DESIGN OF A LOCAL AREA NETWORK AND A WIDE AREA NETWORK TO CONNECT THE US NAVY'S TRAINING ORGANIZATION

by

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(ABSTRACT)

US Navy training commands use a local area and a wide area network known as the Versatile Training System II (VTS). VTS furnishes word processing, electronic mail, and data base functions, all of which can be transferred throughout the network. Enabling this rather old system is a mainframe at each training site with user terminals dispersed throughout the command. The system was installed and is maintained by civilian contractors. VTS does not have the capabilities to develop and maintain curriculum, because advanced word processing and graphics are required. This results in the Navy's training commands having redundant computer systems.

Due to the shortcomings of VTS, a need exists to establish local area networks at training commands. Additionally, a wide area network is required that would give a standard package of electronic mail and file transfer capabilities. All of this must be accomplished using existing command computer resources and at a more economical price than the remaining lifecycle cost of VTS.

To facilitate the design, the systems engineering concept is utilized. A specific design is developed to fill the identified deficiency. Existing resources and "off the shelf" material are to be used exclusively.

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SECTION 1 INTRODUCTION

The United States Navy is a worldwide organization consisting of over 400,000 personnel, over 400 ships, and thousands of aircraft with a huge infrastructure supporting the personnel and equipment[1]. Even though the Navy takes personnel of varying skill levels, most often new recruits are unskilled high school graduates. These personnel are trained to perform all varieties of jobs at institutions supporting different levels of education. This includes three postgraduate institutions, one undergraduate school, a college preparatory school, and numerous technical and trade schools. The Navy's training organization is spread across the country from Pearl Harbor, Hawaii to Newport, Rhode Island. Due to the dispersion of fleet assets and a large student throughput, the same courses are often taught on different sides of the country. A sailor might criss-cross the country while progressing through a training pipeline required for an individual to achieve a certain skill level known as a NEC (navy education code) for enlisted personnel or Officer Billet subspecialty code for officers. Maintaining uniformity of these courses, controlling and tracking the student during the pipeline progression, and keeping track of the Navy's personnel assets requires good communication. With

[1]Norman Polmar, The Naval Institute Guide to the Ships and Aircraft of the U.S. Fleet, (Annapolis, MD: Naval Institute Press, 1993), p.2.

recent advances in the communication field, it is becoming easier to transfer data around the world, and the Navy desires to take advantage of this.

With the end of the cold war, the nation is looking for a peace dividend, and the result is a "downsizing" of the military. Bases are being closed, ships are being decommissioned, and squadrons are being deactivated. The end result of downsizing is that a "jointness" between different branches of the services is evolving and fiscal responsibilities are vital. This unknown evolution makes it very difficult to predict the navy's configuration in the year 2000[2]. With this in mind, a communication system to transfer educational data must be flexible, easily able to link different systems, and economical.

The purpose of this project is to design a computer network to link offices within a training command and, in turn, link training commands throughout the Navy, independent of where they may be located. A typical training command has been chosen, which is the Naval Guided Missiles School (NAVGMSCOL) located at Fleet Combat Training Center, Dam Neck, VA. After the local area network (LAN) is developed, a wide area network (WAN) is developed, allowing all training commands and other commands that require access to training data, such as the Office of Naval Personnel (BUPERS), to have

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[2]Polmar, p. ix.

access. To fully understand why a computer network is required, the current computer equipment used and data to be transferred is covered.

To properly design this computer network system, the systems engineering concept is used. The project starts with the definition of need. Next, conceptual design is accomplished based on need requirements, followed by a preliminary design. During this phase, specific system tasks are defined, alternatives are weighed, and resources are allocated. Results of preliminary design are then used to perform the detail design. Finally, a framework is developed to actually construct and operate the system.

SECTION 2 NEED DEFINITION

2.1 Existing Conditions

Currently, the Navy has both a LAN and a WAN used by training commands called the Versatile Training System (VTS). This network is a mainframe system with Wang minicomputer terminals serving as workstations dispersed throughout a given command. The workstations are connected by unshielded twisted pair cables. A Command's LAN is linked via the Defense Data Network (DDN)[3] to other commands. There are 11 years remaining in the lifetime of VTS. The following data reports, an output of the Navy Integrated Training and Resources Administration System (NITRAS), are available on VTS:[4]

1. The Master Course Reference File (MCRF) contains the maximum possible yearly student throughput for a command, planned course schedule, and planned student throughput. This file tells a command what the demand is for a certain course so the command can schedule an adequate number of class convenings for the year. File length is 50 KB.

2. Student Master File (SMF) contains training-related data on individual students used on a daily basis to

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[3]Naval Education and Training Program Management Support Agency (NETPMSA), Versatile Training System-II, (From Oral Presentation Prepared 1993), p.8; Hereafter cited as NETPMSA.

[4]Naval Education and Training Command (NAVEDTRA) Instruction 135, Navy School Management Manual, September 1992, p.6-2-2.

account for all students from the time they begin a course until graduation. File length is 10 KB.

3. Training Summary File (TSF) lists historical training statistics for a command updated monthly. File length is 20 KB.

4. Pipeline Management File (PMF) works along with the MCRF and the SMF to track a student through a training pipeline. File length is 15 KB.

Additionally, VTS provides the following services:[5]

1. Word processing.
2. Electronic mail throughout the LAN and WAN.
3. Tests for all courses.
4. Master Course Schedules.
5. Personnel Data Base used to track all training received by a sailor in a career.

All of these capabilities are for unclassified data.

The VTS cost is broken down to each command based upon use. VTS, due to cost, is only available to large commands. A large command is defined as greater than 50 users. The current cost of VTS to a command for the remaining life, 11 years, is $2.2 million.

In addition to the mainframe computer, every office within Naval Guided Missiles School has an IBM compatible standalone computer, ranging from 80286 microprocessor

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[5]NETPMSA, p.10.

computers to 80486 microprocessor computers. For each course taught, a Course Curriculum Model Manager (CCMM) is designated. The CCMM is a command and is in charge of developing the curriculum for a course and updating the course as it is taught. This training system ensures that even though a course may be taught at three separate commands spread across the country, the curriculum used is uniform and that all graduates have the same skill level. The curriculum is currently required to be written on Word Perfect 5.1. After the curriculum is developed or changed, the curriculum is mailed to all applicable training sites on 3.5" computer disks. The largest course is 3 Mb of data. IBM compatible computers are required because the VTS does not have software that is adequate for curriculum. To develop course curriculum, a word processor, graphics software, and optical scanning software is required. VTS simply does not have these capabilities.

2.2 Current Deficiency

The end result of having to use two types of computers at a training command are that:

1. A command must purchase the VTS from a lone vender for $2.2 million for the remaining system life, 11 years,and must purchase IBM compatible computers, a total cost of $400,000 to a large command like Naval Guided Missiles School. Having to use two computer systems is

redundant and very inefficient.

2. Even though student data, course data, and electronic mail can be transmitted within a command, the curriculum cannot be transmitted between commands. This results in curriculum being mailed and drastically reduces how quickly the curriculum can respond to a required change. Currently, the largest data file, 3 Mb, is required to be transmitted within 3 sec on the LAN, and 6 minutes over the WAN.

3. Personnel must be trained to use and maintain two separate computer systems and a wide range of software. Currently, naval personnel maintain the various IBM type computers while a civilian contractor maintains VTS.

4. VTS is inaccessible to small and remote bases due to the expense of requiring civilian contractors and a mainframe at every site, $2.2 million for the remaining 11 years of system life.

The Navy's training community needs one computer system to alleviate these problems, while keeping in mind the potential changes ahead for the military.

2.3 System Requirements

To meet the existing deficiency, a computer network system is required to meet the following needs:

1. To fill the final 10 years of VTS lifetime. This will allow for 1 year of development and installation,

and a 10 year lifetime.

2. The system must be more economical than VTS. This means the lifecycle cost per command must be less than $2 million, the cost of the final 10 years of system life.

3. The wide area network must be available throughout the world and have the capability to link different systems. This requires a worldwide open system based upon industry standards.

4. The system must have the capability to transfer all the data files currently in VTS and, all curriculum to allow for easy and quick curriculum updates. The largest data files, curriculum 3 Mb in length, must be transferred within 6 minutes over the WAN. To meet this requirement, small commands with low usage must have a bandwidth of 9600 bps, but large commands require 1.5 Mbps of bandwidth due to high usage.

5. A local area network must be developed for training commands. Naval Guided Missiles School will be used as the typical command (see Figure 1 for a diagram of the command). The system must be easily adaptable to any type of command. For economical comparison, the system under development will have a lifecycle cost based on installation at Naval Guided Missiles School. This allows comparison to VTS since the cost is based upon individual commands. How the total lifecycle cost varies

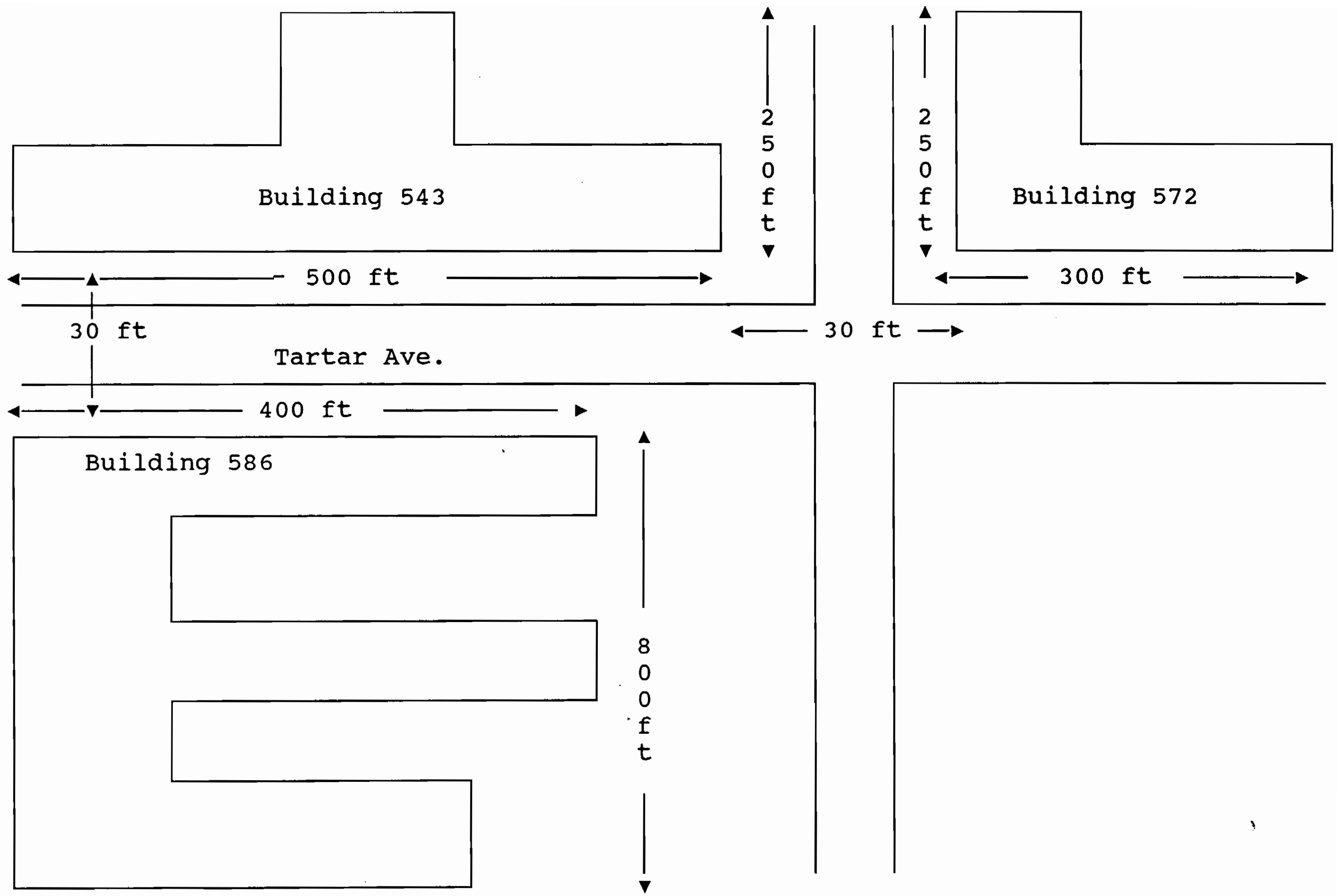

Figure 1. Naval Guided Missiles School, Dam Neck , VA.

depending upon command size requires coverage following lifecycle cost analysis. This allows a large command like Naval Guided Missiles School with over 200 individual workstations and a small command that may only have one workstation to exchange information. The LAN is required to transmit the largest files within 3 seconds, so 1 Mbps bandwidth is required.

6. The system must be easily upgraded as advanced software is developed, so that the navy can take advantage of the advances. This is accomplished by developing an open system using industry standards.

7. The system must be flexible to allow for future base closures and realignments, so that a command's computer resources can be transferred to another site. This may happen if a base is closed, but a tenant training command on this base is not closed, but simply relocated. This is accomplished using an open system and industry standards.

Besides meeting the requirements listed above, the system must provide basic computer services currently offered by VTS to all users, both within a command's LAN and to WAN users. The following must be provided to users of the LAN:

1. Word processing, where files can be accessed at all workstations throughout the command. Currently, all curriculum is on Word Perfect 5.1. The same

software or similar is required so that existing files can be used.

2. Electronic-mail throughout the LAN.
3. Data base files to compile student and course data.
4. File manager.
5. Data storage allowing all users an allotment for storage. Each user requires 15 Mb of storage on the LAN, and each client workstation requires 40 Mb.
6. Graphics to allow graphs and images to be generated and input to a word processing file which in turn can be transferred throughout the network.

The WAN must provide the following user services:

1. File transfer for student, course, and curriculum information. To accept and transmit data files, the WAN gateway terminal requires 100 Mb of data storage.
2. Electronic-mail

Because of current budget cuts and uncertainty of future base existence, this system must be flexible and adaptable to varying command sizes and uses. Therefore, for system uniformity and flexibility the system will take advantage of existing standards to result in an open system easily adapted to various applications. Current technology and off-the-shelf components are to be utilized exclusively. The project must also take maximum advantage of computer resources already existing at the commands, namely Zenith 80286 and Gateway 80486 microprocessor machines.

2.4 System Priorities

The highest priority of the project is implementation in one year which allows the system to replace the final 10 years of VTS lifecycle. This leads to the requirement to use off-the-shelf components so that no new hardware or software will be developed. Existing technology will be utilized. Additionally, the WAN must be available worldwide.

2.5 System Budget

The system budget must be less than the remaining lifecycle cost of VTS, $2 million. Various possibilities must be weighed using cost analysis to ensure the most economical system over the lifecycle has been chosen. A lifecycle cost analysis is required for Naval Guided Missiles School, a large training command. Changes in this cost depending upon command size will be covered.

2.6 Available Resources

The following computer resources exist at Naval Guided Missiles School. The command is broken into three different buildings (see Figure 1 for a Naval Guided Missiles School diagram), and within each building are 80486 IBM compatible computers and 80286 IBM compatible computers. The system must be available for up to 200 users evenly distributed throughout the command. The buildings are adequately wired, have adequate environmental controls, have tiled cement floors, and lowered false overheads where wires can be run.

2.7 Summary of Need Definition

A need exists, and to fill this need, a computer network system is required. The current condition exposing the deficiency is that redundant computer systems exist to transmit student data and curriculum and to provide computer services. To alleviate this deficiency, a system is required to meet stated requirements of bandwidth, cost, software capability, data storage, accessibility, and adaptability. System priorities, budget, and available resources were stated to establish top level guidance. The system now has been broadly defined, but the detail design cannot yet begin. Potential solutions must be examined, and system specifications further defined. While the iterative systems engineering project continues, the requirements defined in this section are constantly reviewed to ensure the system meets the existing need and system requirements. Next, to further define and begin the system, the conceptual design will be performed.

SECTION 3 CONCEPTUAL DESIGN

In the conceptual design, a feasibility study is first conducted. This study examines the different technological alternatives that can be used to satisfy the deficiency or need. Next, the system operational requirements are stated. This permits the engineer to ensure that the product being designed can fully meet the need. Operational requirements are specific parameters the product can be designed to meet. After the operational requirements are stated, the maintenance concept is developed. By knowing how the system will be maintained, the product can be designed to ensure this concept is feasible. Knowing the operational requirements and maintenance concept, all possible technologies that can be used to solve the problem are examined, and a plan of action is developed. Finally, at the conclusion of the conceptual design, the system acquisition process and major milestones can be planned.

3.1 The Feasibility Analysis

What technology options exist to meet the computer network's requirements? System requirements state that existing technology is to be utilized. The alternatives for a LAN and WAN must be examined. The following alternatives exist for the LAN:

1. **Ethernet.** Ethernet technology is the IEEE 802.3 Carrier Sense Multiple Access/Collision Detection

(CSMA/CD) LAN standard. The advantages of this technology are that it is a common, proven, and reliable system; has adequate bandwidth (10 Mbps); is relatively inexpensive; and cable length is minimized because workstations do not require an individual cable from the server as in the Star topology and return cables are not required as in the token ring topology.[6] The major disadvantages are the bandwidth is not as great as fiber optic technology, the technology does not lend itself well to the use of fiber optics,[7] and larger LAN's can be built using other technologies.

2. **Token ring.** This technology lends itself to fiber optic technology, specifically, Fiber Distributed Data Interface (FDDI) which provides 100 Mbps of bandwidth. With conventional cabling, the IEEE 802.5 standard can be used to provide a bandwidth of 4 to 16 Mbps.[8] A token ring also offers larger transmission distances especially with fiber optics.[9] The major disadvantage of the token ring is expense mainly due to Multiple Access Units and,

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[6]Stan Schatt, Understanding Network Management Strategies and Solutions, (Blue Ridge Summit, PA: Windcrest Books, 1993), p.31.

[7]Schatt, p.31.

[8]"Token Ring," Data Communications, Volume 13 Number 3, 1993, p.40.

[9]Schatt, p.31.

if used, fiber optics.[10]

3. **Star topology.** A star network consists of terminals connected to a central node. This technology offers centralized control, which makes network monitoring and management easier. The big disadvantage is that if the centralized node fails, the whole network fails.[11] The first two technologies examined were distributed networks, while the star and the next option are centralized networks.

4. **Mainframe with terminals distributed throughout the offices.** This is what already exists, VTS, but is still an option if the existing standalone computers can be incorporated into the network allowing their capabilities to be used. The advantages of this option are that the system already exists in many commands, the mainframe offers sufficient data storage capacity and computing capacity, and this is known technology with many skilled operators and maintenance personnel. The major disadvantage is stated in the definition of need, that it is a very expensive option for small commands that do not need the large capacity. Also, a mainframe system is not a common industry standard, but is unique to the vendor.

There are two technologies possible for the WAN.

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[10]Schatt, p.31.

[11]Schatt, p.31.

1. **Internet.** The Internet which uses the Transmission Control Protocol/Internet Protocol (TCP/IP) is a reliable virtual circuit service providing worldwide coverage. The Department of Defense developed the Internet to interconnect LANs, and today the noncommercial section is supported by the U. S. National Science Foundation. This WAN is made up of different networks including the DDN which is what VTS uses. The advantage of this WAN is that it is very accessible throughout the world, thus allowing remote commands access. Also, the Internet is flexible, so many different networks can be linked providing the maximum utilization. The primary disadvantage is that compared to emerging technologies, it does not have large bandwidth making it unacceptable for video, but this is not a requirement for this network.

2. **Integrated Services Digital Network (ISDN).** ISDN offers digital communications from the telephone companies. There are two types of services available, basic and primary. The basic rate offers two 64 kbps channels (B channels) for data transfer and a 16 kbps channel (D channel) used to setup and control the B channels or as a low data rate channel. Basic rate ISDN is known as 2B+D. The primary rate service offers 24 64 kbps channels, one of which is designated the D channel

while the rest are B channels. Therefore, with ISDN bandwidths are available from 64 kbps to 1.544 Mbps. This bandwidth can be used for voice, data, and even limited video transmission. The main disadvantages are cost and accessibility.[12] ISDN is not offered throughout the country, but is currently becoming more widely available. This prevents remote commands from having access to the network. ISDN is the predecessor to Broadband ISDN (BISDN) which is an optic network that will eventually offer bandwidth of 150 Mbps[13] and more. By choosing ISDN, this may lead to rapid transition to BISDN once this technology is made available.

There are other technological possibilities, but the above options are the ones most able to meet the need. Continuing the conceptual design, the operational requirements must be stated. After these requirements are stated, a proper technology can be better chosen.

3.2 System Operational Requirements

The following technical parameters describe how the system will be deployed or used. These define the operating characteristics.

1. **Mission Definition.** The purpose of the computer

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[12]Schatt, p.177.

[13]Dimitri Bertsekas and Robert Gallager, Data Networks, (Englewood Cliffs, NJ: Prentice-Hall, Inc., 1992), p.129.

network is to provide a LAN to training commands for electronic mail, word processing, data base for training files (MCRF, SMF, TSF, PMF), file management, graphics, and data storage. Also, a WAN will connect commands together no matter how remote a command may be, and provide data file transfer (curriculum and training files) and electronic-mail. This system will primarily be used by training commands, but other commands may access the network depending upon the need. All information on the system will be unclassified.

2. **Performance and Physical Parameters.** The network must offer reliable data transfer at 1 Mbps bandwidth for the LAN. The WAN requires 9600 bps for small commands and 1.5 Mbps for large commands. Each LAN user requires 15 MB of storage resulting in 3 GB for a 200 user LAN, each client workstation requires 40 Mb of storage, and the WAN gateway requires 100 Mb of storage. Only data will be transferred, not voice or video.

3. **Use Requirements.** The network must have a 95% operational availability. At many commands, training is conducted on several shifts and due to time differences throughout the world, the network requires a high availability. The network will be used by personnel within the training command that are not primarily computer users with no prior formal training. This

requires a user friendly operating system and that training must be offered to the users.

