^{-9} \text{ error / sec} && (1) \\ &= 4 \times 10^{-3} \text{ error / sec} && (2)\end{aligned}$$

The time between errors is therefore 250 seconds or a little over 4 minutes. The time between errors ranges from 100 seconds when 100% utilized, to 1000 seconds when 10% utilized. The network monitor will be able to recover from errors at this rate. However, the network must be capable of error detection and notification of the appropriate person when errors exceed certain limits.

CHAPTER 4

LIFE CYCLE COST

Life cycle cost analysis addresses all aspects of the system. The categories that are considered relevant are studied in greater detail. The Submarine Overhaul Facility Local Area Network life cycle costs are distributed across the categories of Research and Development, Construction and Acquisition, and Operations and Maintenance. The Cost Breakdown Structure in Figure 4-1 allocates costs according to category and then further divides the major categories. The costs associated with this section are estimates based on current literature and experience. Figure 4-2 shows the anticipated life of the system and significant milestones.

4.1 - Research and Development Cost (Cr)

Research and development costs are those incurred early in the system life cycle. For SOFLAN they include Management costs, Planning costs, Design costs and Test and Evaluation costs.

Management costs (Crm) consist of the development of the initial Request For Proposal and the cost of personnel for management of the project. Personnel requirements are one program manager, a systems engineer and a