4. **Operational Deployment and Distribution.** The system will be available to commands throughout the world. This will allow training commands from Dam Neck, VA to San Diego, CA to Naples, Italy to link into the WAN. Within the LAN, a command may have only one or two users, but some commands may have as many as 200 users, but no more are anticipated. All computers will have electrical access (120 VAC, 60 hz, single phase) from standard wall outlets or transformers if overseas. This system must be fully functional in one year.

5. **Operational life cycle.** The system has an 11 year life time, one year for development and construction, and 10 years of operation. At the end of the system's life, BISDN will have been developed, and the Navy plans to take full advantage of this by completely rethinking the computer and network requirements. If this system has a ten year operational life span, the BISDN should have ample time to become available.

6. **Effectiveness Factors.** The system requires a 95% operational availability, so the Mean Time Between Maintenance (MTBM), Mean Active Corrective Maintenance Time ($\overline{M}ct$), Mean Preventive Maintenance Time ($\overline{M}pt$), Mean Active Maintenance Time ($\overline{M}$), Maintenance Downtime (MDT),

Logistics and Administrative Time (LDT, ADT), and Mean Time Between Failure (MTBF) must combine to support the 95% uptime. Operator skill levels are limited to junior levels and maintenance personnel skill levels are limited to junior and intermediate technician levels at the organizational level with senior levels at the depot.

7. **Environment.** The network will be indoors at normal room temperature and humidity. The LAN may have to connect different buildings (it definitely will for Naval Guided Missiles School). The network will not be used at sea. Normal commercial carriers will be used for shipping of hardware and software components.

Now that the possible technologies available for the system and the operational requirements have been stated, the maintenance concept is ready for development. The feasibility study, system operational requirements, and the maintenance concept give enough information so that conceptual design can be completed and the system can proceed to preliminary design.

3.3 Maintenance Concept

When developing the maintenance concept for this system, it must be remembered that the network will be used by large and small commands alike, so resources may be limited in some areas. Additionally, all components will be purchased "off the shelf" allowing warranties and manufacturer's repair capabilities to be available. After all areas of the concept are examined, a chart summarizing the plan is presented. The following delineate the maintenance concept for both the WAN and LAN:

1. **Levels of Maintenance.** The organization and depot levels of maintenance are used. At the organizational level, all preventive maintenance and corrective maintenance by fault isolation down to the circuit card level is performed. At the depot level, corrective maintenance on the components isolated by the organization is performed.

2. **Basic Responsibilities For Support.** The organization will perform all preventive maintenance and corrective maintenance down to the circuit card level or down to major components. These components will be returned to the manufacturer for repair. The depot level will repair returned isolated faulty components.

3. **General Repair Policies.** The organization level is constrained by limited resources. The system requires a MTBM of 10 days and a MTBF of 50 days. The Navy will use Data System Technicians (the DS rating) to perform maintenance. A school will be developed for DS's and will train the technicians for maintenance for both the LAN and WAN components. A Navy Education Code will be granted to graduates.

4. **Major Elements of Logistic Support.** Test equipment

required for preventive and prescribed corrective maintenance will be maintained on site. Spare test equipment must be maintained to account for calibration time. If required, hardware and software spares will be maintained on site to ensure that 95% up time is maintained. This will include computer cards, monitors, cabling, connectors, and software as necessary. Depending on the size of the command, a repair facility will be established with a maintenance organization.

5. **Effectiveness Requirements.** The following requirements are set for the system

MDT - 13 hours

$\overline{M}$ - 7.6 hours

$\overline{M}pt$ - 4 hours

$\overline{M}ct$ - 21 hours

MTBF - 50 days

MTBM - 10 days

ADT - 1 hour

LDT - 12 hours

To validate the above requirements, given that MTBM is 10 days and MTBF is 50 days, then out of a 50 day period, preventive maintenance will be performed four times and corrective maintenance once. This leads to the conclusion that preventive maintenance will be performed 30 times per year and corrective will be performed eight times per year. To allow a 95% operational availability, the MDT is 13 hours. With a MDT of 13 hours, ADT equal to 1 hour, and LDT equal to 12 hours, the $\overline{M}$ equals 7.6 hours. Knowing $\overline{M}$ and $\overline{M}pt$, the $\overline{M}ct$ is then determined to be 21 hours. Supply components must be available to quickly swap out the affected component, which may mean replacing an entire computer to allow for troubleshooting the computer down to a lower component.

6. **The Maintenance Environment.** The maintenance will be performed indoors either at the workstation or in a work shop. Normal room temperatures and humidity will be present. Depot level maintenance will be performed in the manufacturer's repair facility.

Figure 2 summarizes the maintenance concept. With the statement of the maintenance concept, the design can continue by picking a formal technology to use while meeting the need.

3.4 The System Acquisition and Major Milestones

To conclude conceptual design, decisions are made to allow the top-down system design to continue. First, after examining the need analysis, feasibility study, system requirements, and maintenance concept, a technological solution is chosen. This allows the design to progress down to the more specific preliminary design level. Also, guidance for the top-down design is set in the form of a major milestone chart and an organization chart. These guide the

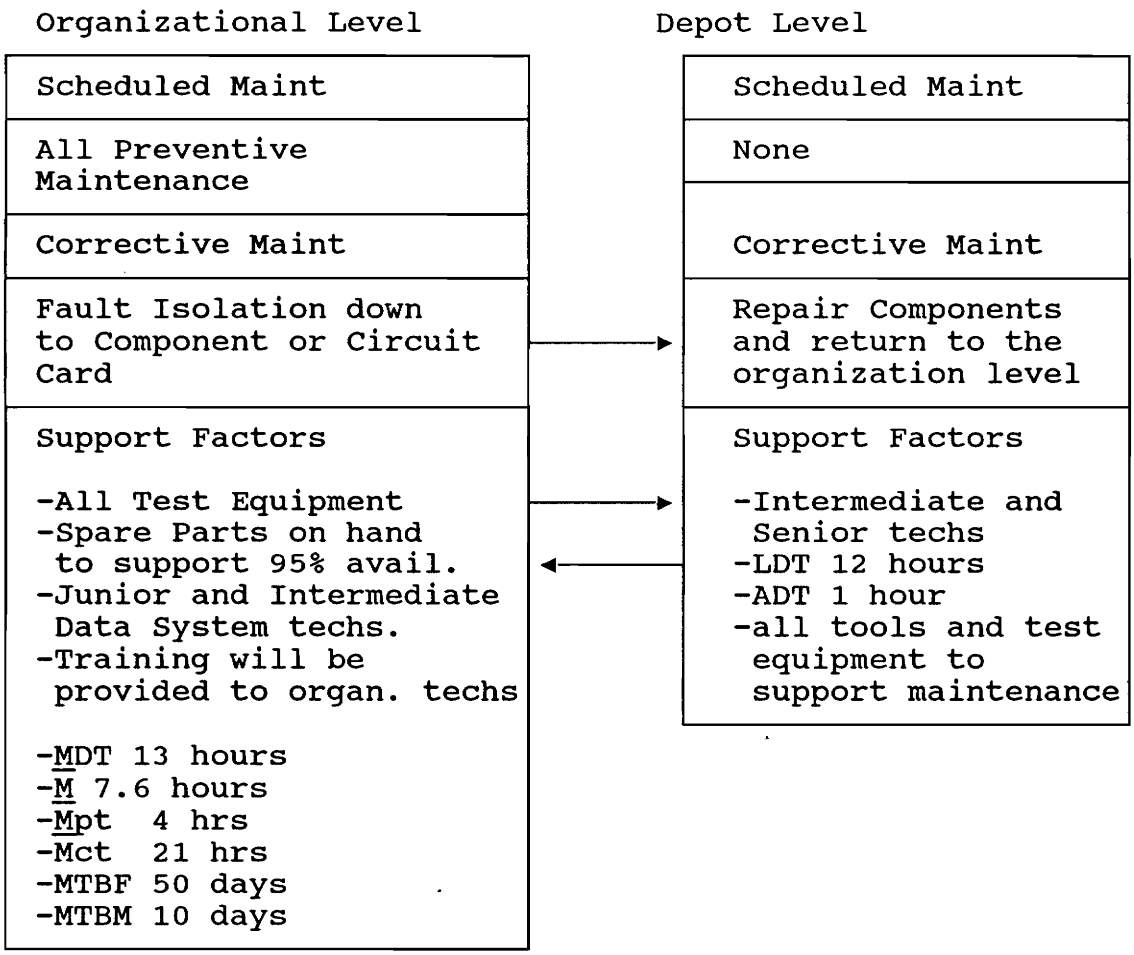


Figure 2. The maintenance concept.

functions until completion.

After reviewing the need analysis and feasibility study, the technological choice for the WAN is obvious, Internet. This WAN is available throughout the world, has adequate bandwidth for data, is economical considering the alternatives, and personnel can easily be trained to operate network components. The largest consideration is that worldwide access will be available for the system. A method to connect the LAN to the Internet is required. There are several possibilities ranging from a modem dialup telephone line to a dedicated T3 telephone line. With all options, a provider is chosen. The Internet connection method will be covered during the preliminary and detail design sections.

The choice for the LAN is more difficult. A token ring using FDDI and an Ethernet bus meet the requirements satisfactorily. They both posses adequate bandwidth, are commercially available, personnel can be trained to operate the system, and the network can be configured to meet the system operability requirements. The deciding factor is cost. After looking at the initial cost of materials, Ethernet appears to be the most economical option, since it is the more inexpensive technology while still fully meeting the need. This solution meets the operational requirements, all components are available off the shelf, and Ethernet provides adequate bandwidth for the data to be transferred.

Now that the technology is known, the major milestones are planned. Figure 3 shows the milestones for the entire system design. This chart gives a timeline on how the project should progress until completion. Note that it does meet the one year requirement established in the needs analysis. Additionally, reviews are held after major sections are completed to allow verification that the design is meeting the required specifications.

Finally, conceptual design is concluded with a personnel organization, as shown in Figure 4. This chart establishes how personnel will be organized under the lead command, the Chief of Naval Education and Training (CNET). The project is broken down to engineering, construction, and operation. Within each category, further subdivisions are performed and their major responsibilities are defined.

3.5 Conceptual Design Summary

At the conclusion of conceptual design, the foundation is laid to continue the top-down design. The technology has been chosen, maintenance requirements have been stated, operating requirements have been set, a major milestone time table made, and the personnel organized. Now the design can continue into the more specific preliminary design.

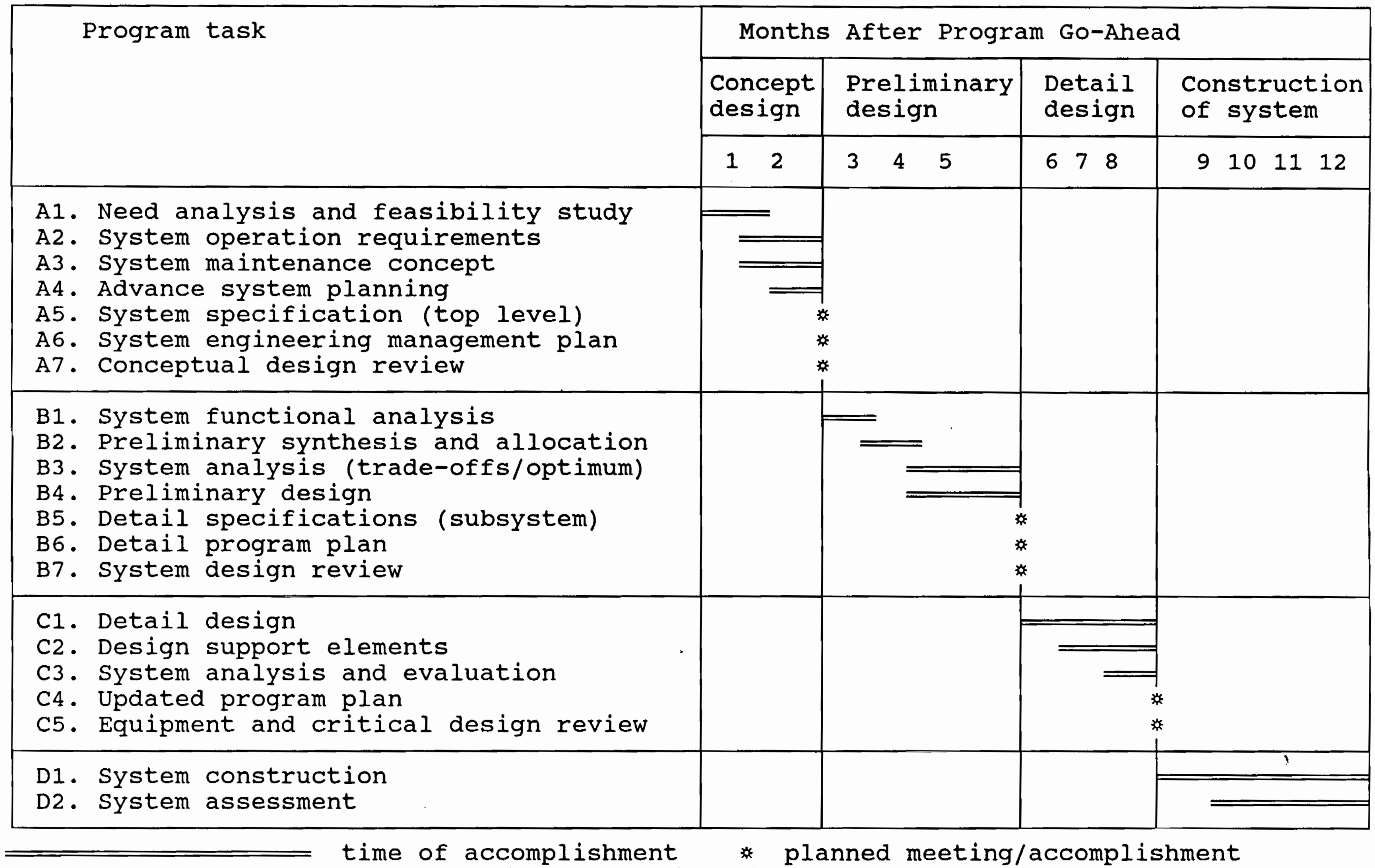


Figure 3. Major milestones.

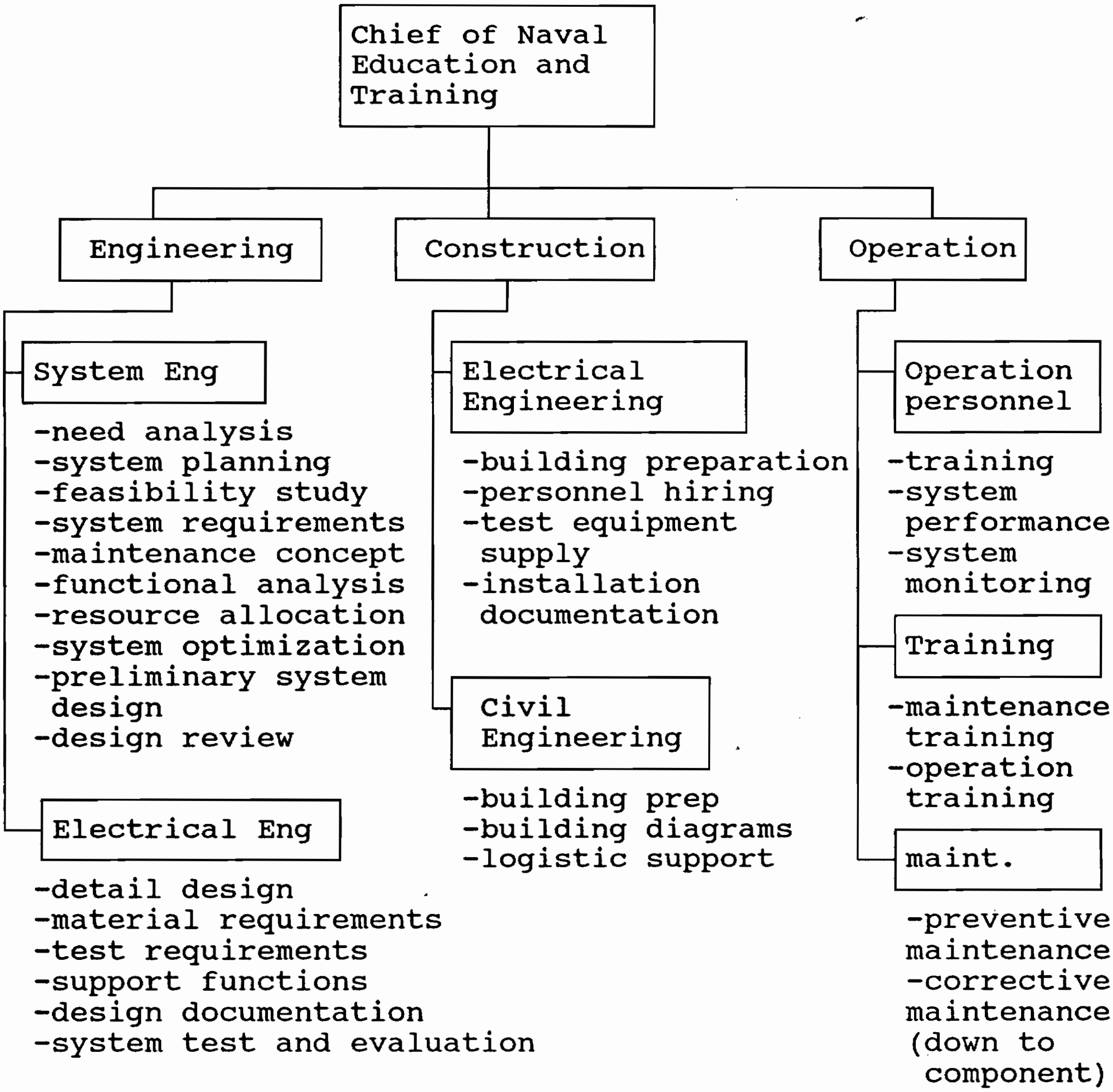


Figure 4. Personnel organization.

SECTION 4 PRELIMINARY DESIGN

After performing the conceptual design, a framework has been established to continue the top-down design of the computer network system. The next phase is the preliminary design that results in a specific system synthesis to allow the detail design to be performed. The objective is to give specific guidance allowing the detail design to fully meet the need.

4.1 Functional Analysis

To begin this specification, a functional analysis is performed (See the Appendix for the functional block diagram.) A functional analysis describes the operations that must be accomplished during the lifetime of the system. The highest level (blocks 1.0 through 8.0) describes operations in a general sense, but logically the functions are partitioned into more detailed operations down to the fourth level. This gives guidance into the design requirements and justifies the end design of the product.

Block 2.0, the design function, systematically states tasks to be performed during the design phase. It can be seen in the breakdown of block 2.4.1 that the WAN and LAN are designed in parallel and required tasks are broadly stated. The connection method of the LAN to the WAN is not determined and must be decided upon during the system synthesis phase. Additionally, during the detail design, the logistics for the system are developed ensuring a system that can be fully supported is the end result of the design. The next block, 3.0, gives guidance during the production phase on the acquisition of materials. Blocks 4.0 and 5.0 are performed in parallel; that is the LAN is installed at Naval Guided Missiles School and information to purchase the LAN "off the shelf" for other commands is generated. To have a properly functioning system, there must be personnel to adequately operate and maintain the system, so the next logical function is to train personnel. Training must be an ongoing function throughout the life of the system, so that newly arrived personnel will be able to operate the system. From block 7.0, "Operation," all functions that the system will perform are determined and this will drive the various types of software required (e.g. electronic-mail and word processing). Finally, the system is retired in block 8.0. This is an important function, because hidden costs or salvage value may exist and this must be considered during the determination of system lifecycle cost.

In block 7.0, the operation functions when broken down into more specific tasks lead to the maintenance functional flow. Basically, from the normal operation tasks, when the system fails a check or does not operate properly, a NO GO condition is generated, which leads into required maintenance tasks to correct the NO GO condition. From the maintenance functional flow, formal maintenance procedures can be written during the development of logistics support.

This maintenance functional flow combined with the operational function flow analysis states what is required to be performed during the lifetime of the system. This further defines the system from the initial need analysis, and leads into the next part of the process, the allocation of resources defined for the system level to lower levels.

4.2 Allocation of Resources

After the functional analysis, the system requirements are allocated to lower levels in the system. The computer network system has requirements developed in conceptual design and the system along with these requirements are decomposed into lower level entities. The system requirements are allocated to these lower level entities. During the detail design, the specific lower level entities are designed to meet the allocated requirements. Figures 5 and 6 show the allocation of resources.

From Figures 5 and 6 it can be seen that the computer network system is decomposed into LAN and WAN units. These, in turn, are further broken into subunits. The maintenance and reliability requirements established for the system level are allocated down through the subsystem components. For example, the MTBF and MTBM at the LAN and WAN level add in parallel to give the total system value. Likewise, the mean time for

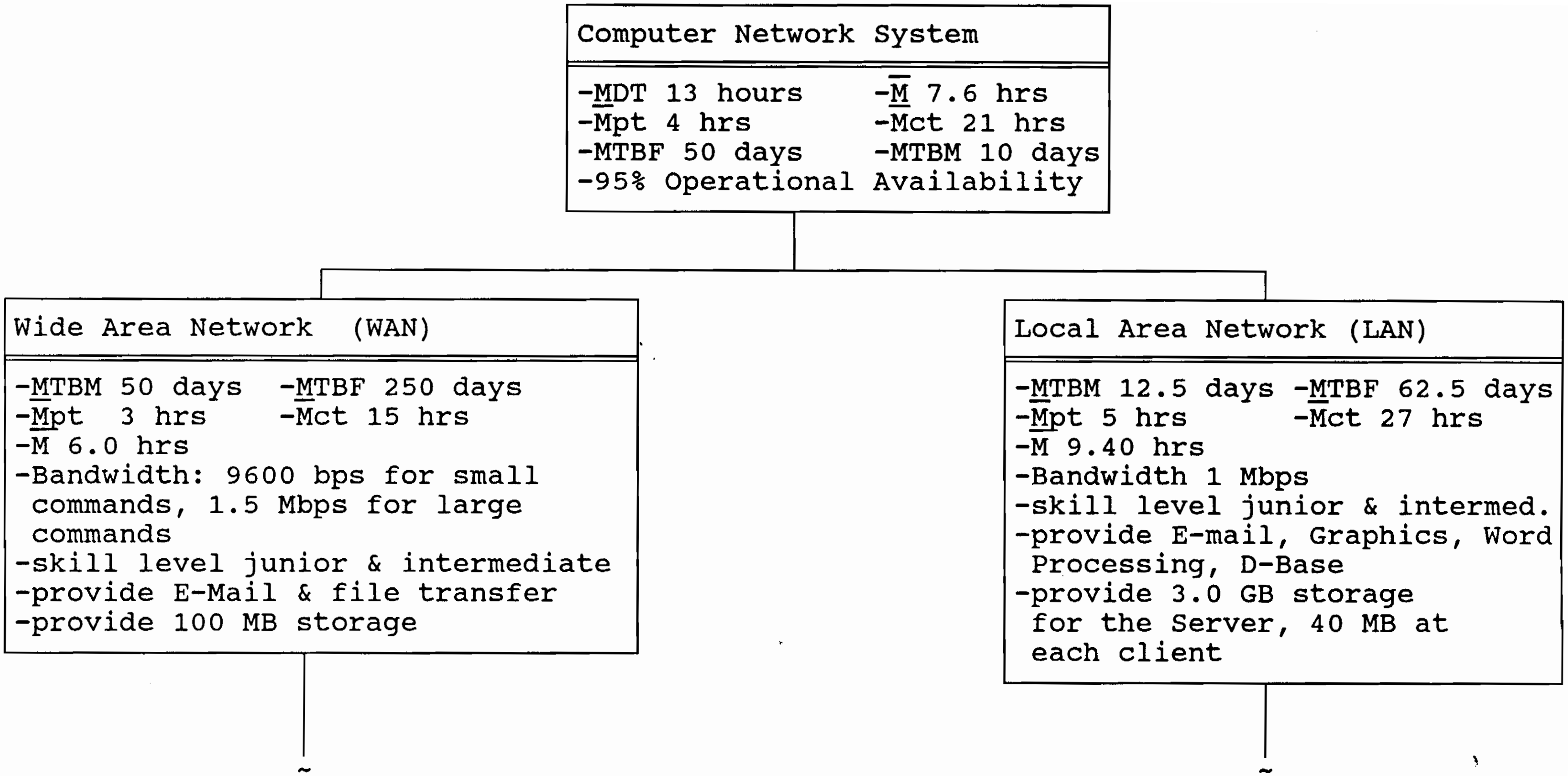
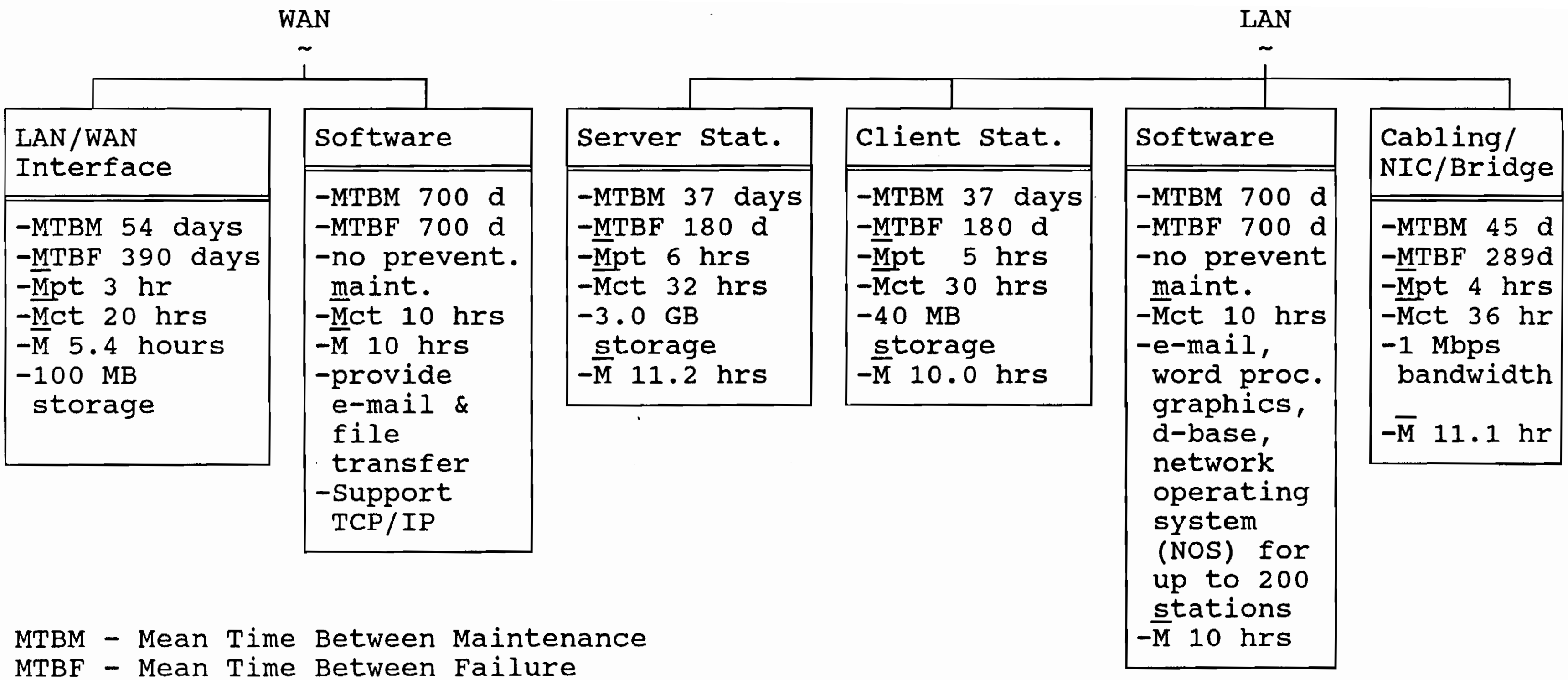


Figure 5. Allocation of resources (continued as Figure 6).



MTBM - Mean Time Between Maintenance
MTBF - Mean Time Between Failure
Mct - Mean Active Corrective Maintenance Time
Mpt - Mean Active Preventive Maintenance Time
M - Mean Active Maintenance Time
MDT - Mean Down Time

Figure 6. Allocation of resources (continued)

corrective maintenance, $\overline{M}ct$, values at a given layer average to the next higher level. Additionally, other design requirements previously set are stipulated and allocated such as data storage capacity, bandwidth, software capabilities, and number of workstations on the LAN.

The allocation of resources further defines the design and continues to narrow the scope of the final form of the system. However, the exact design has not yet been specified and there could be several different designs that would meet the allocated resources. Now, the options must be examined.

4.3 Trade-Off and Optimization

Looking at the functional analysis and allocation of resources, the design is becoming clearer. For the LAN, the server workstation and client workstations are well defined, leaving specific hardware required to meet the system specifications to be chosen. The LAN's software requirements are stated, resulting in just the specific brands and the configuration to be determined in the detail design. The Ethernet cabling and network interface cards must be chosen to meet the bandwidth specifications and fit the buildings. Turning to the WAN, the software and hardware still cannot quite be narrowed down because the method to access the Internet has not been determined. Depending on the access method, the software and hardware requirements change. The different access methods will now be examined and the optimal chosen.

There are three methods to connect a LAN to the Internet; an online account, a dialup account (Serial Line Internet Protocol (SLIP) or Point to Point Protocol (PPP)), and a dedicated connection.[14] With an online account, the LAN is not connected directly to the Internet, but is connected via a modem to a host computer that is directly connected to the Internet. An account is established with the host computer known as a provider. The host provides the Internet services such as electronic mail and FTP. The Internet data is then down loaded via a modem communication package such as Procomm Plus. This connection method has several advantages, with the main one being that Internet software and expensive hardware such as a channel service unit/digital service unit (CSU/DSU), which connects the LAN to the dedicated telephone company line and in turn to the Internet, and a router, a unit that controls the transfer of data between networks, are not required. The disadvantage is that the data transfer rate is limited to the modem bandwidth which for a large amount of traffic or numerous users is not a practical alternative due to long data transfer times. This would be a proper solution for small commands that need to infrequently connect to other networks.

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[14]Susan Estrada, Connecting to the Internet an O'Reilly Buyer's Guide, (Sebastopol, CA: O'Reilly & Associates, Inc., 1993), p. 49.

With a dialup connection, the LAN is connected directly to the Internet. Once again an account with a provider is established and this provider is accessed via a modem over a dialup telephone line, but upon connection the network computers are running TCP/IP applications via either the SLIP or PPP protocols. One advantage of this method is that full Internet access is gained whereas with an online account, often only limited Internet access is offered. Also, this is a less expensive solution since the connection is only billed when actually being used as opposed to a dedicated line.[15] Once again, the major drawback is that the bandwidth is limited to the modem and dial telephone line.

The last alternative is to have a dedicated line, which is basically having a digital telephone line specifically connecting the LAN via a router and CSU/DSU to a provider which in turn connects to the Internet. Once again, an account must be established with a provider, but the LAN has continuous access to the Internet. This is an expensive option since the LAN must have a CSU/DSU, router, dedicated telephone circuit, TCP/IP software, and supporting software. The telephone lines vary depending on what the user needs, but can be from 56 kbps to a T1 line (1.544 Mbps) or even a T3 line (4.5 Mbps). The real advantage of this connection method is the large bandwidth available that can make transmitting

[15]Estrada, p.57.

large data files practical as required for large commands.

To determine which alternative is best, the applications must be examined. For a large command like Naval Guided Missiles School, where there will be up to 200 users on the LAN all of whom may require Internet access, a dedicated line is the only option, because 1.5 Mbps bandwidth is required. Without this high bandwidth, there would be a large backlog of data awaiting transmission over the modem. For small commands where there may only be one user requiring access to the Internet, a dedicated line would be expensive and result in a significant amount of wasted bandwidth. For these commands an online account or a dialup account with a 9600 bps modem meets system requirements.

A life cycle cost analysis for just the WAN comparing online vs. dialup Internet connection methods has been done assuming access of 4 hours per day, 10 year lifetime, and 7 percent interest. Results are shown in Figures 7 and 8. "Life Cycle Cost Calculator (LCCC)" software developed at the Systems Engineering Design Laboratory, Virginia Polytechnic Institute and State University was used for calculations. The results are close, but an online account is cheaper. Surprisingly, the operating fees were similar for the two providers chosen, but this may vary due to the wide range of providers. The most significant difference is that the dialup account has a higher startup fee and requires

Cost Category	Online Acc. Cost ($)	%	Dialup Acc. Cost ($)	%
1. Hardware				
a. 486 Server[16]	1829	1.73	1829	1.71
b. 9.6 kbps Modem[17]	469	.44	469	.44
c. 100 Mb Hard drive (included with Server)	N/A		N/A	
Subtotal	2298	2.17	2298	2.15
2. Software[18]				
a. Procomm Plus V2.01	100	.10	100	.10
b. SLIP (included in Startup Charge)	N/A		N/A	
c. LAN Work Place for DOS[19]	N/A		319	.30
d. cc:mail	N/A		209	.20
e. Word Perfect 6.0	279	.26	279	.26
f. Harvard Graphics V3.0	410	.39	410	.38
g. Microsoft Foxpro V2.5	325	.31	325	.30
h. Dos 6.0 (included with Server)	N/A		N/A	
i. Windows 3.1 (included with Server)	N/A		N/A	
subtotal	1114	1.05	1642	1.54

Figure 7. Online account vs. dialup account (continued as figure 8).

16"Computer Sales Professional Ltd," Computer Shopper, Jan 1994, p.43.

17"Modems/Telcom," Misco Computer Products Catalog, Fall 1993, p.105.

18"Dos Software," Misco Computer Products Catalog, Fall 1993, p.46.

19"Network Express," Computer Shopper, Jan 1994, p.92.

3. Installation Fees	Provider: Comm. News Service		Provider: PrepNet	
a. Startup Fees	35[20]	.03	325[21]	.30
b. Labor ($10/hr)	40	.04	160	.15
Subtotal	75	.10	485	.45
4. Operating Fees (Based upon 4 hrs/day use)				
a. Monthly Charge	16456[22]	15.5	16456[23]	15.4
b. Toll charge (based on $5/hr)	51272	48.4	51272	48.0
c. maintenance	35,000	33.0	35,000	32.8
subtotal	102,728	96.9	102,728	96.1
Total	105,987	100	106,864	100

Figure 8. Online account vs. dialup account (continued).

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[20]Estrada, p.85.

[21]Estrada, p.97.

[22]Estrada, p.85.

[23]Estrada, p.97.

applications for TCP/IP provided by LAN Work Place for DOS (FTP, TELNET, etc.), while this software is run on the provider's computer for online accounts.

Now that alternatives have been examined, a clear picture of the system exists. The system can be synthesized and defined allowing the detail design to commence with a clear picture of the end goal.

4.4 System Synthesis and Definition

After the functional analysis, allocation of resources, and optimization of alternatives, the system has been largely defined. The computer network system will consist of a local area network within a command that may have few users or as many as 200 users. The LAN will be connected to other commands to form a wide area network using the Internet.

The LAN will be an Ethernet to link DOS workstations varying from Intel 80286 microprocessor computers, which will act as clients, to Intel 80486 microprocessors computers, which will act as servers. Each client workstation will have a 40 megabyte hard drive and will be attached to the Ethernet via a network interface card and a transceiver. The server will have 3 gigabytes of storage to allow adequate network storage. The network will be provided throughout the command using a series of Ethernet segments, repeaters, hubs, and bridges, as necessary. During the detail design phase, the exact layout and hardware requirements will be designed. For small commands, as little as two computers may be on the net, so the large storage capacity and cable and hardware configuration may not be required, but this information will be made available to the smaller commands allowing them to set up their own networks.

The LANs will be connected forming a WAN via the Internet. Large commands like Naval Guided Missiles School will use a dedicated digital telephone line to connect the LAN to the Internet. To accomplish this a router and a CSU/DSU will be required along with software for TCP/IP and application software. During the detail design, the bandwidth of the dedicated telephone line will be determined based upon the need and use requirements. The bandwidth required is 1.5 Mbps. The exact type of software will be selected to meet the system requirements and a provider for the dedicated line will be selected. Smaller commands will use an online account to access the Internet via a provider's host computer.

4.5 Preliminary Design Summary

With the conceptual and preliminary design phases complete, the system requirements are well defined and the technology and alternatives to meet the need have been defined. Now the detailed design will specifically choose the required equipment and determine a configuration plan.

SECTION 5 DETAIL DESIGN

After the need analysis, conceptual design, and preliminary design phases are completed, a well defined system has been generated and it is time for detail design. Besides finalizing the system design, logistics must be determined which will include supply support, maintenance support, training, and complete system documentation. Looking at the life cycle of the system, a complete cost analysis will be performed. Finally, the system, upon completion of construction, must be tested to verify that the design goals set have been reached. This requires that a test and evaluation plan be formulated while still in the design phase. The testing and design evaluation will last throughout the life of the system to ensure the system is functioning as designed. If specifications are not met, then reevaluation is required to check if the system requires changing or if the needs can still be met. First, however, a design team must be assembled.

5.1 Design Team Establishment

When designing a system, the design engineer must keep in mind that the system must do more than meet the specifications set up through the preliminary design. The system will have maintenance performed on it, so the design should aid in maintenance, not hinder maintenance. The network will be operated by personnel with varying skill levels, so the more user friendly the system becomes, the better operation will be and the need will be more fully met. For these reasons, when establishing a design team, more personnel than just the design engineer must be sought. The following make up the design team for the computer network system:

a. **The Design Engineer.** An electrical or computer engineer is required for technical expertise to ensure the system performs at the level established previously. Using the guidelines and allocated resources, the engineer will take input from the design team to ensure the detail design output meets requirements.

b. **A Senior Data Systems Specialist (DS).** The DS is the person who will construct and perform maintenance on the system throughout the life cycle. A senior technician is chosen due to previous experience. The DS can lend expertise to ensure the system is configured ergonomically and practically, thus allowing both preventive and corrective maintenance to be easily performed.

c. **Two Operations Personnel.** These two people can comment on ease of understanding operation instructions, physical placement of workstations to ensure the stations are where they are most needed, software and data storage requirements, and adequate documentation. Documentation explaining system operation may seem adequate to the design engineer, but be completely inadequate for personnel with limited system knowledge. Therefore, comments from users enable the production of concise and clear documentation.

Including personnel from phases throughout the life cycle in the initial design team produces a system that is better functionally for the entire life of system.

Now that a design team has been established, the detail functional design is ready to begin. Referring to the functional analysis, the detail functional design activity covers design tasks.

5.2 Detail Functional Design.

Referring back to the Appendix, functional Analysis Block 2.4.1, "Perform Detail Functional Design," the steps required to design the computer network system are stated. The LAN and WAN will be designed in parallel, with the two designs coming together when the LAN is connected to the WAN or Internet. Blocks 2.4.1.1 through 2.4.1.8 of the functional analysis describe the LAN design steps, while Blocks 2.4.1.9 through 2.4.1.12 describe the WAN design phase.

The LAN design will be discussed first in accordance with the functional analysis. Naval Guided Missiles School will be the example for LAN configuration, but the LAN can be configured to other commands as required. The steps for the LAN design follow with the corresponding functional analysis blocks indicated in parentheses:

1. **Determine the Size of the LAN** (2.4.1.1). As stated in the need analysis, the LAN for Naval Guided Missiles School will consist of up to 200 users evenly dispersed throughout the three command buildings. The best connection method for these personnel is to run an Ethernet coaxial backbone cable (10Base5) through the three buildings. Users can either connect directly to the cable via a transceiver, or can connect to an eight port fanout unit via a transceiver drop cable or attachment unit interface (AUI). These fanout units will be dispersed along the backbone cable. When configuring the Ethernet LAN, the following restrictions must be kept in mind:[24]

A. The maximum length of a 10Base5 backbone cable is 500 meters or 1,640 ft. Each 500 meter cable is a segment and the entire LAN is limited to 101 segments.

B. A dual port repeater can link two segments (a repeater works like an amplifier), but data should pass through no more than two repeaters from origination to destination.

C. A transceiver is used to connect a unit to the 10Base5 Ethernet cable, no more than 100 transceivers

[24] "Ethernet Technical Reference," South Hills DataCom Catalog, 1993, p.90.

can be connected to a single 500 meter segment, and the transceivers must be at least 2.5 meters apart.

D. A transceiver drop cable (AUI) connects the transceiver to the attaching unit. This drop cable can be no more than 50 meters or 164 ft long.

E. The maximum number of stations on a standard Ethernet network is 1024.

F. To maximize efficiency and simplify cabling, instead of each individual workstation connecting to the backbone cable, a fanout unit can be utilized. These units connect to the thick cable via a transceiver, and workstations can then connect to the fanout unit via a transceiver drop cable. Usually, 8 or 16 workstations can be clustered using a fanout unit. The maximum cable length from the workstation to the fanout unit is 50 meters or 163 ft.

G. The thick Ethernet cable has a 50 ohm impedance, so each cable must terminate with a 50 ohm terminator.

Looking at figure 1, the physical layout of Naval Guided Missiles School, it can be determined that 3135 ft. of backbone thick Ethernet cable is required to cover the entire command. This also includes the cabling required to link the three buildings. Obviously, repeaters and terminators will be required in addition to fanout units. Additionally, the server workstation will be in building

543. This server will also have a large file disk for the 3 gigabytes of storage required for the LAN.

2. **Choose LAN Network Operating System Software (2.4.1.2).** The LAN will consist of an Intel 80486 microprocessor server with Intel 80286 clients dispersed throughout the command. Each of these machines will be running some form of DOS and the server will be running Windows 3.1. To configure the LAN, a Network Operating System (NOS) must be chosen. Also, since the LAN will connect to the Internet, the optimal NOS is one that supports TCP/IP. There are several companies that offer a NOS for a system this size, the most popular are Novell Netware 4.0, LAN Manager 2.11, LANtastic/AI 5.0, and the newest NOS, Windows NT. Some of these are not practical, namely Windows NT because windows does not run on the 80286 machines, and LAN Manager 2.11 because it requires the server to have the OS/2 operating system.[25] One of the requirements of the project is to utilize, when practical, existing resources. These resources are 80486 machines running DOS 6.0 with Windows 3.1 for the server and DOS 80286 machines for clients. This leaves Netware 4.0 and LAN Manager 2.11 as potential options for the NOS. A large benefit of Netware 4.0 is that TCP/IP is

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[25]Aubrey Pligrim, Build Your Own LAN and Save a Bundle, (Blue Ridge Summit, PA: Windcrest Books, 1992), p.42.

included, so there is no need to purchase separate TCP/IP software, only the application software.[26] Additionally, Novell sells TCP/IP application software such as FTP and TELNET combined in one product, "LAN Workplace for DOS."[27] Netware 4.0 is well suited for an Ethernet LAN connected to the Internet. Another decisive issue is price. One copy of Netware 4.0 is required for a LAN plus a license for each workstation. For LANtastic/AI 5.0, each workstation must purchase a copy of the software. For example, a 250 user edition of Netware 4.0 is $9998,[28] while for LANtastic/AI 5.0 one set of software costs $79,[29] so for a 200 user network the cost would be $15,800. Clearly, for the LAN the size of Naval Guided Missiles School, Netware 4.0 is the best NOS.

Another advantage of choosing the Novell Netware NOS is that besides Netware 4.0, Novell makes NOS for smaller LAN's, namely Netware Lite. This NOS can be used at smaller commands, giving the advantage that personnel will not have to learn a new operating system every time they transfer to another command. This attempts to

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[26]Personal Interview with Novell Service Representative, 16 February 1994; hereafter cited as Novell.