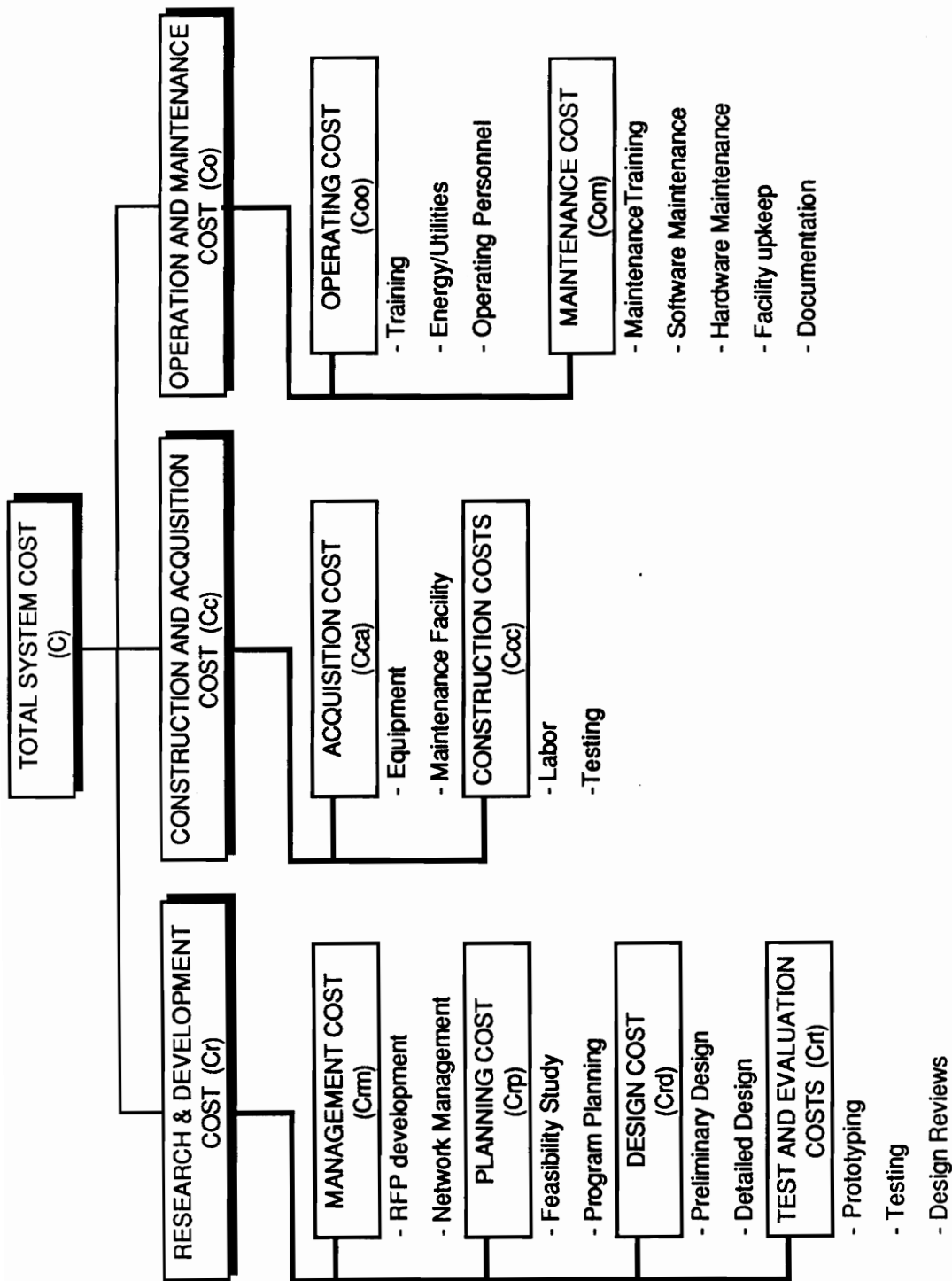


Figure 4 - 1 SOFLAN Cost Breakdown Structure

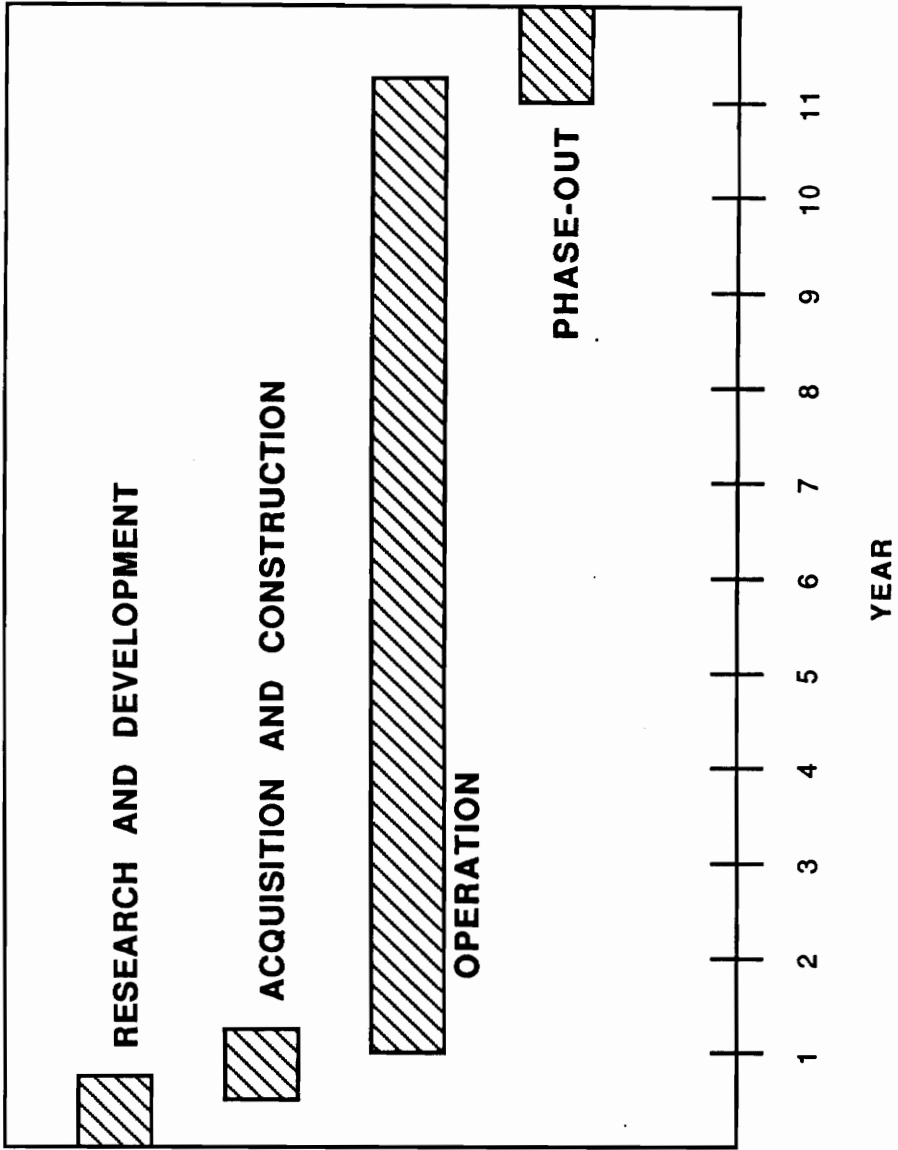


Figure 4 - 2 SOFLAN Program Plan

programmer.

Planning costs (Crp) cover feasibility study and other planning functions such as logistics and vendor support, maintenance plans, and overall network setup. Since the system is small scale, the program manager and staff will facilitate the planning function.

Design costs (Crd) cover all costs of design from conception to final design. The design of the network is accomplished by an experienced vendor who reports to the program manager. Design cost is estimated at \$10,000.

All testing, prototyping and design review costs are included in the Test and Evaluation (Crt) category. The system engineer and programmer are responsible for these stages and report to the program manager.

Costs associated with Research and Development are attributed to the salaries of the program manager, programmer and system engineer. Salaries, including benefits are estimated at an average of \$75,000 per person.

4.2 - Construction and Acquisition Cost (Cc)

Construction and Acquisition costs (Cc) are the costs incurred by the shipyard in the purchase of the network equipment and software and the subsequent creation of the network. The vendor is responsible for actual system configuration under the direction of the program manger and staff.

Acquisition costs (Cca) cover the cost of equipment and the cost of the maintenance facility that houses the operational maintenance personnel. A breakdown of the anticipated hardware and software costs are shown in Table 4.2-1. An additional \$20,000 is allotted for spare parts purchases in years two through eleven.

The maintenance facility is located in an existing building. An estimate of \$50,000 is required for materials, tools, work areas and test equipment for the maintenance facility.

Construction costs (Ccc) are a result of the labor involved in system configuration and testing of the system. All testing is accomplished by the system engineer and programmer with vendor support. Cost of construction with vendor support is estimated at \$25,000.

4.3 - Operation and Maintenance Cost (Co)

The cost of operating and maintaining the system will cover a majority of the anticipated system life and make up 98% of the costs in years two through eleven and 79% of the total system cost. Since these costs occur over a ten year span, an inflation factor of 5% is applied to the figures.

Operating costs (Coo) include training of individual users, the cost of electricity to power the system, and the cost of personnel operating or administering the system.