[27]Novell, 16 February 1994.

[28]"Network Express," p.92.

[29]"Network Express," p.92.

standardize network operating systems in the Navy.

3. **Choose Cabling and Determine Amount** (2.4.1.3). As previously determined, the LAN will use 10Base5 thick Ethernet cable to form the backbone of the LAN. 3135 ft. are required to fully cover the command. Additionally, a transceiver drop cable is required for each user to connect to either a fanout unit or to a transceiver, and each fanout unit must connect to a transceiver via a transceiver cable. Looking at the building diagrams, the furthest distance from the backbone cable to any workstation or fanout unit can be is 50 feet or approximately 17 meters. Therefore, for each transceiver attached to the thick cable, a standard 20 meter transceiver cable ($78.00 each[30]) is required. This cable also includes the connectors. A 20 meter transceiver cable also sufficiently connects any user to a fanout unit. These two cable types are the only cables needed. When the exact system layout is finished, the specific number of each type of cables can be determined.

4. **Determine Required Hardware for LAN** (2.4.1.4). The hardware required for the LAN includes dual port thickwire to thickwire repeaters to ensure adequate thick

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[30]"Preassembled Cables for Your Ethernet Network," South Hills Datacom Catalog, 1993, p.112.

Ethernet cable coverage for the command ($765.00 each[31]), 50 ohm cable terminators ($8.00 each[32]), eight port fanout units ($925.00 each[33]), transceivers ($225.00 each[34]), and a CD-ROM (price: $549.00 including software[35]) for data storage (Novell Netware 4.0 comes on a CD-ROM). It should be noted that individual workstations will not be purchased since the command's existing computers are being utilized. Naval Guided Missiles School already possesses adequate computers for client workstations and 80486 machines for server workstations. The way a client-server network functions is that clients can access resources such as files and printers on the server workstation, but not on the other client workstations. Therefore, when configuring the network, certain workstations are designated as servers, and the rest are designated as clients. At Naval Guided Missiles School, one at a minimum will be designated as

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[31]"Economical Dual Port Repeaters," South Hills Datacom Catalog, 1993, p.98.

[32]"Additional Baseband Ethernet Products," South Hills Datacom Catalog, 1993, p.115.

[33]"8 Port Fan Out Units," South Hills Datacom Catalog, 1993, p.95.

[34]"Single Port Transceiver," South Hills Datacom Catalog, 1993, p.104.

[35]"Hardware," Data Communications, Vol. 13 Number 3, 1993, p.12.

a server, but the network has the capability to have more than one. No additional printers are required, because the current printers attached to the 80486 machines can be accessed from the network by making these workstations servers instead of clients.

5. **Choose Brand/Type of Network Interface Cards** (2.4.1.5). To connect a workstation to the Ethernet either directly to the thickwire or to a fanout unit port, each workstation must have a network interface card (NIC). These cards come in either 8 or 16 bit adapters for the Industry Standard Architecture (ISA) bus and 32 bit adapters for the Extended ISA (EISA) bus. The clients will only require 8 bit NIC's ($141.00[36]), while the servers will use 16 bit cards ($159.00[37]). The EISA 32 bit NIC's could have been used for the server, but these cards are much more expensive ($695.00[38]) and their use does not seem economical or necessary.

6. **Examine Number of Computers on Site, and Purchase Client/Server Computers as Necessary** (2.4.1.6). As stated in item 4, no extra computers are necessary for Naval Guided Missiles School. If any new requirements

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[36]"Economical Ethernet Adapter Cards," South Hills Datacom Catalog, 1993, p.93.

[37]"Economical Ethernet Adapter Cards," p.93.

[38]"Economical Ethernet Adapter Cards," p.92.

arise, the computers will then be purchased and attached to the network.

7. **Choose Memory Storage Device for the Server** (2.4.1.7). As stated in the allocation of resources, 3 gigabytes of storage is required for the server. This is a very large amount that provides each user with 15 MB. To obtain this magnitude of storage capacity, a rewritable optical mass storage unit will be used ($5249.00[39]). The particular unit, "Ricoh Hyperspace Shuttle Optical Drives," is specifically configured for Novell networks, so it should work well with the LAN.

8. **Purchase Application Software** (2.4.1.8). As stated in the need analysis, the LAN requires word processing, data base, electronic-mail, graphics, and file management software. The NOS and DOS can provide file management and the rest of the software was previously listed in Figures 7 and 8, the lifecycle cost analysis for the types of WAN's. CC:Mail will be used for electronic-mail, both for the LAN and WAN ($209.00), Word Perfect 6.0 for word processing ($279.00), Harvard Graphics 3.0 for graphics ($409.95), and Microsoft Foxpro 2.5 ($325.00) for data base. The electronic mail standard for Internet is Simple Mail Transfer Protocol (SMTP). When transferring electronic, SMTP assumes the

[39]"Hardware," p.12.

destination is always monitoring for incoming mail, but this is not necessarily true with DOS workstations, since DOS only runs one program at a time. To get around this, CC:Mail designates one workstation as the mail server.[40] The mail server will control Internet mail traffic. This completes the steps in the functional analysis of the LAN design.

Now the LAN design is ready for completion and summary. Figures 9, 10, and 11 show the building layout for the LAN. There are 21 eight port fanout units distributed evenly throughout the command to accommodate 168 users, leaving only 32 users to attach directly to the backbone. Repeaters are used so that a backbone thickwire is extended over the entire command. No matter where a workstation is, it can communicate with any other workstation while encountering at most two repeaters. The 50 ohm terminators, the server, and Internet connection are shown. Materials used are listed.

Item	Number	Price/unit
8 Port Fanout Units	21	$925.00
Terminators	6	$8.00
500 m thickwire segments	1	$1796.00[41]

[40] CC:Mail Remote Users Guide, (Mountain View, CA: CC:Mail Inc,), 1991, p.72.

[41] "Preassembled Cables for Your Ethernet Network," p.112.

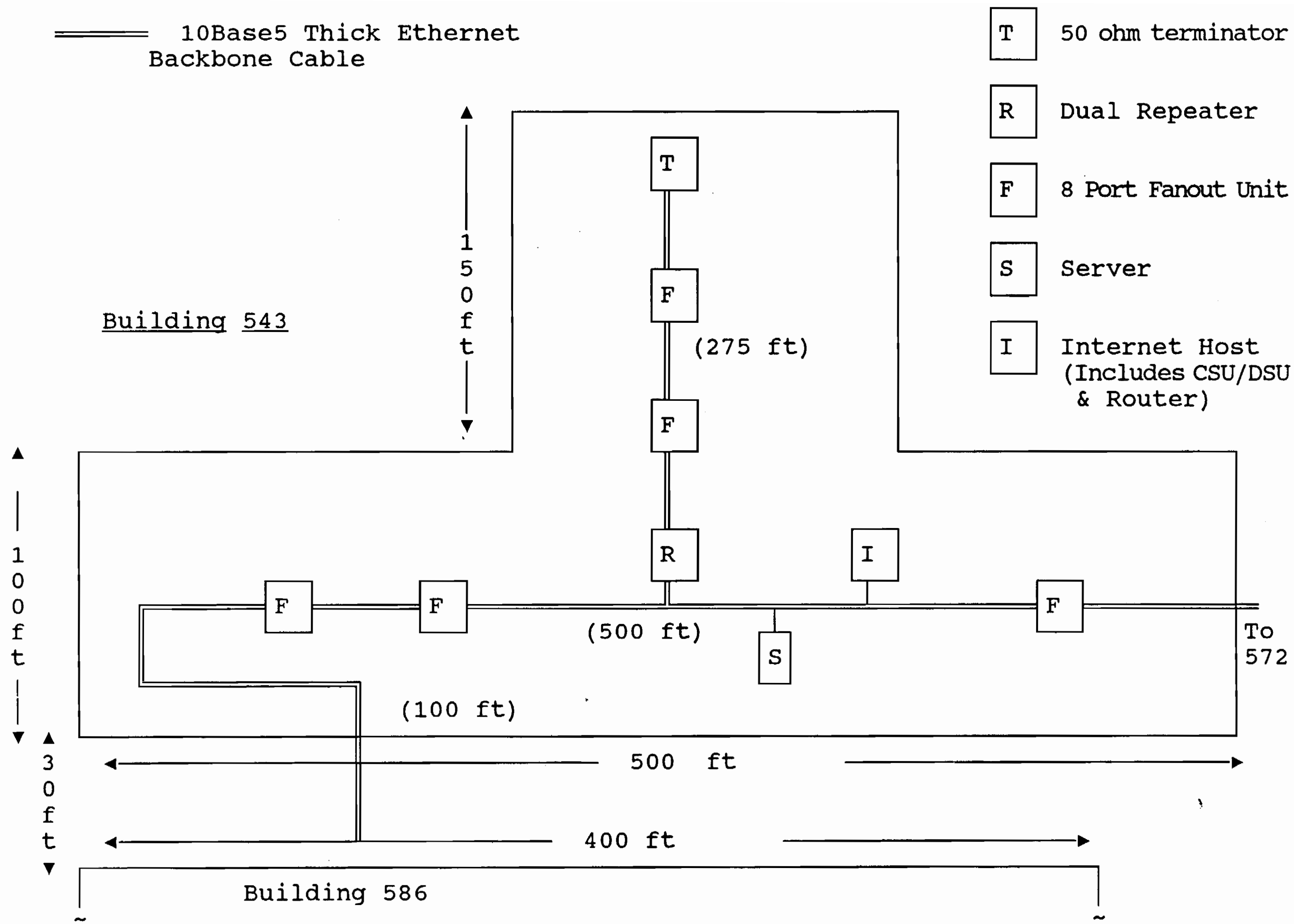

Figure 9. Building 543 LAN configuration.

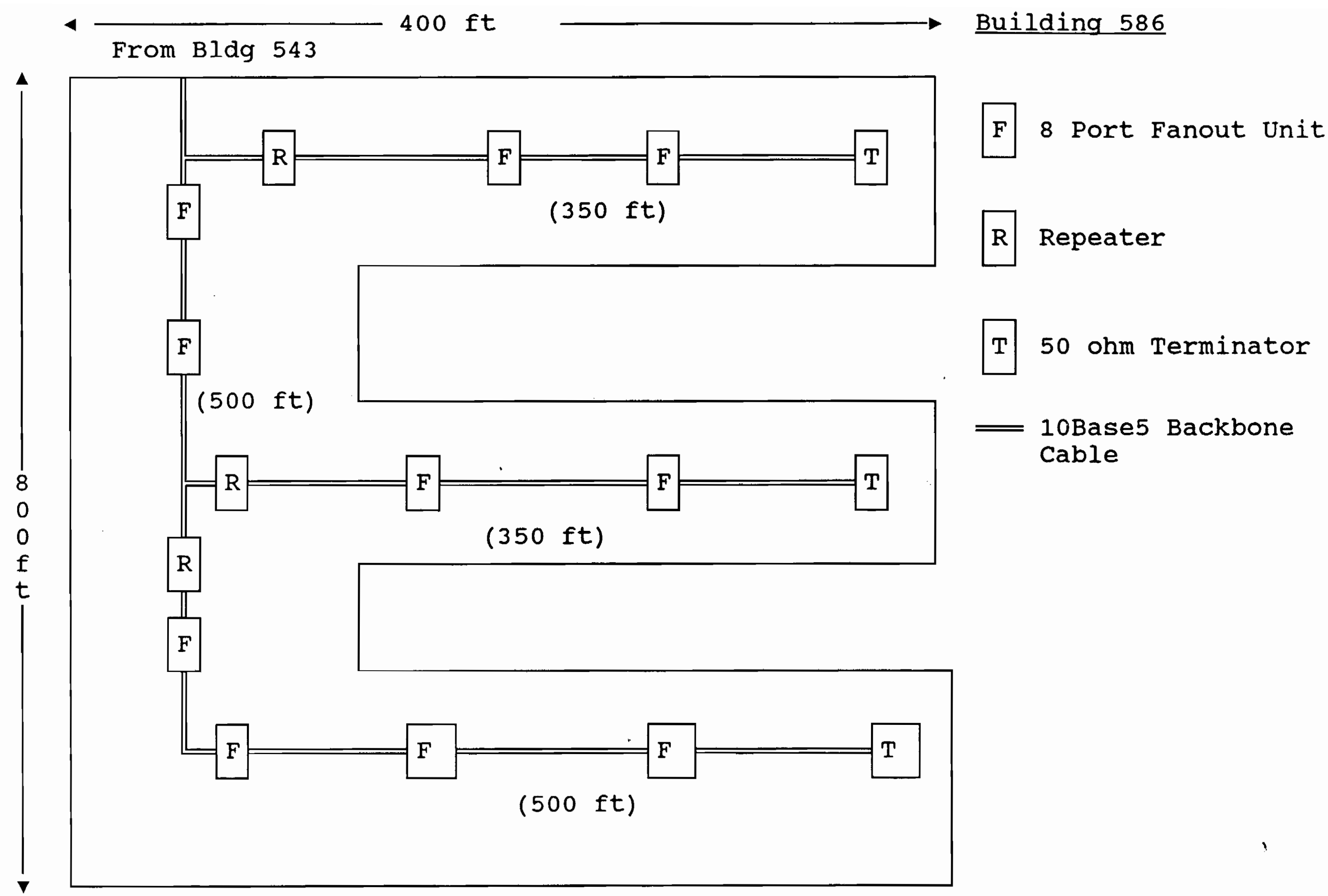

Figure 10. Building 586 LAN configuration.

Building 572

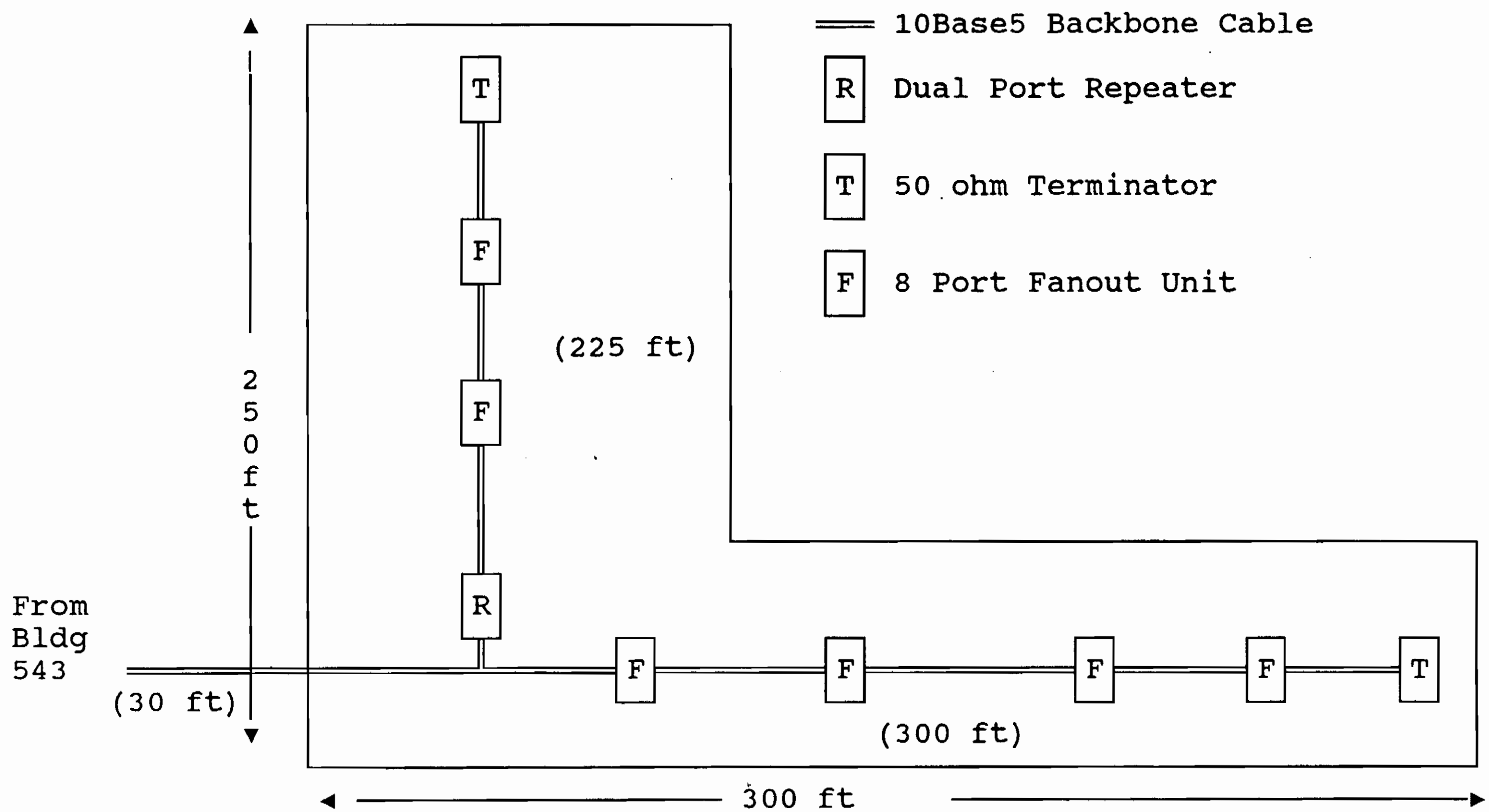

Figure 11. Building 572 LAN configuration.

Item	Number	Price/Unit
100 m thickwire segments	4	$318.00[42]
500 ft thickwire	1	$408.00[43]
Repeaters	5	$765.00
Server	1	$1829.00
Transceiver	53	$225.00
Optical Data Storage	1	$5249.00
CD ROM	1	$549.00
Novell Netware 4.0	200 users	$9998.00
16 bit NIC	1	$199.00
8 Bit NIC	199	$141.00
20 m Transceiver Cable	221	$78.00

The LAN will be configured by installing the cabling and hardware as shown in Figures 9, 10, and 11, and installing the prescribed software on the individual workstations. Of the 200 users, 168 will connect to fanout unit ports while the remaining 32 attach directly to the backbone. Once all of the workstations are established, the NOS software can be installed, each individual workstation will be designated as either server or client, and the command personnel will be given access and passwords in accordance with the Netware 4.0 operators manual. A network manager, which will be discussed below in Section 5.3, must administer this phase.

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[42] "Preassembled Cables for Your Ethernet Network," p.112.

[43] "Preassembled Cables for Your Ethernet Network," p.112.

To complete the functional design, the WAN is designed, and a connection method to the Internet is be decided upon. Once again, the functional analysis steps are utilized. The following sections cover the WAN design:

1. **Choose WAN Software** (2.4.1.9). As stated in the discussion of the need analysis, the WAN is required for electronic-mail and to transfer data files. To support this; TCP/IP, the Internet's protocol; FTP, which allows files to be transferred to LANs; Telnet, which allows the remote logon control of a UNIX workstation which may be encountered at some training command's LAN; and electronic-mail are required. For electronic-mail, cc:mail used on the LAN can also be utilized for the WAN. As previously stated, the NOS has TCP/IP, thus no additional software is required. The only required software is "LAN Workplace for DOS" ($319.00) which is a network application software and includes FTP and Telnet.

2. **Determine Method to Connect LAN to WAN** (2.4.1.10). As stated in the discussion of the preliminary design, a dedicated telephone line from a provider will connect the Naval Guided Missiles School LAN to the Internet. For smaller commands, an online account will be utilized. The provider chosen is AlterNet, offered by UUNET Technologies, and a T1 bandwidth (1.5 Mbps) is required. When using a dedicated line, there are three fees

involved, a onetime startup fee, a monthly charge, and a monthly line fee. The monthly line fee is determined by the distance from the LAN to the nearest Point of Presence (POP). For Alternet, the POP is provided by Sprint. This charge varies depending upon the command, an average cost of $300 will be used in lifecycle cost analysis.[44] AlterNet offers two T1 options, a full T1 line ($5000.00 startup fee, $2000.00 monthly fee[45]) or a low volume T1 access ($5000.00 startup fee, $1250.00 monthly fee[46]). For the low volume T1, there is still 1.5 Mbps bandwidth available, but the overall monthly average use must be less than 128 kbps or the full T1 line will be charged. This will meet the Naval Guided Missiles School requirements.

3. **Determine Required WAN Hardware** (2.4.11). To support the dedicated T1 line, a router which controls the data transfer between two networks, a channel service unit/digital service unit (CSU/DSU) which connects the T1 line to the network, and a workstation acting as the gateway between the LAN and WAN are required. As specified in the preliminary design, the gateway

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[44]Estrada, p.76.

[45]AlterNet Product Family Summary, from UUNET Technologies Fax transmittal, 15 February 1994, p.1; Hereafter cited as AlterNet.

[46]AlterNet, p.1.

workstation is required to have 100 megabytes of data storage capacity. The gateway workstation will be the LAN's server and already has adequate storage, so only the router and CSU/DSU are required. A single link full T1 CSU/DSU is chosen ($1500.00[47]) and a multiprotocol router ($729.00[48]) are chosen .

Figure 12 shows the WAN configuration. This figure summarizes the WAN showing the LAN gateway workstation, the router, CSU/DSU, and the T1 cable to the provider. The provider also requires a CSU/DSU, a router, and a gateway at the POP to the Internet. This hardware is provided by AlterNet.

With the completion of the LAN and WAN detail functional design, this section of detail design is completed. Next, the support for the system throughout the life cycle must be planned in the form "Logistics and Supply Support" which is block 2.4.2 on the functional analysis diagram of Appendix.

5.3 Logistics and Supply Support

Four areas are essential for a productive and full life time of a system: proper preventive and corrective maintenance to keep the system fully operational, personnel training, adequate supply support to return the system to operation in a timely manner following a failure, and proper documentation

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[47]"Single and Dual Link Fractional T1 CSU/DSUs," South Hills Datacom Catalog, 1993, p.195.

[48]"Network Express," p.92.

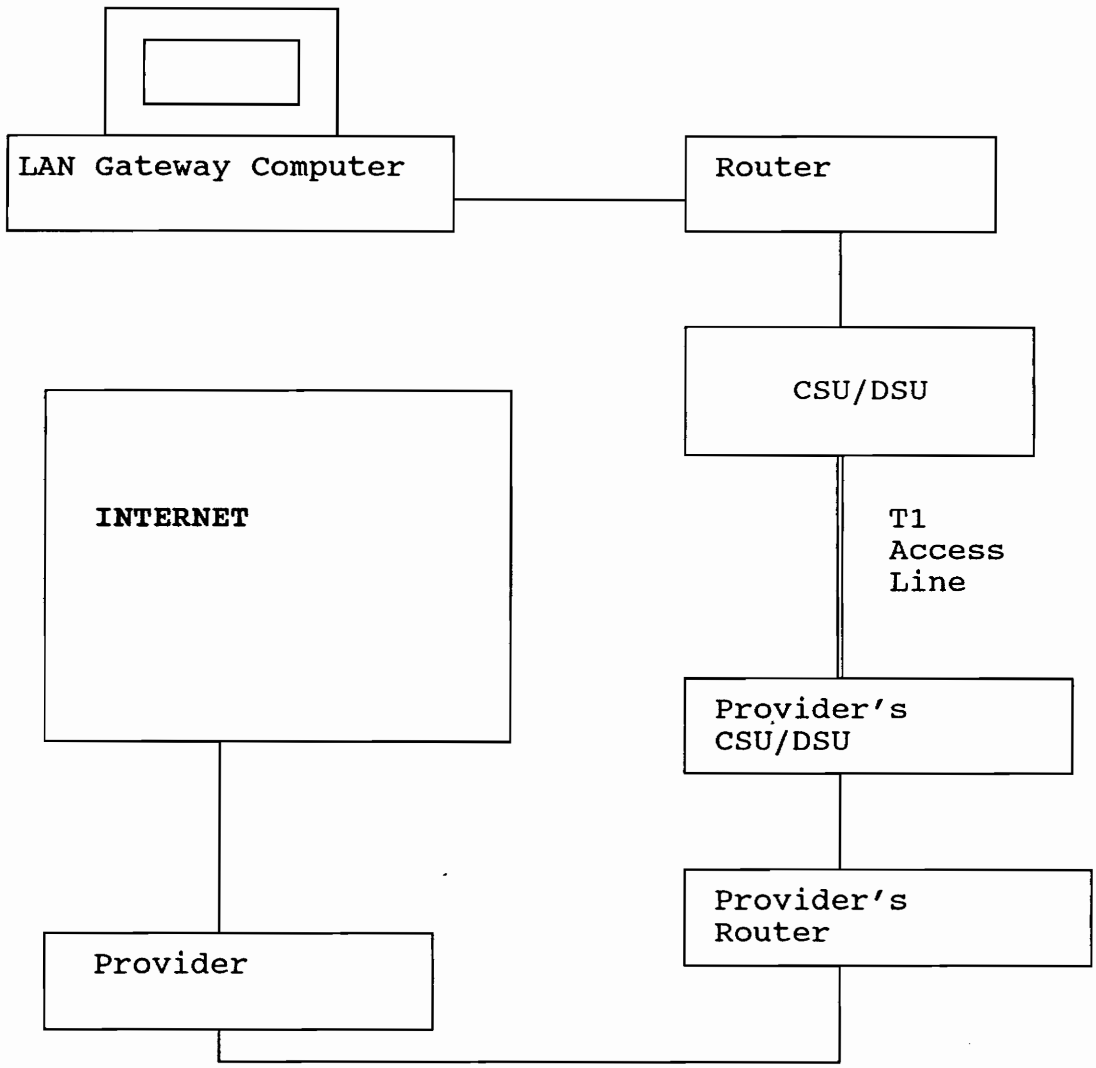

Figure 12. WAN access configuration.[49]

[49]Estrada, p. 68.

allowing operators and maintenance personnel to fully understand system operation and required maintenance. The following describes the logistics of the system:

a. **Maintenance.** Referring to the conceptual design's maintenance concept, both preventive and corrective maintenance are required. Maintenance will be performed at two levels, the organization and depot level. The organization level maintenance staffing will vary depending upon command size. At a minimum, a network manager and a maintenance technician are required to perform maintenance at frequencies specified in the maintenance concept. At small commands, these can be collateral duties, but at Naval Guided Missiles School these will be full time jobs. The network manager will be a Data Systems Specialist Chief Petty Officer (DSC), intermediate skill level with 12 years of experience (annual salary $33,651[50]) and a third class Petty Officer DS, junior skill level with 1 year of experience (annual salary $20,296[51]).

To support maintenance, a maintenance shop will be established with the following equipment:

1. Office System Kit, (electronics cleaning gear)

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[50]"All Hands FY94 Monthly Basic Pay Chart," <u>All Hands</u>, January 1994, p.23.

[51]"All Hands FY94 Monthly Basic Pay Chart," p.23.

price $39.99[52]

2. Softpack Tool Kit, price $450.00[53]

3. 6 inline Ethernet monitors (one to isolate each segment), price $49.00[54]

4. 2 LANcat cable and activity testers, price $1595.00[55]

This equipment is required to perform preventive and corrective maintenance.

The preventive maintenance activities are derived from the functional analysis, block 7.0, and will be performed by organization personnel. The following summarizes the required preventive maintenance:

1. Clean and visually inspect all hardware components quarterly.
2. Perform startup cable continuity checks.
3. Verify individual workstations pass startup diagnostic checks.
4. Review operator logs daily.
5. Install and monitor inline ethernet monitors.

The required corrective maintenance activities are

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[52]"Tools," Data Communications, Volume 13 Number 3, 1993, p.15.

[53]"Tools," p.20

[54]"Test Sets," Data Communications, Volume 13 Number 3, 1993, p.22.

[55]"Test Sets," p.25.

derived from the "Maintenance Functional Flow" section of the functional analysis. For corrective maintenance, when a fault occurs, the fault will be isolated to the faulty component. This component will be replaced and then either discarded or returned to the depot for repair depending upon the part.

b. **Training.** A vital ingredient to proper system maintenance and operation is having properly trained personnel. As covered in block 6 of the functional analysis, training will be established for maintenance and operational personnel. The maintenance training will cover system operation, component operation, and preventive maintenance. The operational training will teach routine tasks. For network managers, an advanced operations course will be taught. This training will be held in a centralized location, such as Fleet Training Center, Norfolk, VA, to prevent redundant training amongst commands and to allow small commands without training resources the opportunity to obtain training. An annual training budget of $10,000 is set with an initial $20,000 for startup.

c. **Supply Support.** Throughout the design, as software and hardware were identified, the price and suppliers were also identified, namely South Hills Datacom, Misco, and Network Express. These three vendors offer one year warranties. Also, since these vendors offer overnight express delivery, no spare parts are required to be maintained on site. With project MTBF, this supply support is more than adequate to furnish repair parts in timely fashion. There will be some additional cabling maintained on site, but this was accounted for in the initial hardware purchase.

d. **Documentation.** Documentation is required for the operation and maintenance of the system. Operation documentation comes from user's manuals of both the software and the hardware. When a command purchases the system and all of the individual components, they will receive the manuals. The only other operator's guide is for the WAN. Unfortunately, there is not an Internet operators manual, but popular books can be purchased on the subject (e.g. The Whole Internet User's Guide and Catalog, by Donnalyn Frey and Rick Adams, O'Reilly and Associates, Sebastopol, CA, 1992). As for maintenance documentation, both preventive and corrective maintenance procedures will be written covering the required preventive and corrective maintenance described in the maintenance functional flow diagrams. A budget of $1000.00 is allocated for this.

This concludes the logistics and supply support section of the detail design phase. Next, a lifecycle cost analysis will be done to project the cost of the system.

5.4 LifeCycle Cost Analysis.

Figure 13 gives a summary of all system costs for the lifecycle based upon Naval Guided Missiles School. These results were determined assuming 7 percent average annual interest rate for the 11 year life time (1 year to design and construct the network and 10 operating years) with the help of "LCCC." The total costs could, therefore, be discounted due to the time value of money. The resulting discounted system cost is $1,021,020, almost half the price of the remaining cost of VTS. Figure 14 provides the system costs for each year. The design and construction occurs in the first year, and then for the next 10 years only operating costs arise. It should be noted that the total cost from this analysis is $1,338,000. This is not discounted, but is the actual amount outlayed.

As stated in system requirements, this system must be available to all commands. Naval Guided Missiles School is a large command, so the lifecycle cost determined in figure 13 is the maximum cost a command would pay. As the number of users a command has decreases, LAN hardware costs lower because less is required, training costs decrease due to having less personnel, less technical data is required due to having less workstations, and less test equipment is used due to having less equipment to perform maintenance upon. Less

Cost Category	Cost ($)	% of Total
1. Research and Development		
(a) System Eng.	22,986	2.25
(b) Design Eng.	34,206	3.35
Subtotal	57,192	5.60
2. Construction		
(a) Personnel	13,487	1.32
(b) WAN Hardware	2,229	.22
(c) WAN Software	63,800	6.25
(d) LAN Hardware	71,068	6.96
(e) LAN Software	254,588	24.93
(f) Cabling	20,714	2.03
(g) Initial Logistics Sup.		
(1) Training	20,000	1.95
(2) Technical data	1,000	.10
(3) Test/Support Equip.	3,968	.30
(h) T1 Startup Fee	5,000	.49
Subtotal	455,854	44.65
3. Operations*		
(a) Maintenance	353,805	34.65
(b) Fractional T1	122,092	11.96
(c) Training	65,641	6.43
Subtotal	541,538	53.04
Total	1,021,020	100.0

* Discounted costs over 10 year Operating Period

interest rate 7%

Figure 13. Life-cycle cost breakdown.

Cost Category	Cost by Program Year (Thousands of Dollars)										
	1	2	3	4	5	6	7	8	9	10	11	Tot.
1. R & D												
(a) Sys. Eng	23.0	0	0	0	0	0	0	0	0	0	0	22.9
(b) Design Eng.	34.2	0	0	0	0	0	0	0	0	0	0	34.2
Sub total	57.2	0	0	0	0	0	0	0	0	0	0	57.1
2. Construction												
(a) Personnel	13.5	0	0	0	0	0	0	0	0	0	0	13.5
(b) WAN Hard.	2.2	0	0	0	0	0	0	0	0	0	0	2.2
(c) WAN Soft.	63.8	0	0	0	0	0	0	0	0	0	0	63.8
(d) LAN Hard.	71.1	0	0	0	0	0	0	0	0	0	0	71.1
(e) LAN Soft.	254.6	0	0	0	0	0	0	0	0	0	0	254.6
(f) Cabling	20.7	0	0	0	0	0	0	0	0	0	0	17.8
(g) Log. Sup.												
(1) Training	20.0	0	0	0	0	0	0	0	0	0	0	20.0
(2) Tech data	1.0	0	0	0	0	0	0	0	0	0	0	1.0
(3) Test equip	4.0	0	0	0	0	0	0	0	0	0	0	4.0
(h) T1 S/U	5.0	0	0	0	0	0	0	0	0	0	0	5.0
Sub total	455.9	0	0	0	0	0	0	0	0	0	0	452.9
3. Operations												
(a) Maint.	0	53.9	53.9	53.9	53.9	53.9	53.9	53.9	53.9	54	53.9	539.0
(b) Fract. T1	0	18.6	18.6	18.6	18.6	18.6	18.6	18.6	18.6	18	18.6	186
(c) Training	0	10	10	10	10	10	10	10	10	10	10.0	100
Sub total		82.5	82.5	82.5	82.5	82.5	82.5	82.5	82.5	82	82.5	825
Total	512.9	82.5	82.5	82.5	82.5	82.5	82.5	82.5	82.5	82	82.5	1338

Figure 14. Cost per year summary.

cabling is required for physically smaller commands. For commands with less than 50 people, the WAN cost would decrease, because an online account is utilized for internet access vice T1 dedicated line.

5.5 Test and Evaluation Plan.

To conclude the detail design phase, the design is tested to ensure that it meets design specifications. This is done as type 3 testing, performed upon system installation but prior to operational use, and type 4 testing, performed throughout the lifecycle of the system.[56] Since all components are purchased off the shelf, there is no individual component testing required. Because models or prototypes are not being constructed, type 1 or type 2 testing is not required.[57]

The type 3 testing is performed in accordance with block 4.9 of the functional analysis, "Test The System," and is conducted upon initial installation. This is performed by the maintenance personnel and a network manager. The testing consists of verifying proper system operations by sending and receiving electronic-mail and data files to and from all workstations throughout the LAN and uploading and downloading files over the Internet. Finally, the clients verify that

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[56]Benjamin S. Blanchard and Wolter J. Fabrycky, Systems Engineering and Analysis, (Englewood Cliffs, NJ: Prentice Hall Inc.), 1990, p. 106.

[57]Blanchard, p. 107.

they can access server resources.

Type 4 testing is conducted throughout the system's lifecycle, and consists of verifying the maintenance and reliability criteria set in the conceptual design. Every corrective maintenance action required is documented on an OPNAV 4950 Form 2K. These forms are forwarded to Naval Sea Systems Command where the maintenance criteria is calculated and checked to verify that the system is meeting proper reliability goals. If goals are not met, the impact is determined, and an alteration to the system is made if required.

5.6 Detail Design Summary

At the completion of this section, the detail function design has been performed, logistics and supply support has been planned, and a test and evaluation plan has been formed. With the knowledge of system requirements and planned uses, the project lifecycle costs have been determined. Because the systems engineering concept was used, the lifecycle cost analysis is an all inclusive function. Besides the required hardware and software costs, lifetime maintenance, operation fees, training, documentation, and support have been included. This gives validity to the final cost figure. The system is now ready for construction

SECTION 6 SUMMARY

At the conclusion of this project, a system has been designed to fill a defined deficiency or to satisfy a need. This need began the design and defined the design throughout the system development. Before any mention was given to specific hardware and software, there was a desire to share information between people in the training organization of the U. S. Navy. Several avenues were examined and a computer network was chosen. Among the various types of wide area and local area networks, the Internet and Ethernet, respectively, were selected, because these meet a specific set of guidelines established in the need definition. Before the detail design could begin, exact system tasks were defined and alternatives were examined.

The end result of this project is that a product has been designed that fills a deficiency, and not the other way around. The network was not designed, and then an application sought. On the contrary, personnel involved in every facet of the system lifecycle were included in the beginning to ensure that the end result was usable, maintainable, and easily learned. This is a vital point to be considered, because if the system fulfills defined operational specifications but cannot be easily operated or maintained, then the full capabilities will never be achieved.

Besides utilizing the systems engineering concept, a flexible system has been designed. The example used has been Naval Guided Missiles School but the system is adaptable to any command. During the lifecycle cost analysis, how the system costs will vary, depending upon command size, was covered. This point was emphasized in specifying the WAN to LAN connection method, because depending upon command size, the connection method and cost are different. The techniques utilized to design the LAN at Naval Guided Missiles School can also be easily applied to other commands. Therefore, the end result of the project has been a system able to be utilized throughout the navy. In these days of fiscal constraints, this "off the shelf" system lowers costs.

Another key point is the expected system life. In approximately ten years, the "information superhighway" is likely to be a reality, and the Navy will want to take advantage of it. Until then, however, the benefits of a more traditional computer network can still be gained, but without a large investment. By investing in a 10 year economical network, the Navy is meeting existing demands at a more economical price than the large mainframe system being used. When FDDI and BISDN become available, the Navy already will be experienced at networking, and will be able to readily utilize these resources.

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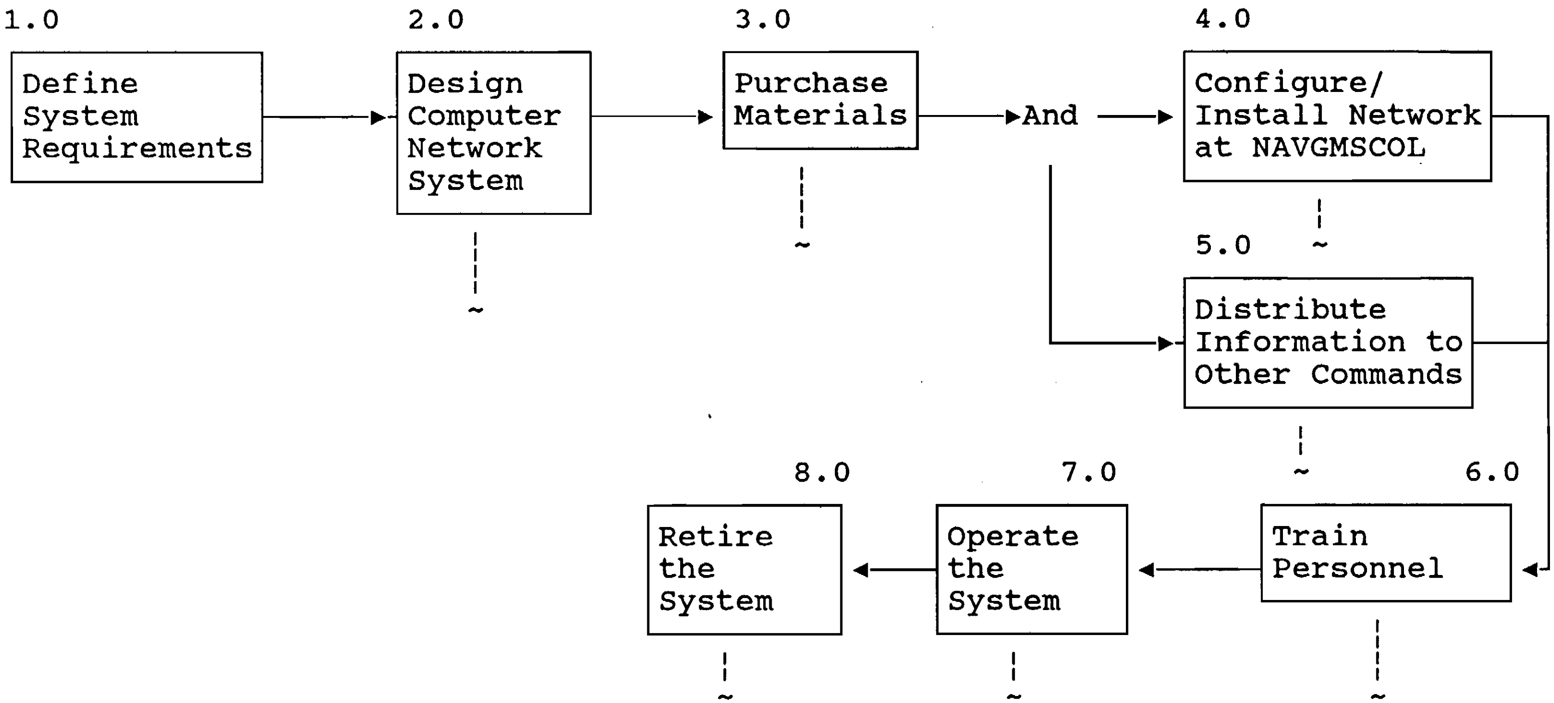
Appendix

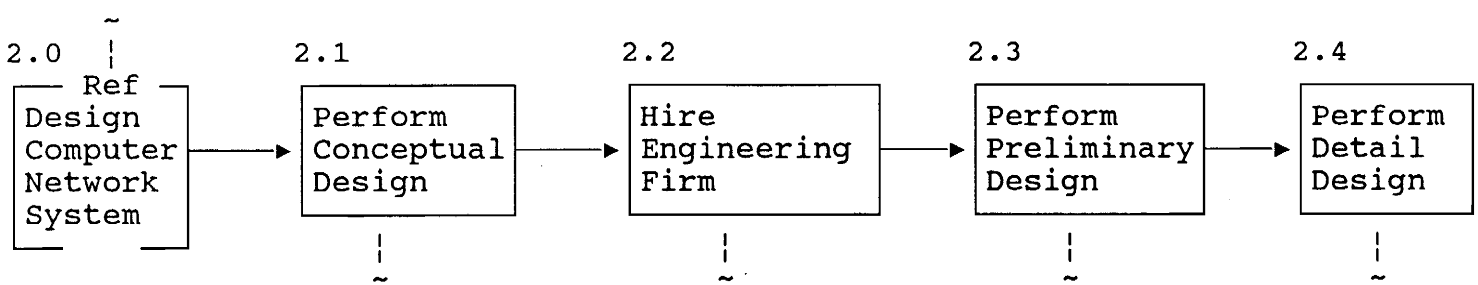
Functional Analysis

FUNCTIONAL ANALYSIS

Operational Functional Flow



2.0 Design Computer Network System



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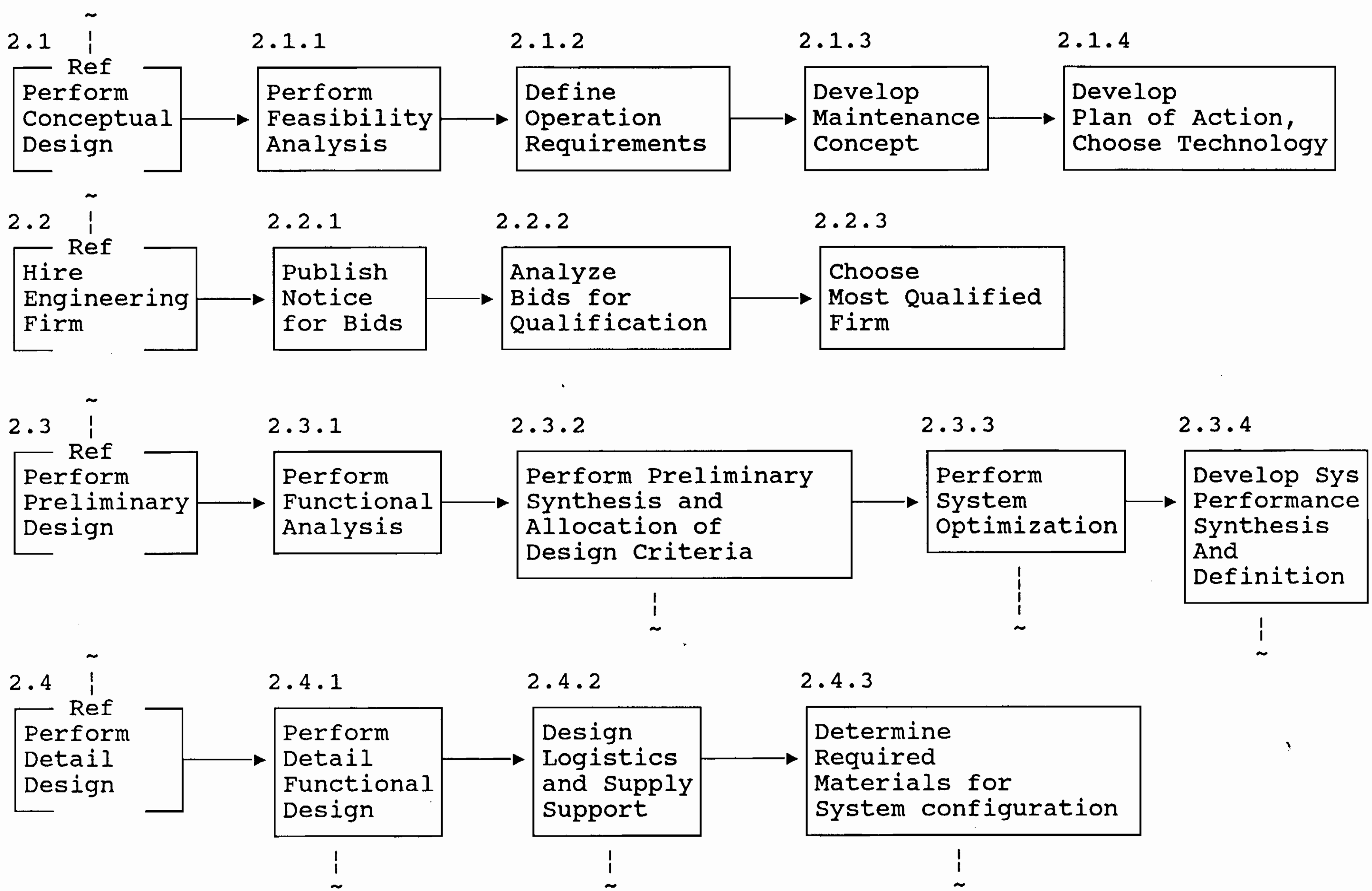