Table 4.2 - 1 Equipment Costs

	QUANTITY	UNIT COST	TOTAL
Microcomputers	35	\$2000	\$70000
Server	1	\$10000	\$10000
Transceivers	35	\$250	\$8750
Repeaters	8	\$1000	\$8000
Software:			
Network Operating System	1	\$1000	\$1000
DBMS	35	\$300	\$10500
Word Processing	35	\$250	\$8750
E-Mail	35	\$100	\$3500
File Transfer	35	\$100	\$3500
Cable (meters)	2000	\$3	\$6000
Network Interface Cards	35	\$425	\$14875
Server Interface Card	1	\$925	\$925
Dot Matrix Printers	35	\$500	\$17500
Laser Printers	5	\$1500	\$7500
TOTAL			\$170800

A one-day training session is necessary for all new users to learn correct operating procedures. Training sessions are held once per month with five users attending at a cost of \$200 per user.

Energy costs are estimated at \$25,000 over system life based on thirty-six stations operating twenty-four hours per day, 350 days per year for ten years at \$0.01/kilo-watt-hour.

One administrator oversees the system at a salary of \$75,000 per year for the life of the system.

Maintenance costs (Com) covers network hardware and software and maintenance at all three maintenance levels, training of maintenance personnel, operational maintenance facility upkeep and maintaining documentation.

Maintenance training is for two technicians at a cost of \$5,000 incurred in the first year. Salary for each technician is estimated at \$30,000 per year.

Software and hardware maintenance contracts total \$2500 per year while documentation is estimated at \$500 per year.

Facility upkeep is taken care of by existing cleaning crews, therefore, no additional hiring is necessary. The cost of upkeep is \$1500 per year.

4.4 - Total System Cost (C)

The total cost of the system must take into consideration all costs incurred in bringing the system into being. The significant costs are then identified and concentration is given to the highest contributors. Table 4.4-1 shows the estimated costs per category for the entire system. As expected, Research and Development Costs and Construction and Acquisition Costs are 88% of the total costs for the first year. Operations and Maintenance activities make up 98% of the costs in years two through eleven. The cost for phase-out is assumed negligible compared to the other costs and are not considered in the analysis.

4.5 - System Benefits

The benefits gained by implementing the network are realized in terms of time saved in the overhaul process. The network permits faster processing times of documents and faster and more accurate retrieval of information. As mentioned in the introduction, an overhaul that used to take eighteen months to complete is now taking twenty-four months. The shipyard is no longer partaking in any awards issued for finishing the overhaul on time. The contract price is set whether the overhaul is finished on time or not. The only way for the shipyard to profit beyond the contract price is through incentives for finishing on time. These incentives are usually 2% of the contract price. For a 50-million dollar overhaul,

Table 4.4 - 1 System Life Cycle Cost**RESEARCH AND DEVELOPMENT COST (Cr)**

	YEAR 1	YEARS 2-11	TOTAL
Crn Management	\$75,000	\$0	\$75,000
Crp Planning	\$75,000	\$0	\$75,000
Crd Design	\$10,000	\$0	\$10,000
Crt Test & Evaluation	\$75,000	\$15,000	\$90,000
Cr Total	\$235,000	\$15,000	\$250,000

CONSTRUCTION AND ACQUISITION COST (Cc)

	YEAR 1	YEARS 2-11	TOTAL
Cca Acquisition	\$220,800	\$20,000	\$240,800
Ccc Construction	\$25,000	\$0	\$25,000
Cc Total	\$245,800	\$20,000	\$265,800

OPERATION AND MAINTENANCE COST (Co)

	YEAR 1	YEARS 2-11	TOTAL
Coo Operating	\$0	\$1,279,000	\$1,279,000
Com Maintenance	\$65,000	\$916,400	\$981,400
Co Total	\$65,000	\$2,195,400	\$2,260,400

TOTALS	\$545,800	\$2,230,400	\$2,776,200
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the shipyard is forfeiting over \$1,000,000 per ship. Over the ten year life of the network, after fifteen ships have completed overhaul, the shipyard will have lost 15-million dollars. When compared to 2.7-million dollars for a networked information system, the choice is clear.

Earlier chapters revealed that over 1000 hours per overhaul are required to transport discrepancy reports and to wait for approval signatures on changes to procedures. It is estimated that an additional 500 hours can be saved with the ability to retrieve information faster and more accurately. This is a total saving of 1500 hours for the overhaul or approximately two months. Although the use of the network does not reduce the overhaul period below eighteen months, it does permit a significant reduction in the overhaul period.

The fact that better information is attainable will also result in higher productivity from the entire work force, from management on down. Managers will be able to spend more time solving problems instead of trying to locate the information necessary to solve the problem. Engineers will be freed from searching mounds of paperwork to obtain information. Trades will have the paperwork necessary in a timely fashion and stagnant periods will be eliminated. This increase in production may eventually reduce the overhaul period even further, allowing the shipyard to become more competitive and eventually participate in the award fees and incentives.

CHAPTER 5

MISSION PROTOTYPE

MISSION (Management Information System for a Submarine In Qverhaul-Nuclear) is a functional data base and retrieval application resident on SOFLAN (Submarine Qverhaul Eacility Local Area Network). MISSION is a menu driven system that allows the user to efficiently and effectively use the capabilities of the network. Besides the database, MISSION will incorporate a scheduling utility, electronic mail, word processing, electronic file transfer of procedures and a spare parts inventory system.