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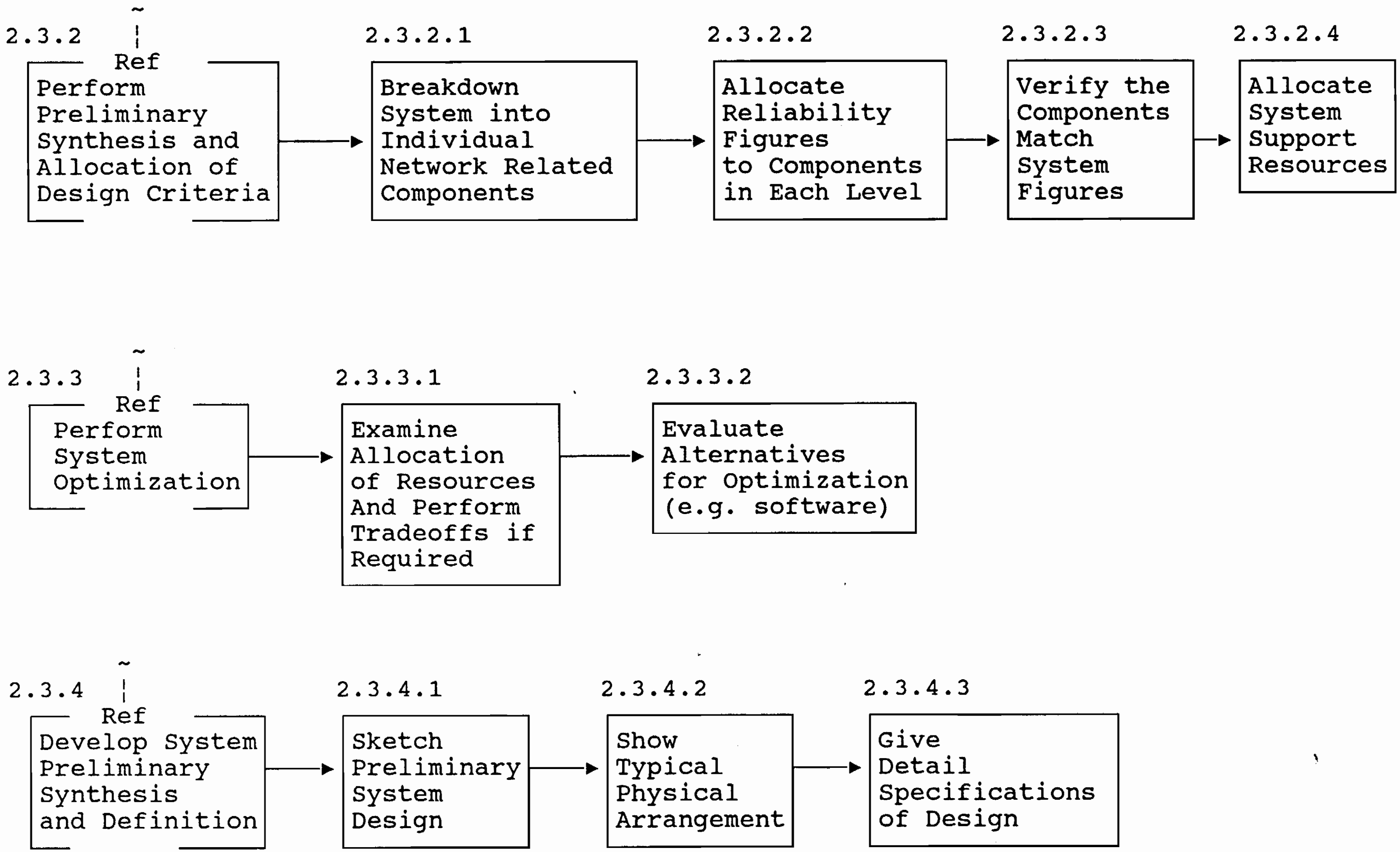

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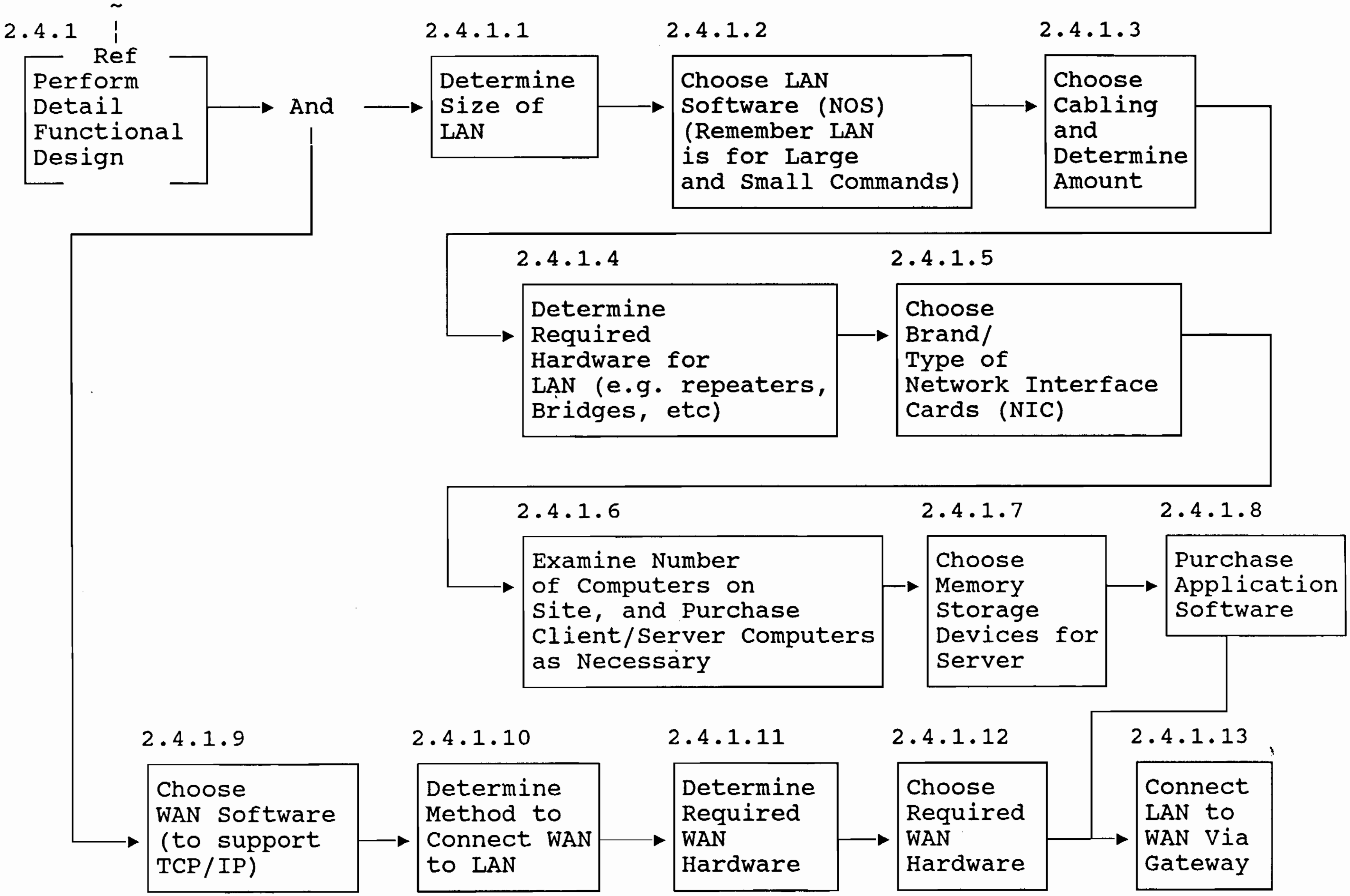

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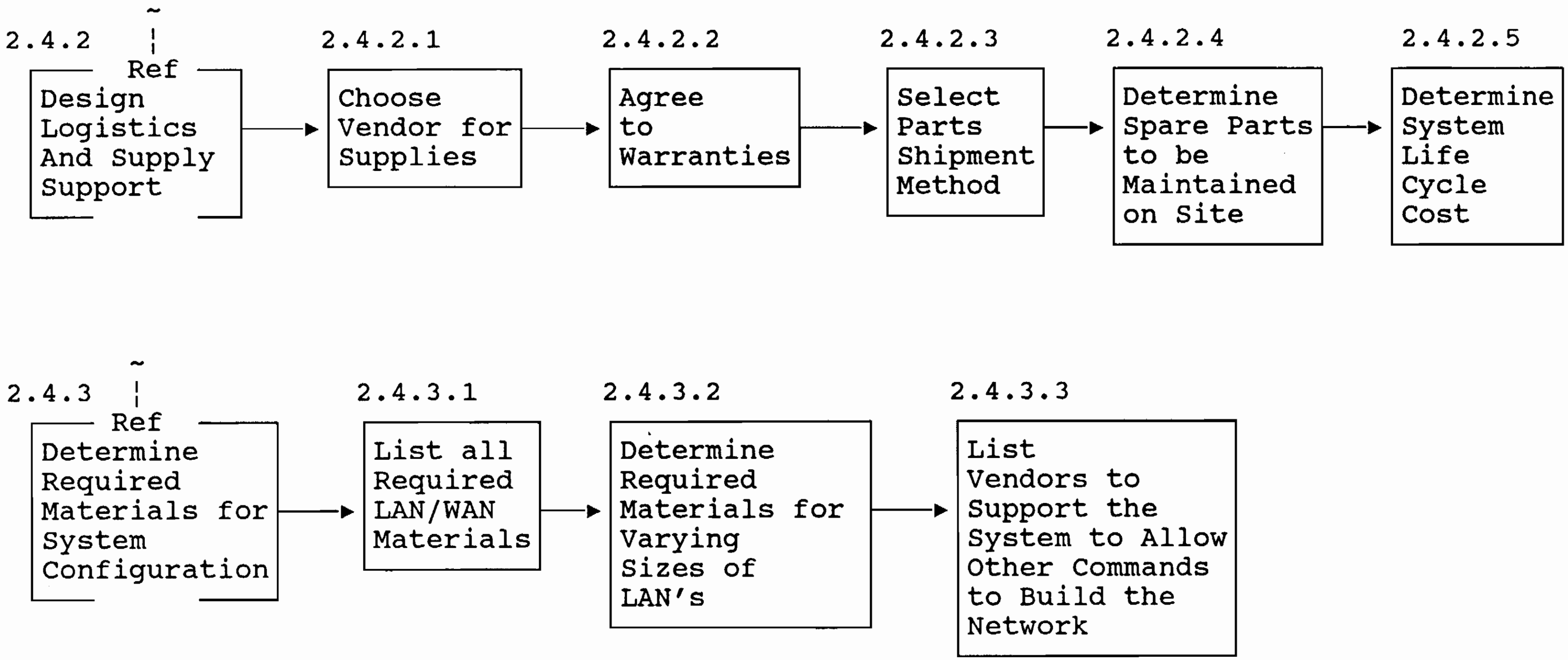
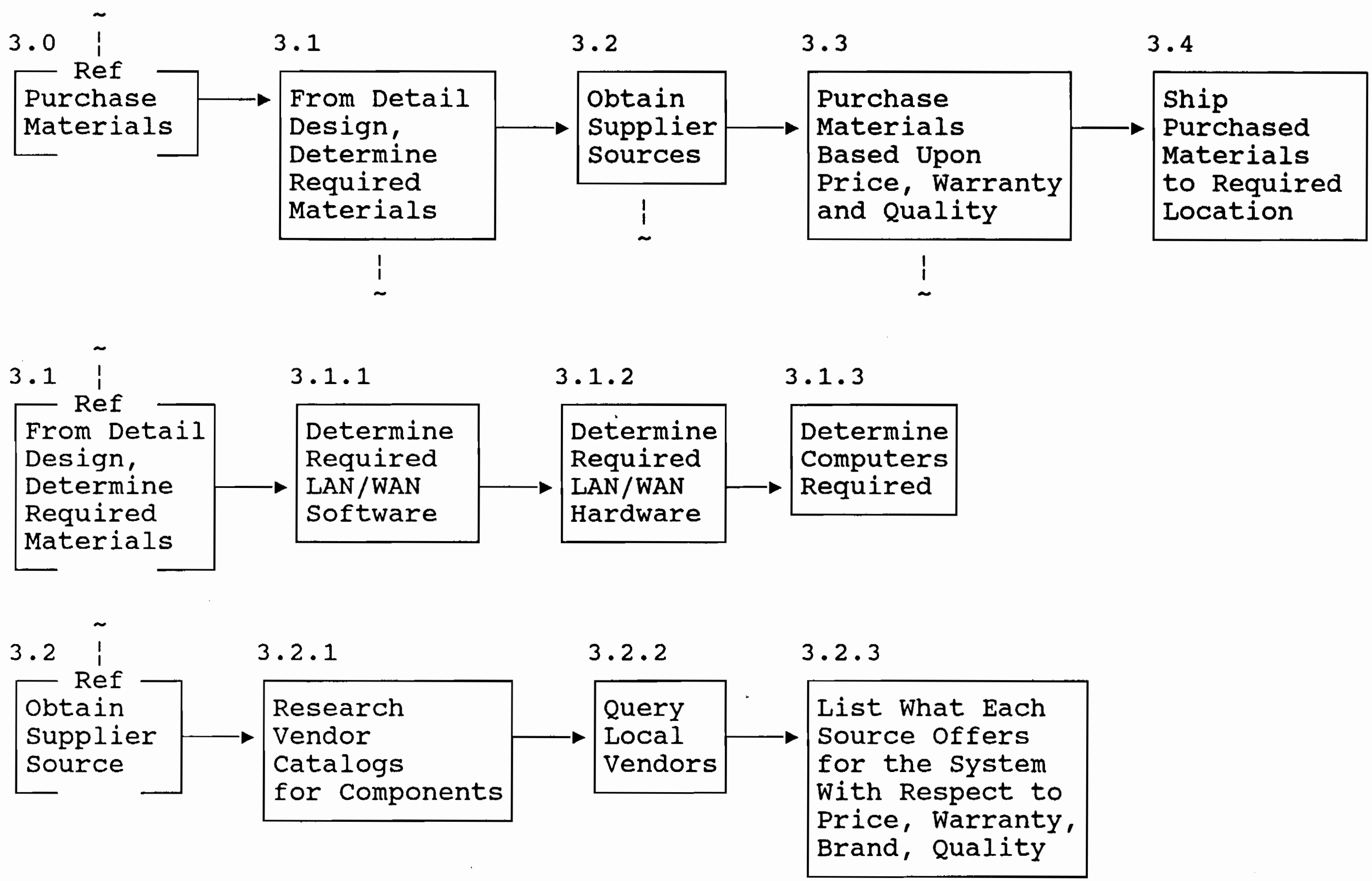


3.0 Purchase Materials



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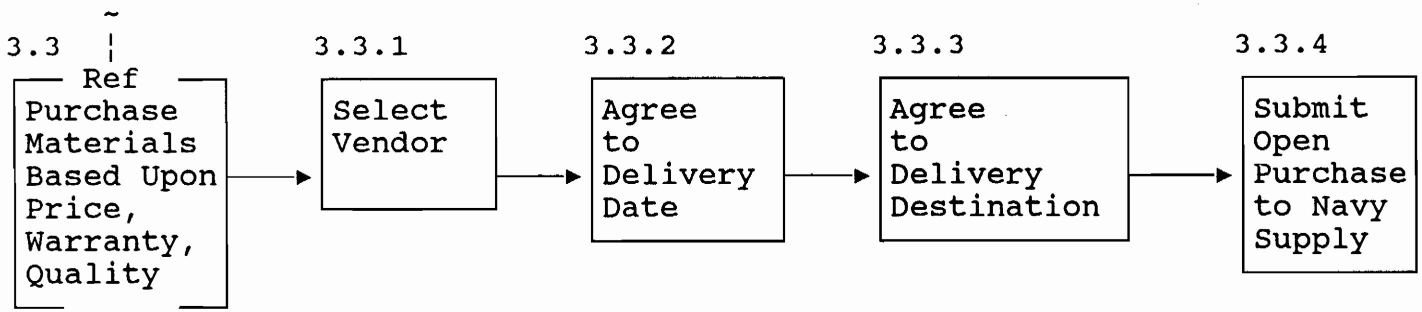
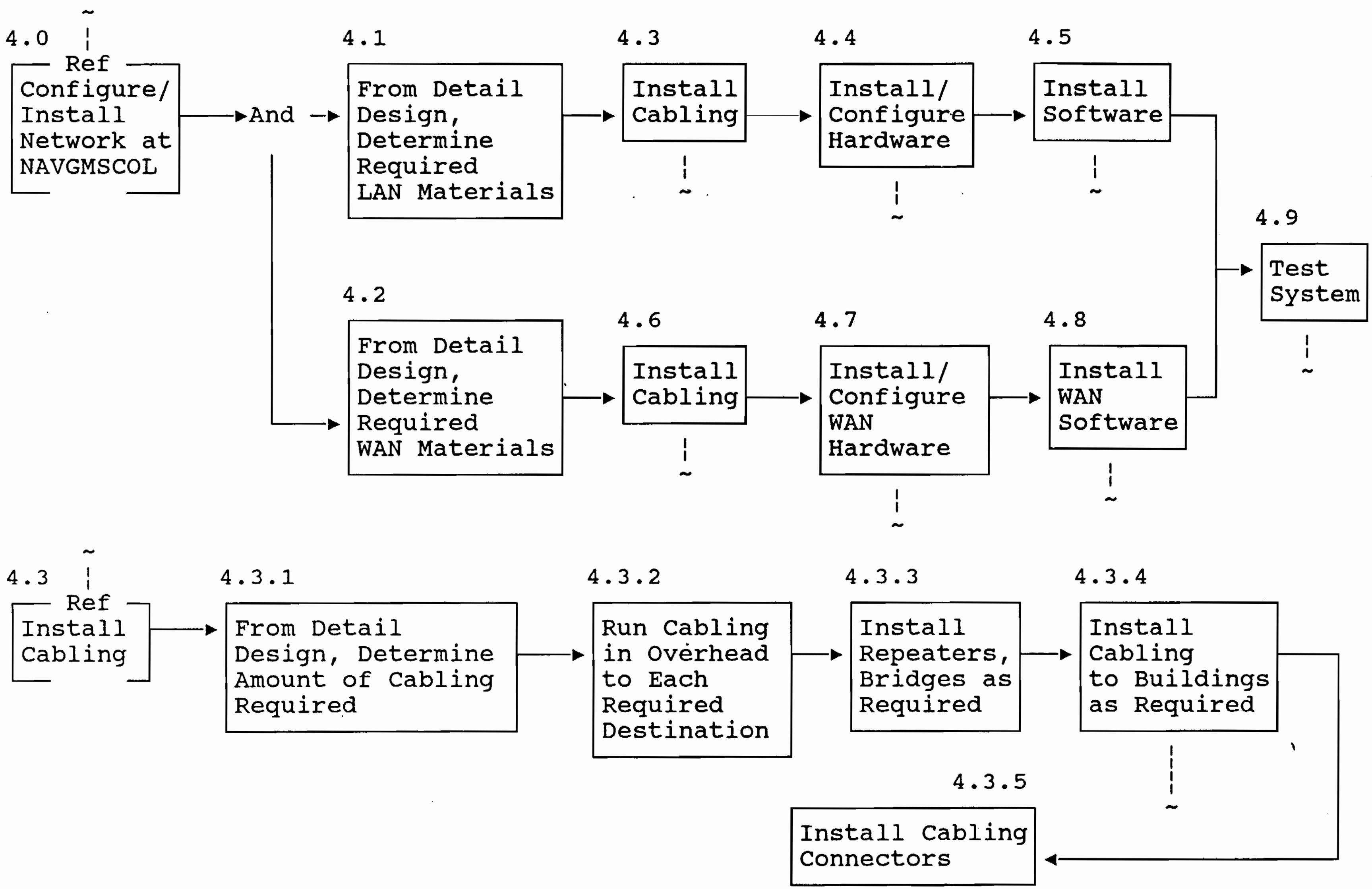