The MISSION prototype allows the user to interact with the database containing information pertaining to work permits and discrepancy reports for a submarine in overhaul. The prototype is developed using WingZ, a spreadsheet application for the Apple Macintosh. Wingz permits configuration of a spreadsheet into a database file where records and fields are defined. The database can be queried by using a series of menu selections. The menus are created using the graphics capability of Wingz. The database and menus are manipulated using the Wingz programming language, Hyperscript. Programs, or scripts as they are called in Wingz, can be attached to the menu items. When the menu items are selected, the program is executed. The programs are used to call subsequent menus or retrieve data from the database. The prototype

provides the capability to review data in various modes or add additional data to the database. Review of data is performed through menu item selections. Addition of data to the database is through menu item selections and inputs to requests from dialog boxes. A model of the menu structure is shown in Figure 5-1.

WingZ cannot run on S/OFLAN since the network is configured using IBM compatible equipment. However, the prototype does show how information is gained by user interaction with a database.

The user interacts with MISSION prototype through a series of graphical menus arranged in hierarchical order. The menus give the user the option to journey forward, backward one panel or backward to the main menu.

All functions dealing with discrepancy reports and work permits is presented in the prototype. However, all users will not have access to all functions. For example, the quality inspection department generates discrepancy reports, therefore, only they have authorization to add a discrepancy report to the system.

5.1 - Prototype Description

The first menu in the prototype allows the user to choose any of the MISSION functions. These include Scheduling, Work Tracking, Test Procedures, Spare Parts, Electronic Mail or Word Processing. Only the Work

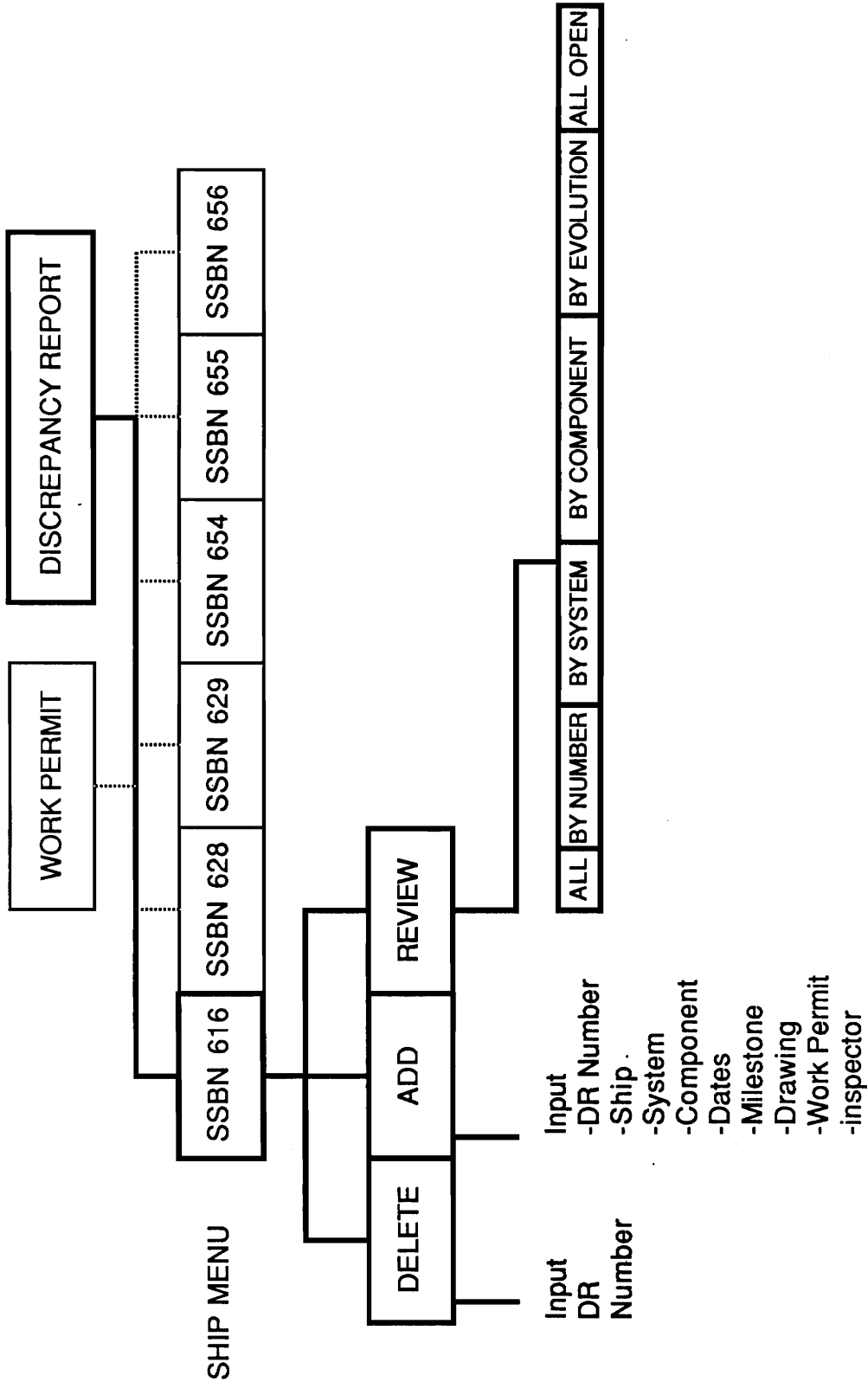


Figure 5 - 1 Hierarchical Menu Structure

Tracking function is actually coded in the prototype. Figure 5.1-1 shows MISSION's main menu.

After selecting the Work Tracking option the Work Permit and Discrepancy Report menu is presented as shown in Figure 5.1-2. Only the Discrepancy Report function is coded since the Work Permit function is very similar. Selecting Discrepancy Report from the menu gives the user a choice of ship and then a choice to Delete, Add or Review a discrepancy report as shown in Figure 5.1-3. By selecting Add or Delete, the user is prompted to input the necessary information. Selecting Review gives the user the option to review or retrieve data from the database in a variety of methods. The user can review all the discrepancy reports on a ship, by discrepancy report number, by system, by component, by major evolution, and all open discrepancy reports for a particular ship. The review menu is shown in Figure 5.1-4. Each request for information is presented on the screen with the option to print the report. Figure 5.1-5 is a sample report output.

The prototype clearly shows how data that previously took hours or days for a highly paid engineer to retrieve will now only take a manager only a few minutes. This ability to quickly and accurately retrieve information will allow better planning and scheduling on the part of management, will free the test engineers for test and overhaul related activities, will result in fewer delays, thus lowering the cost and time of a submarine overhaul.

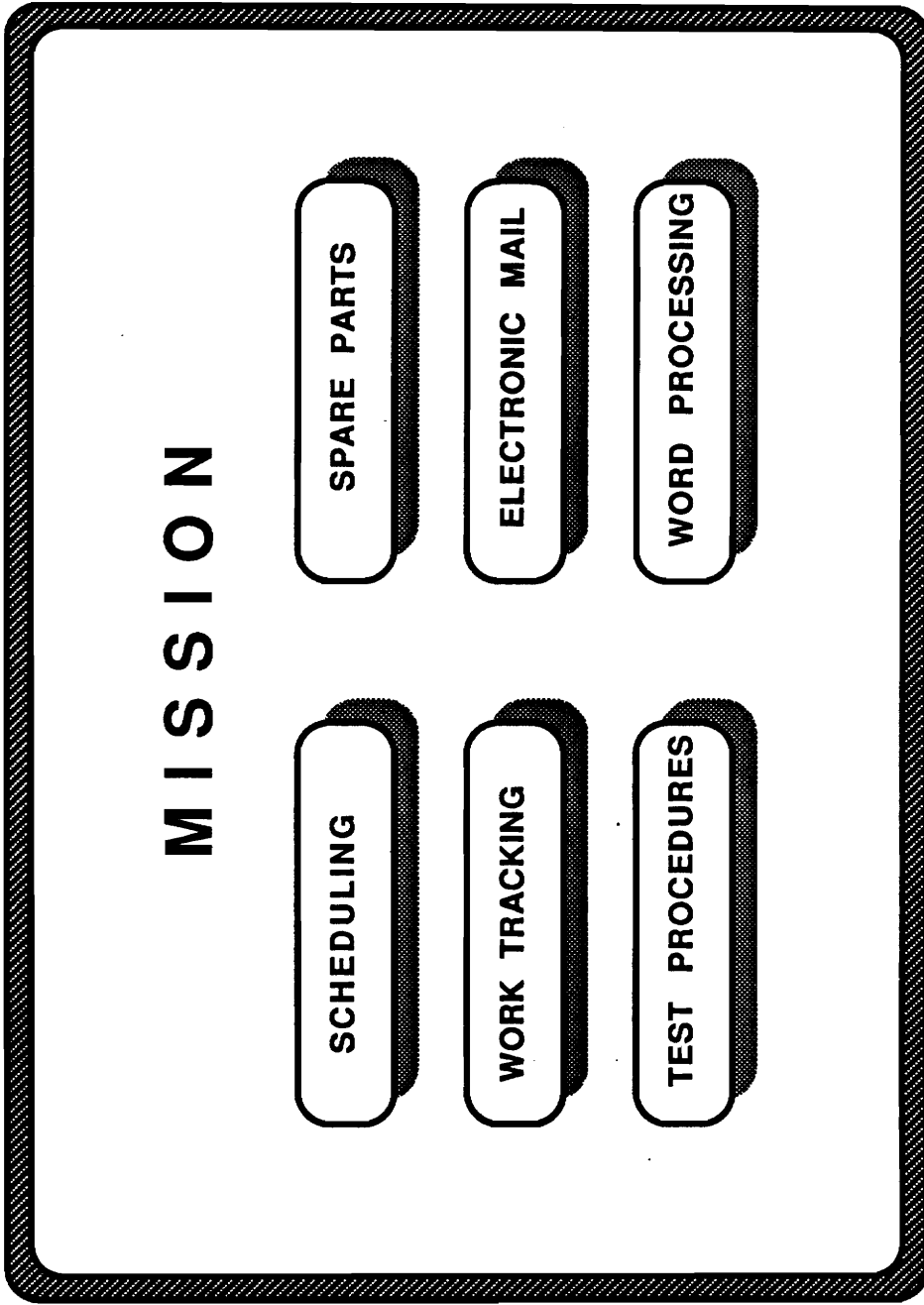


Figure 5.1 - 1 MISSION Main Menu

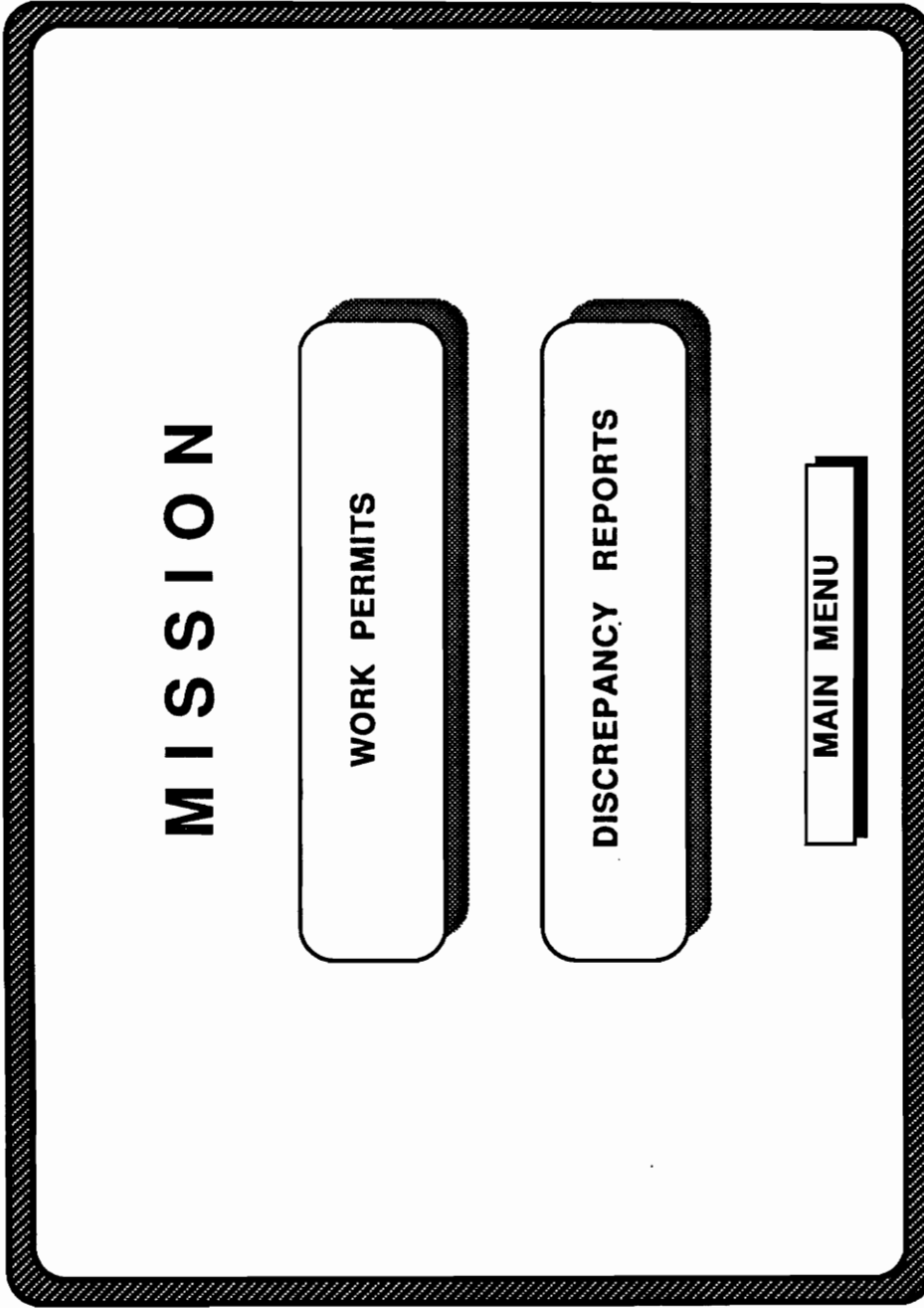


Figure 5.1 - 2 MISSION DR or WP Menu

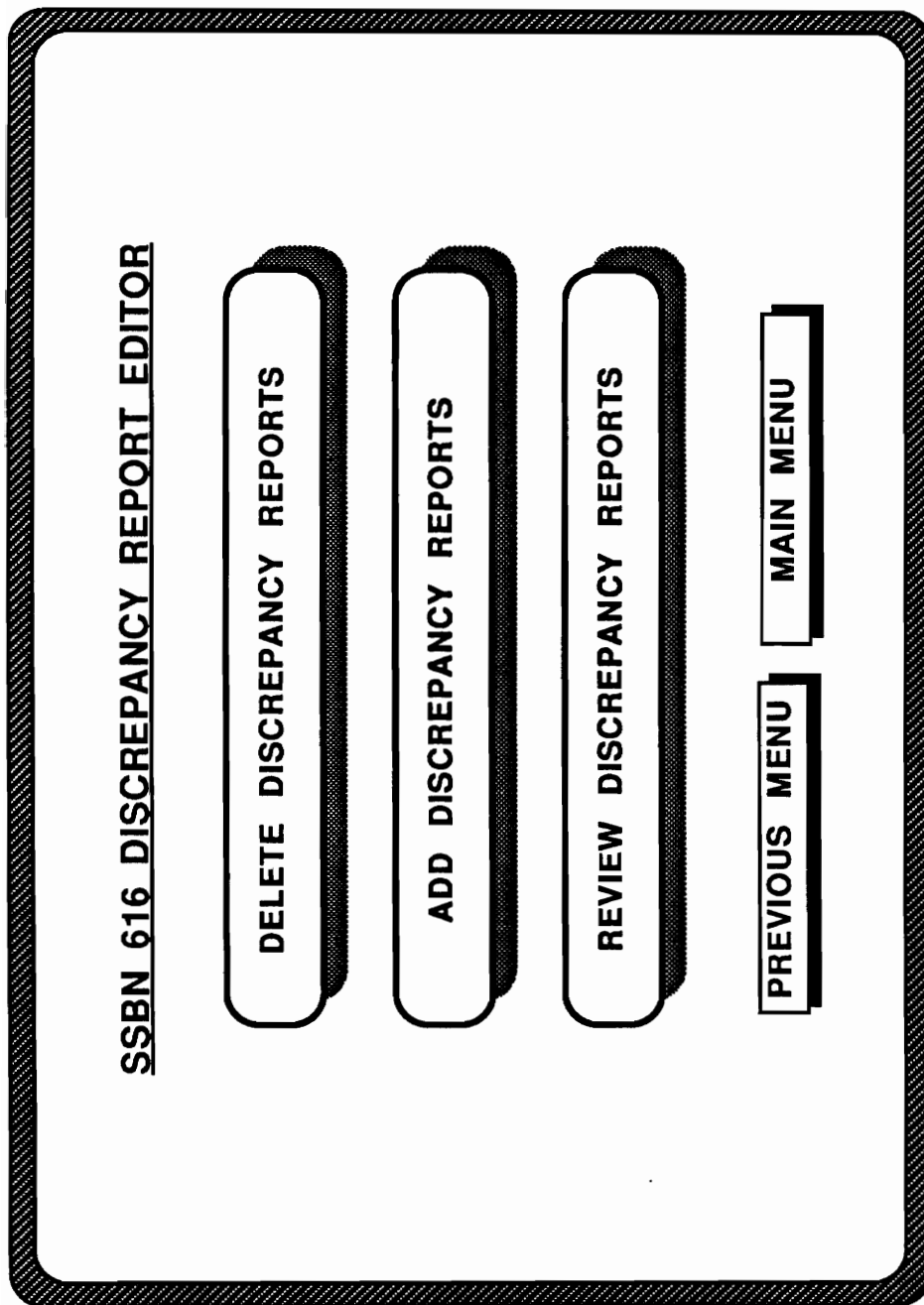


Figure 5.1 - 3 MISSION Discrepancy Report Editor Menu

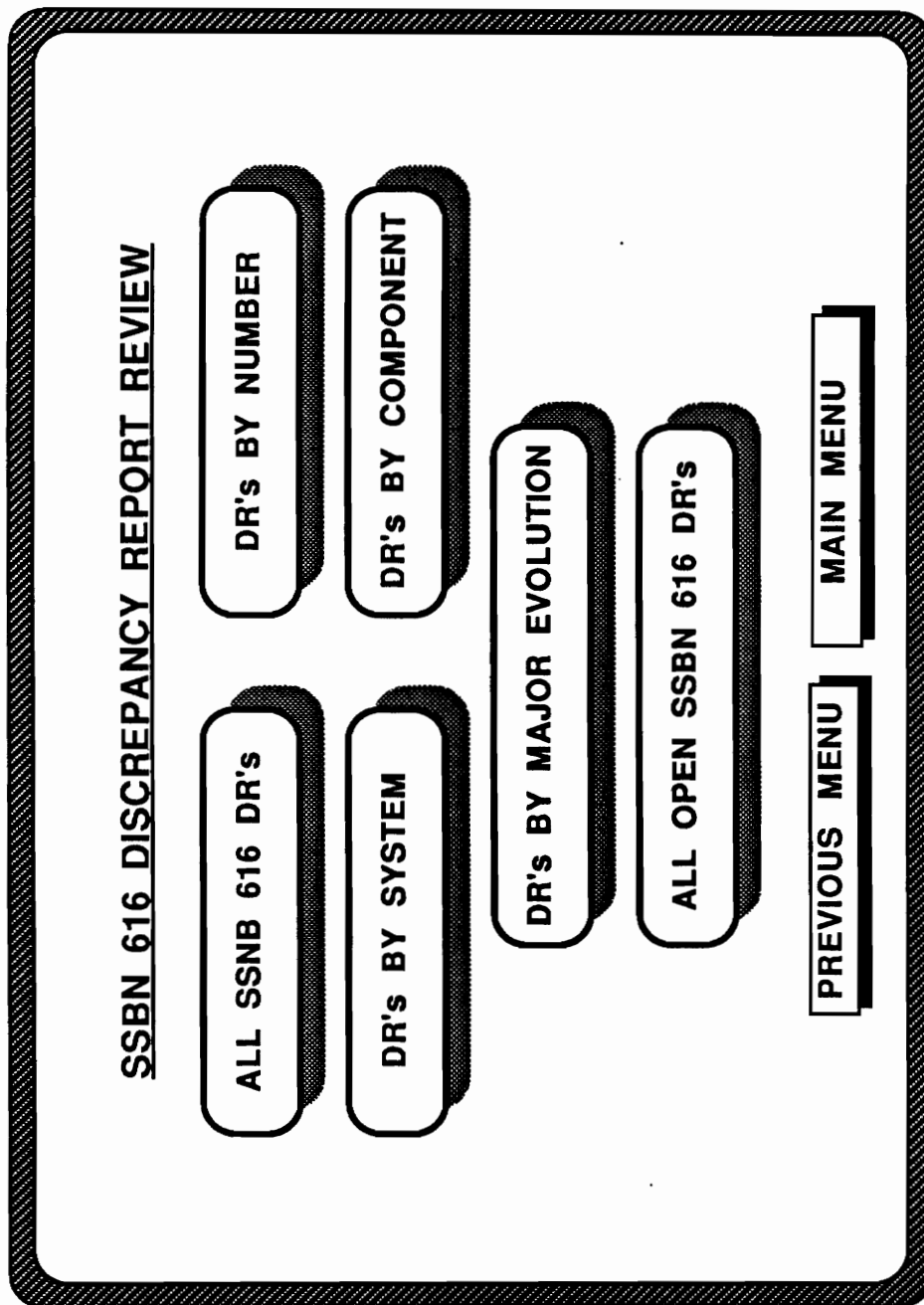