4.0 Configure/Install Network at NAVGMSCOL



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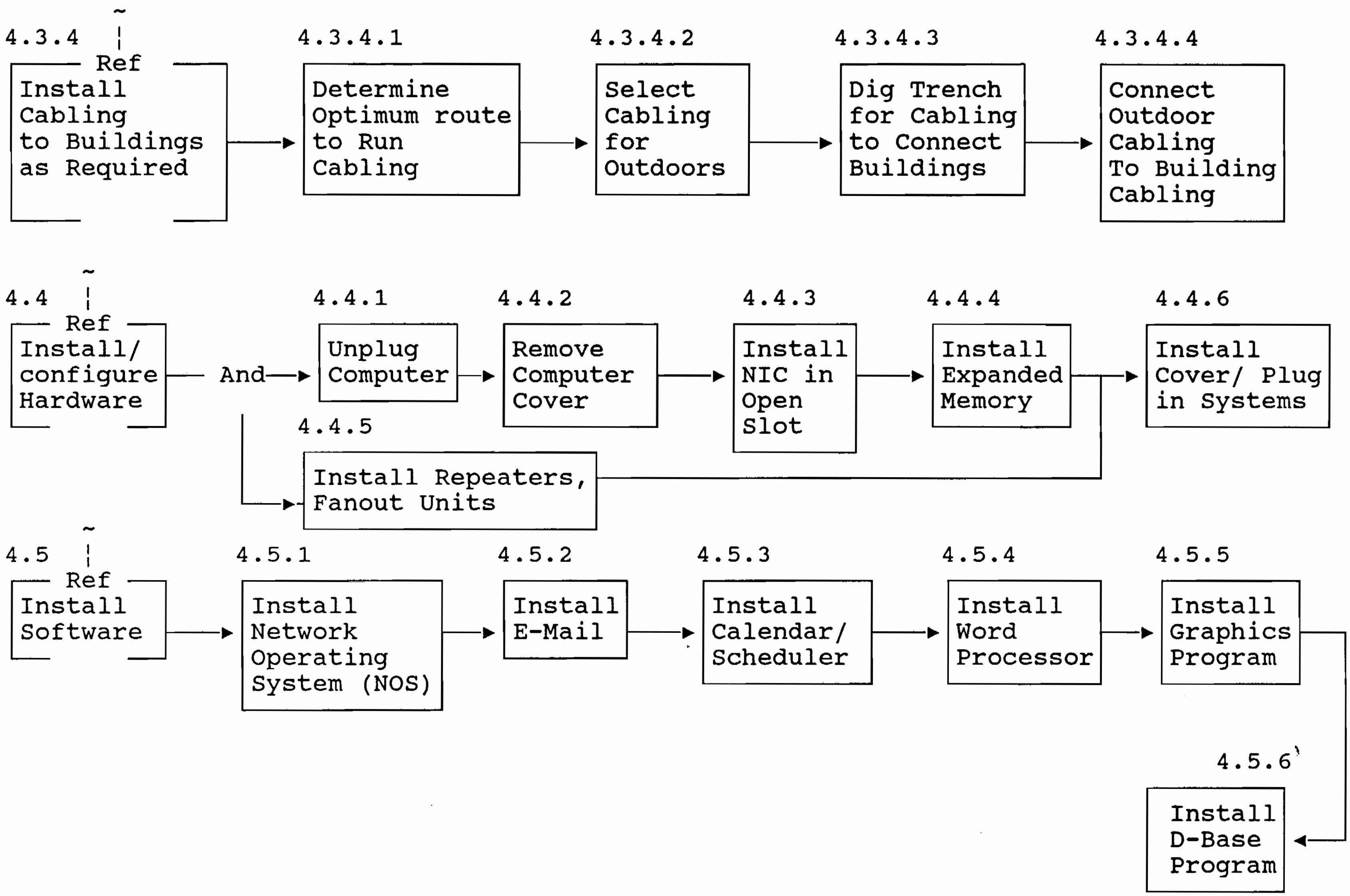

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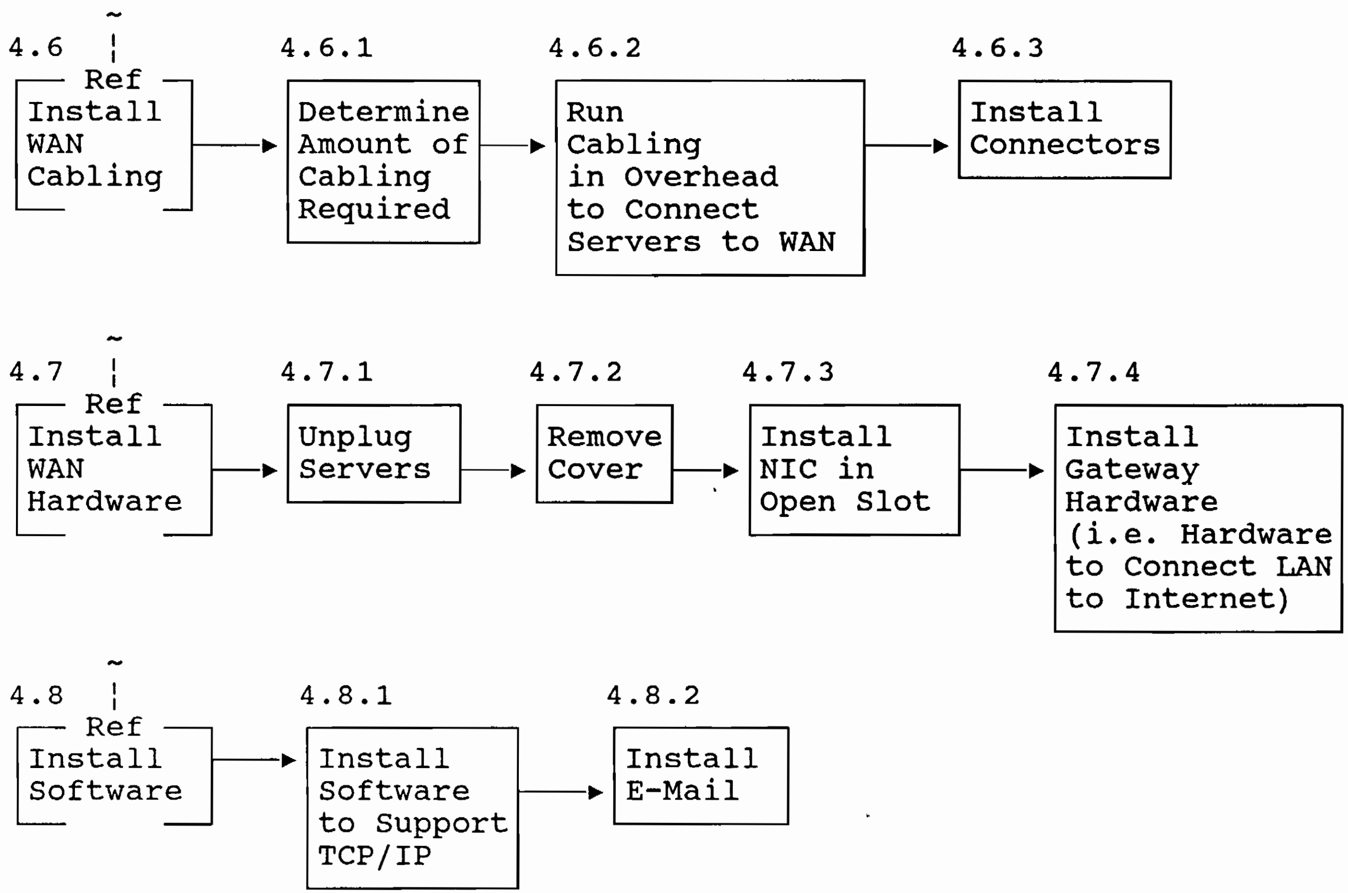

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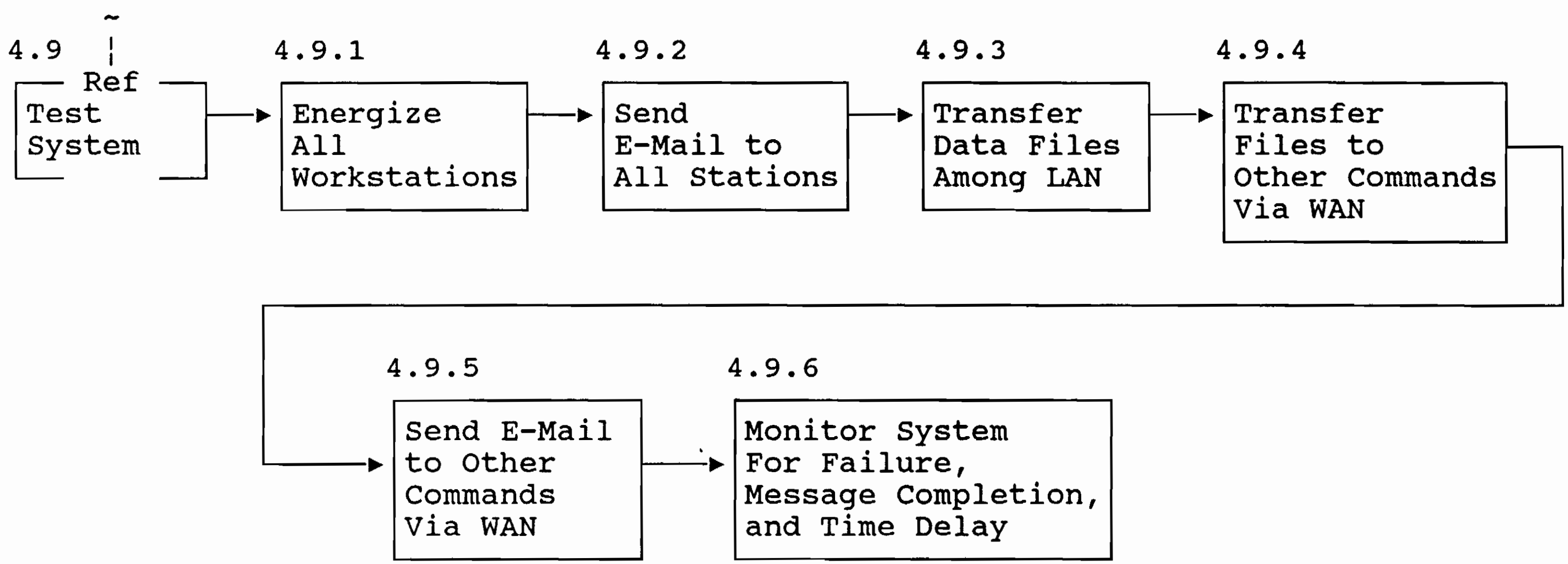
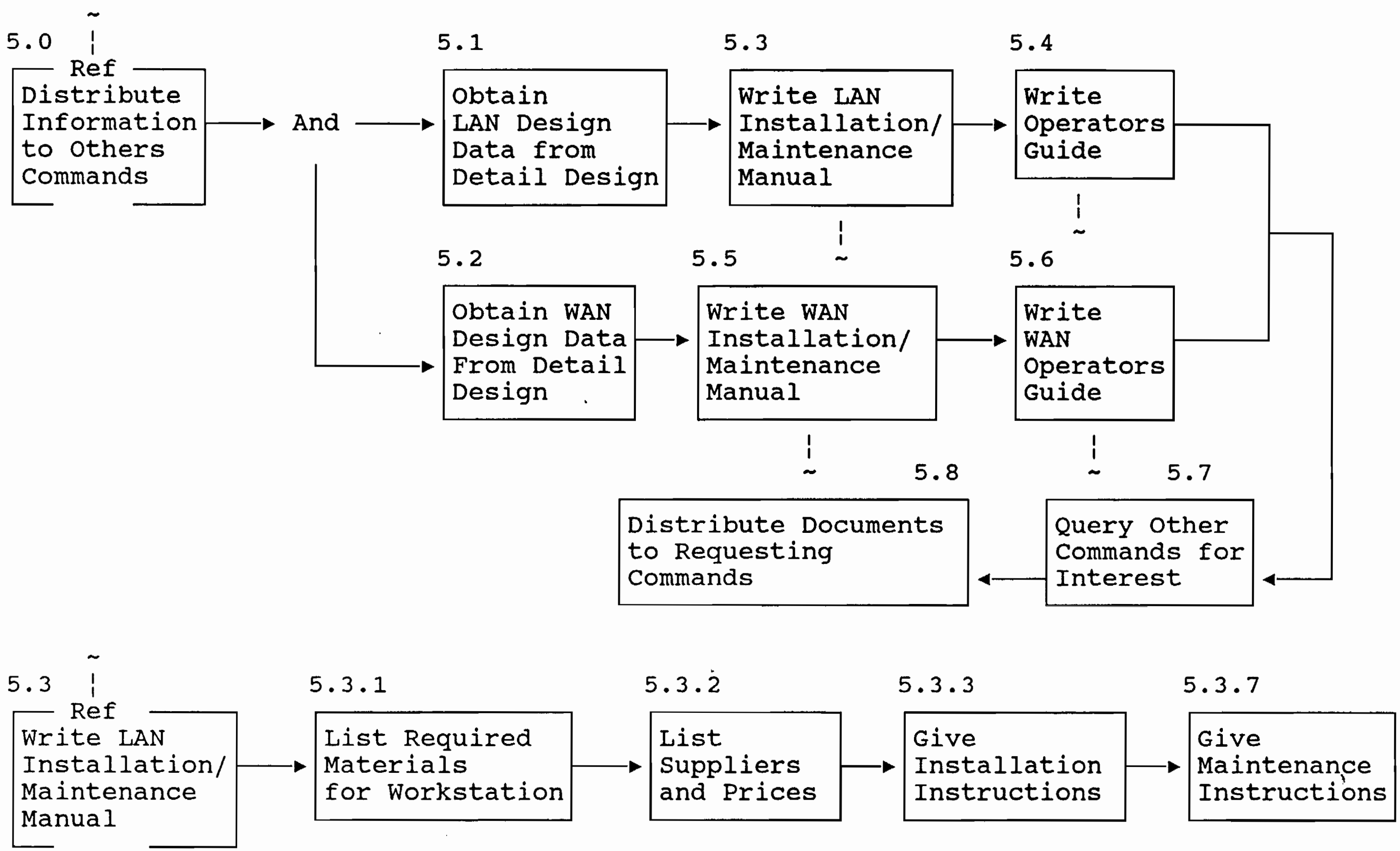


5.0 Distribute Information to Other Commands



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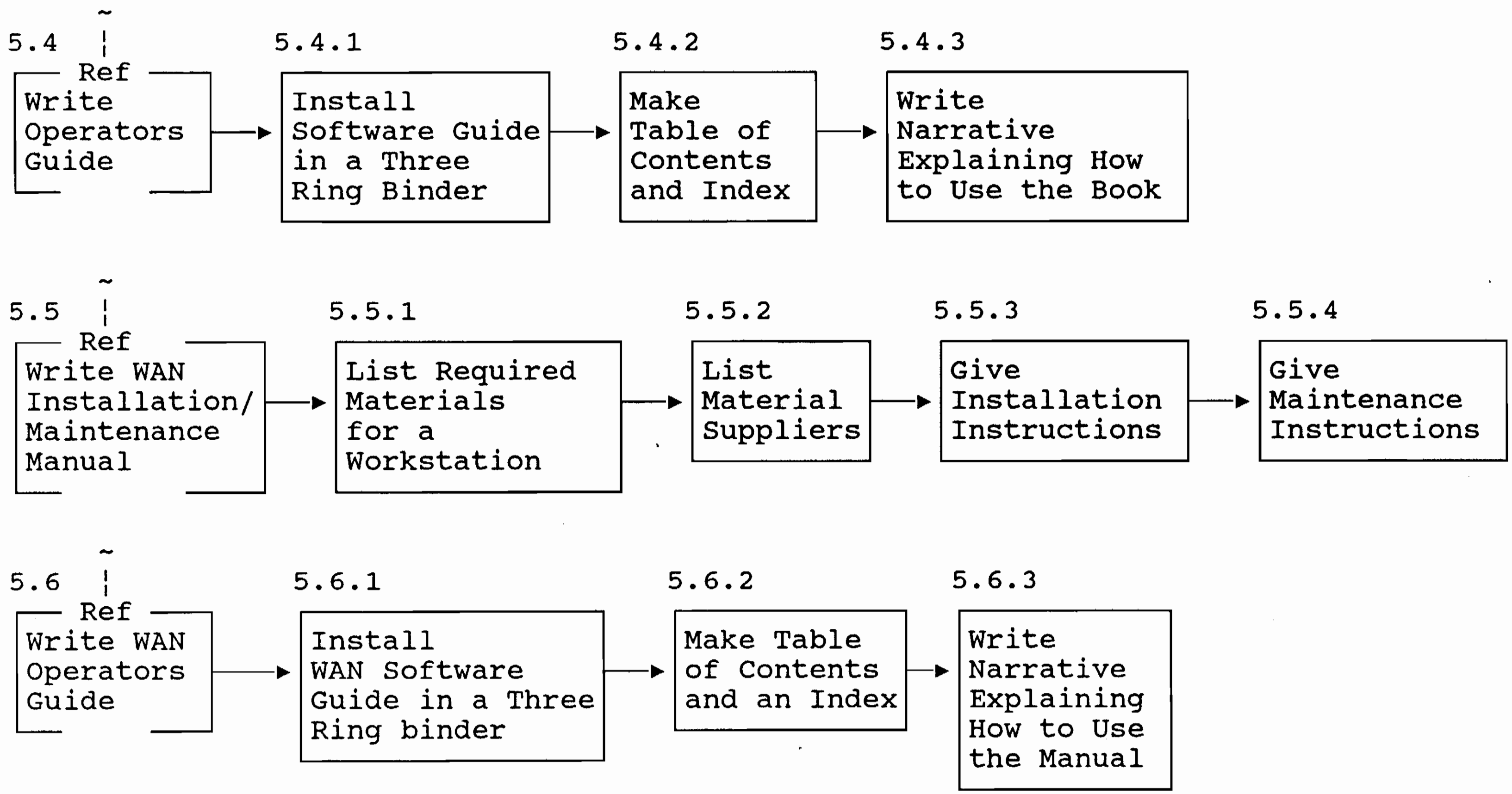
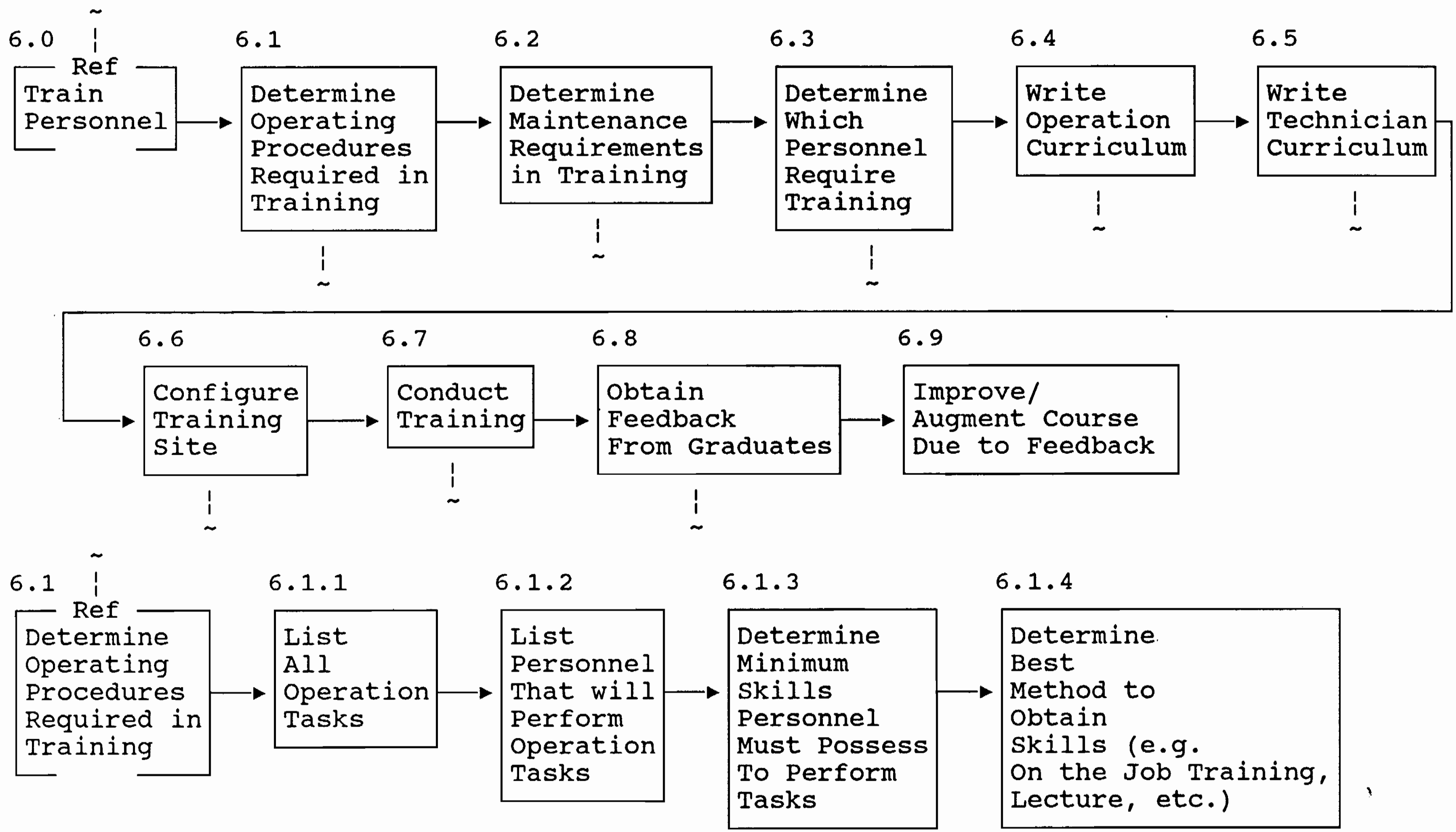