Figure 5.1 - 4 MISSION Review Menu

SSBN 616 DR's

						PRINT	MAIN MENU	PREVIOUS MENU
DR NUMBER	SHIP	SYSTEM	COMPONENT	DATE ISSUED	INSPECTOR			
12345	616	RA	123	1-Oct-60	123-23-2323			
55555	616	FE	666	9-Sep-90	888-88-8888			
17154	616	CH	99	1-Oct-89	878-45-0925			
98765	616	VO	56	4-Dec-89	166-22-2323			
22222	616	RA	33	9-Sep-90	121-22-2222			
16577	616	FW	14	13-Jan-90	171-54-4290			
28570	616	SG	28	12-Jan-90	211-56-8068			
31569	616	CH	31	14-Jan-90	211-56-8068			
34567	616	VO	35	6-Jan-90	211-56-8068			
37565	616	MC	38	18-Feb-90	211-56-8068			
40563	616	PS	41	21-Jan-90	211-56-8068			
43562	616	RA	45	3-Jan-90	157-40-9943			
52556	616	FW	55	29-Jan-90	157-40-9943			
70546	616	FW	75	2-Feb-90	834-12-0987			
73544	616	MC	78	14-Feb-90	834-12-0987			
88536	616	FW	95	25-Feb-90	123-54-4289			
91534	616	MC	98	27-Feb-90	321-09-8765			
94532	616	PS	102	2-Mar-90	321-09-8765			

Figure 5.1 - 5 MISSION Sample Output

CHAPTER 6

THE FUTURE

The anticipated system life of SOFLAN is ten years. After this time the system must be re-evaluated to determine if it still functions in a cost effective manner. This decision will be based on several factors including; available funds, priority, cost benefits of replacement or upgrade, system performance, competition, maintenance costs, availability of replacement parts and vendor support. Increasing capabilities and decreasing prices may also be a driving factor in an effort to obtain new and better equipment, i.e., the latest in technology. The field of networking and computing is quickly evolving. This section deals with the future and anticipated changes in the computer and networking environment.

6.1 - Looking Ahead

SOFLAN is designed using coaxial cable. This medium has been around for many years and will continue to be the medium of choice for local area networks for years to come. New and improved hardware will simply replace the existing hardware. The equipment connected to the network is usually the limiting factor in terms of data rate and not the network itself. Ethernet is

capable of delivering 10- Mbps and it is not anticipated that data rate requirements for the shipyard ten years from now will be greater than this. However, in the unlikely event that this is not true and data rate requirements exceed the capabilities of SOFLAN then fiber optic cable may be a viable alternative. Costs for fiber optic cable will be comparable to coaxial cable with the added benefit of much higher data rates. Fiber optics also eliminates the problem of electromagnetic interference. Technology will advances will allow easier connection permitting multipoint configurations instead of existing point-to-point links.

SOFLAN is currently configured as a server-based system. The centralized database receives requests for data from the stations and outputs the necessary information. Since much of the data in the database is ship specific, distributed databases are anticipated in the future. The constant reduction in price and advancing capabilities of hardware will make de-centralization an even more attractive alternative. Intel's CEO anticipates 64-Mb chips by the year 2000 with 256-Mb chips following a few years later. Compare this with today's 1-Mb chips.

Software development will also realize advancements in the next decade. The ability to generate code more easily and quickly with application generators and 4th-generation languages will aid programmers as well as managers. Prototypes will be developed more easily and earlier in the design stage to

determine if continuation is worthwhile.

Another development is client/server computing. In client/server computing, the processing is split between the server and the user or client. This frees up the server for other requests and jobs while providing faster processing times. The faster times are a result of the user station accepting some of the processing load.

Adaptation to standards such as the OSI model and IEEE specification will be paramount for survival of a vendor. Customers will be searching for interconnectivity of components regardless of make. Customers of the twenty-first century will not be satisfied with proprietary systems; diversification will be the norm.

And finally human factors considerations must be addressed. Graphical User Interfaces (GUI's) like that of the Apple Macintosh will be necessary for non-computer users to accept changes. Computer interaction must be made simple and straightforward. Speaker-independent voice recognition systems will be possible with the increasing capacity of chips. Requests for data will be made in an unstructured format with the system keying off of specific words or groups of words.

These advances and others not imagined will continue to improve the quality and quantity of information obtained for the next generation of decision making.

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VITA

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Jeff married Lisa G. Beitle in September of 1983. They are expecting their first child this summer.