6.0 Train Personnel



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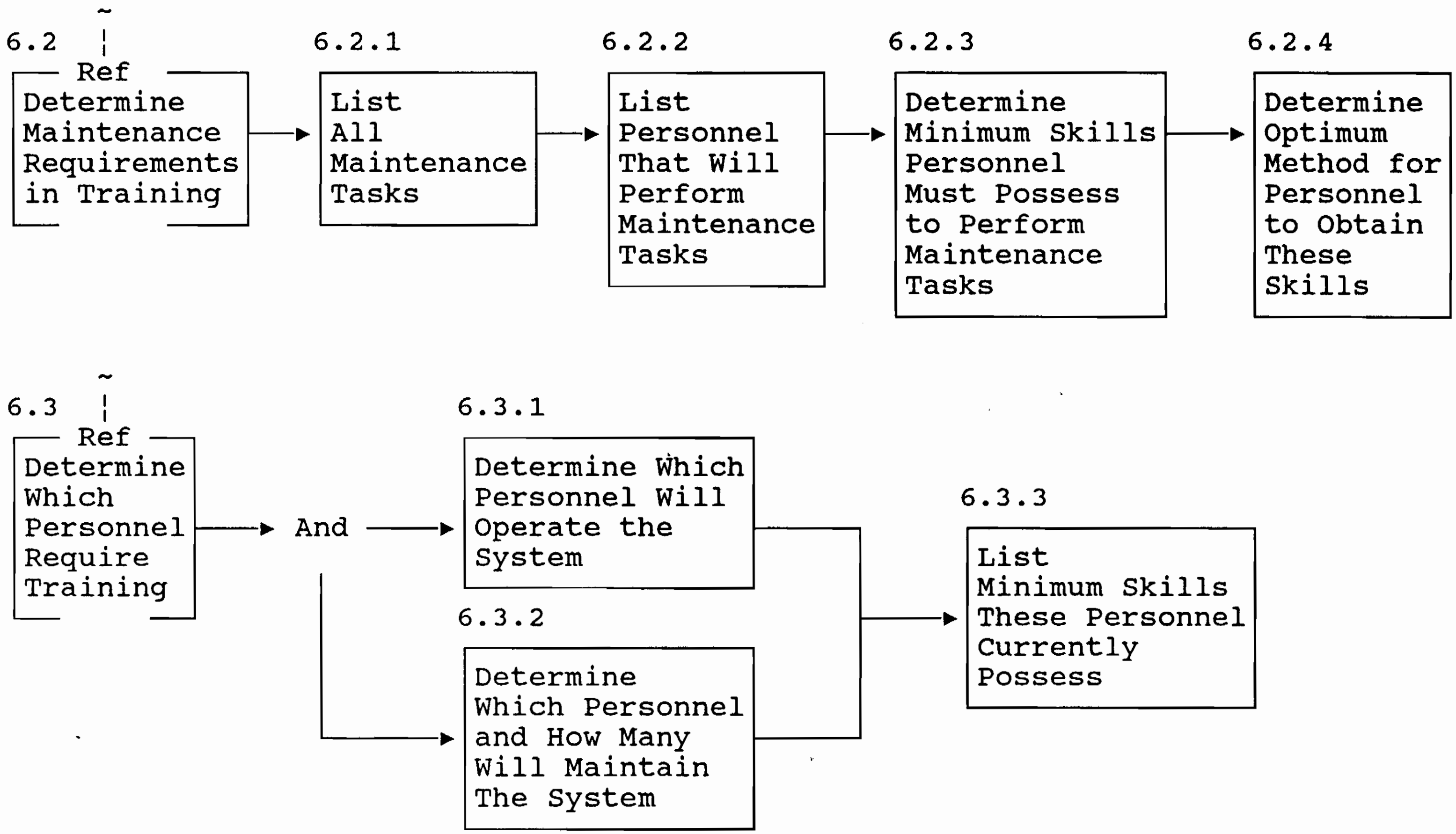

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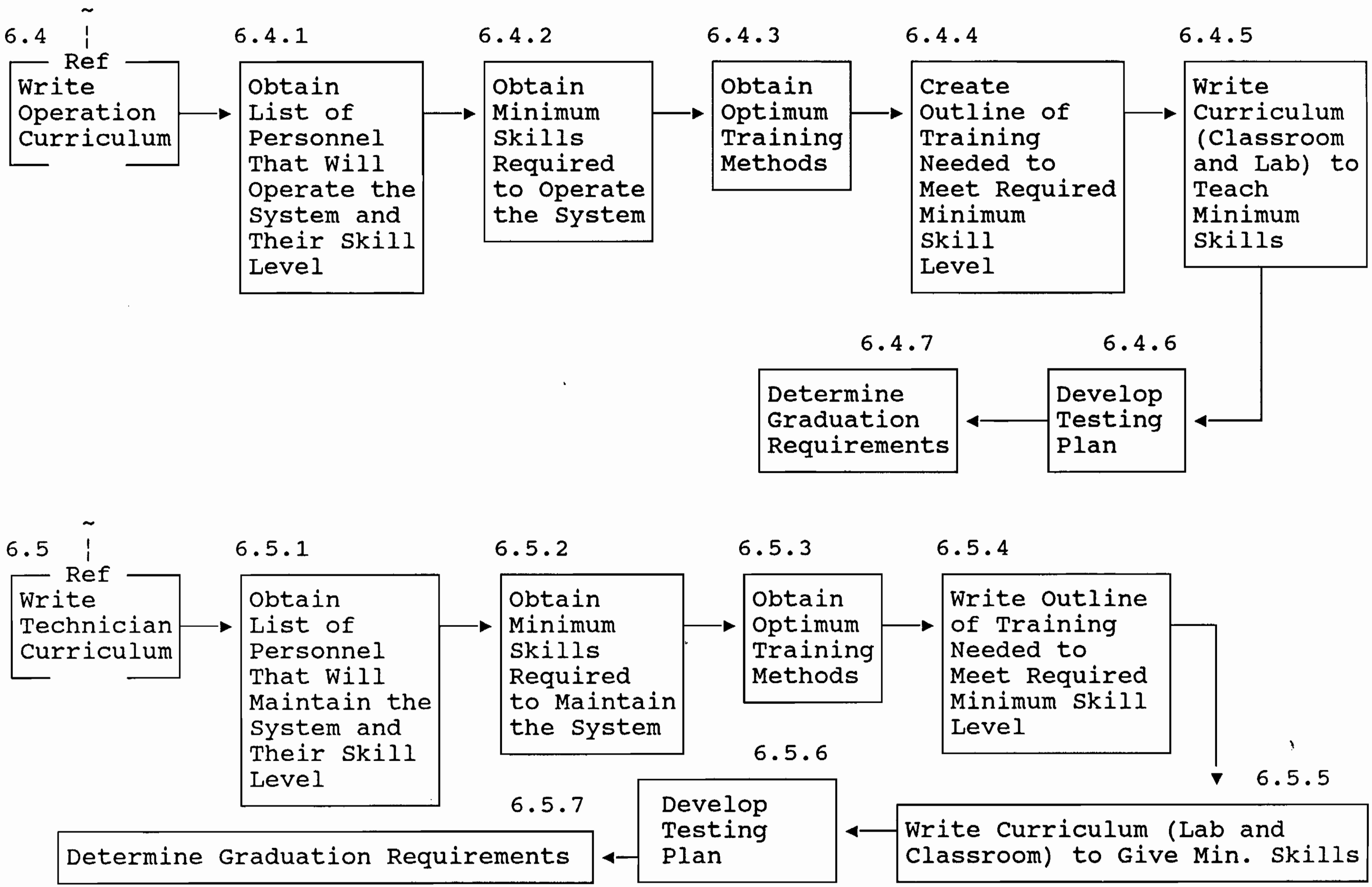

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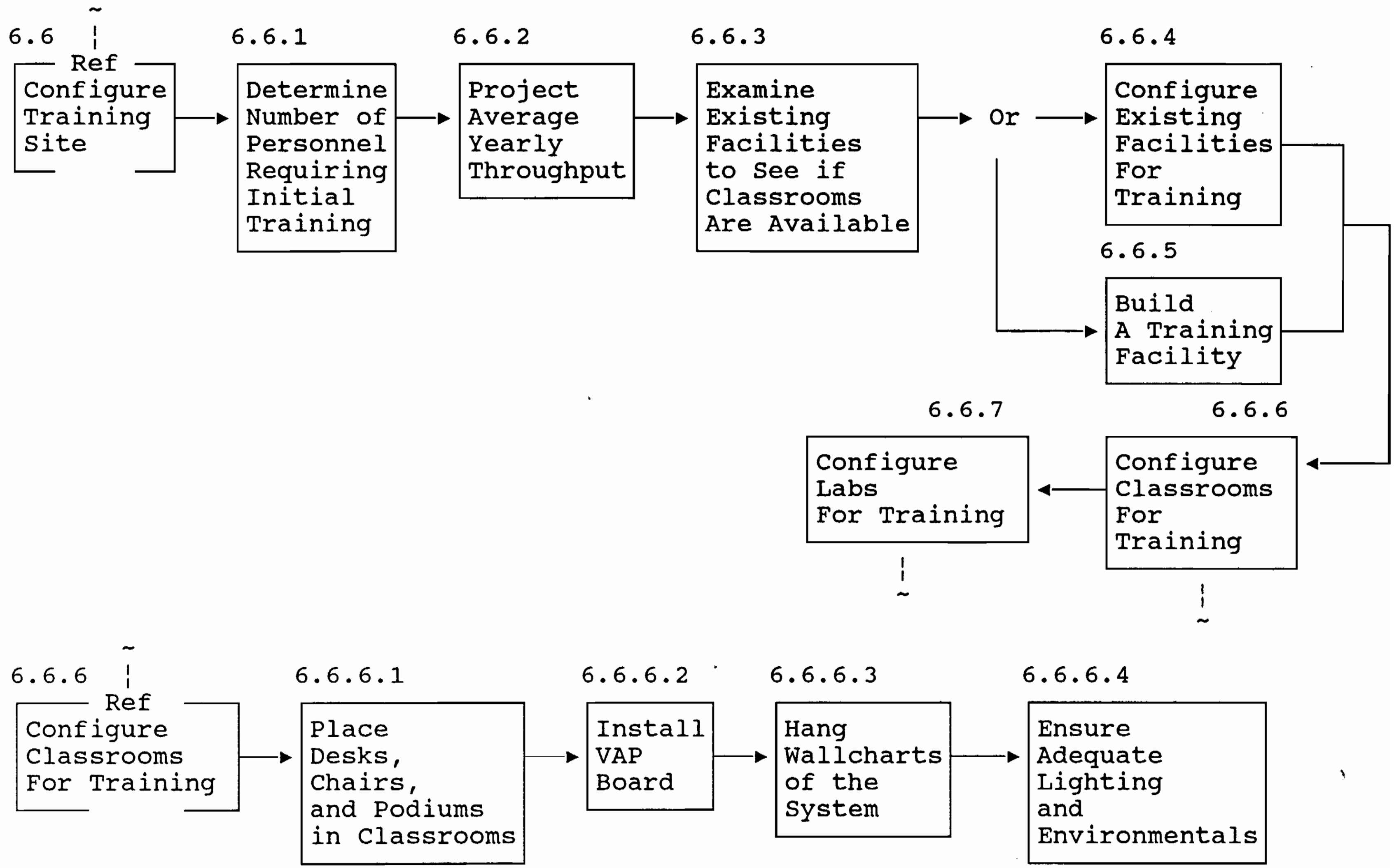

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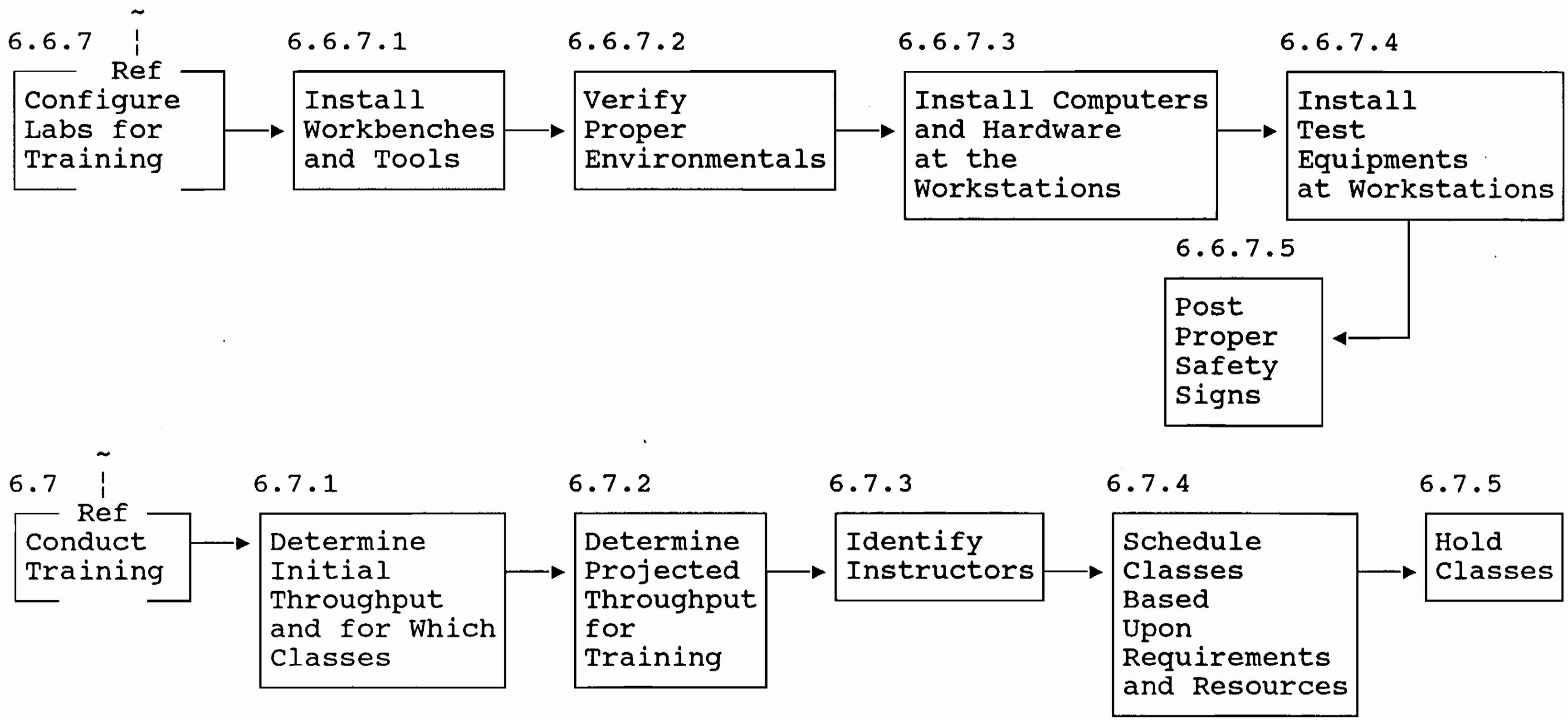

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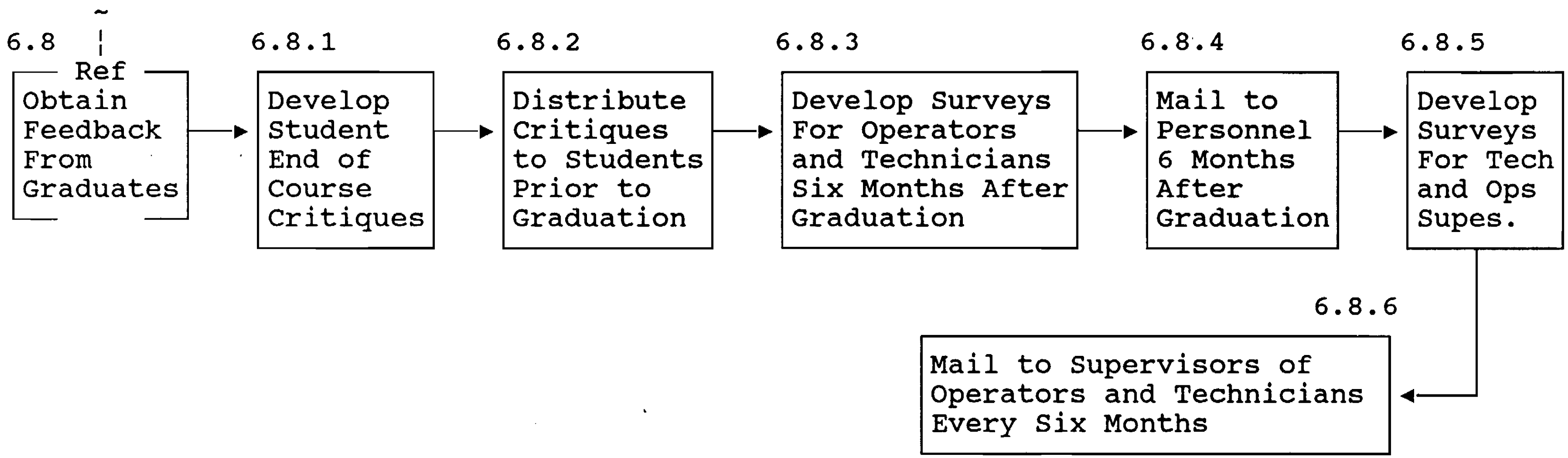
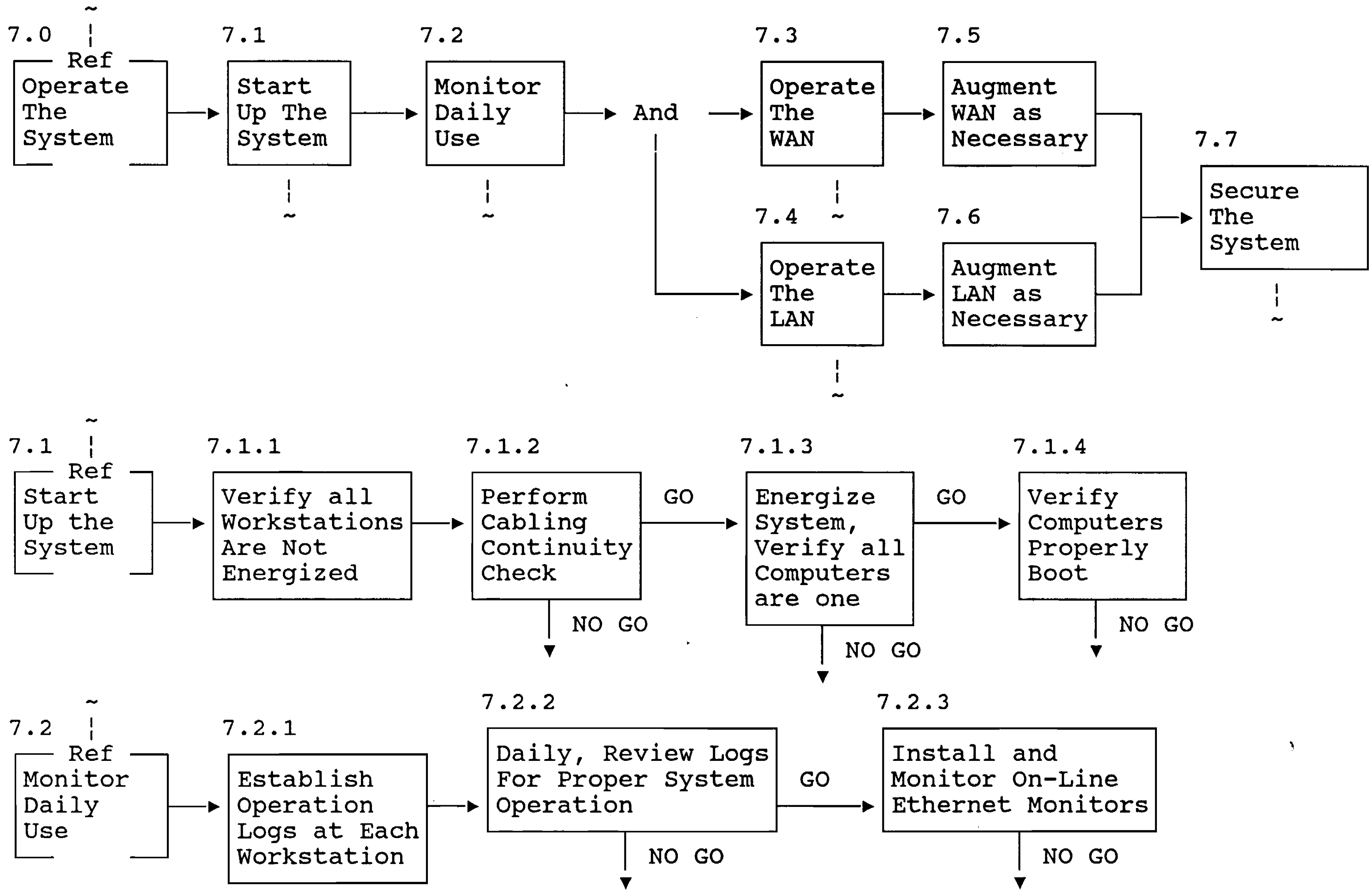


7.0 Operate the System



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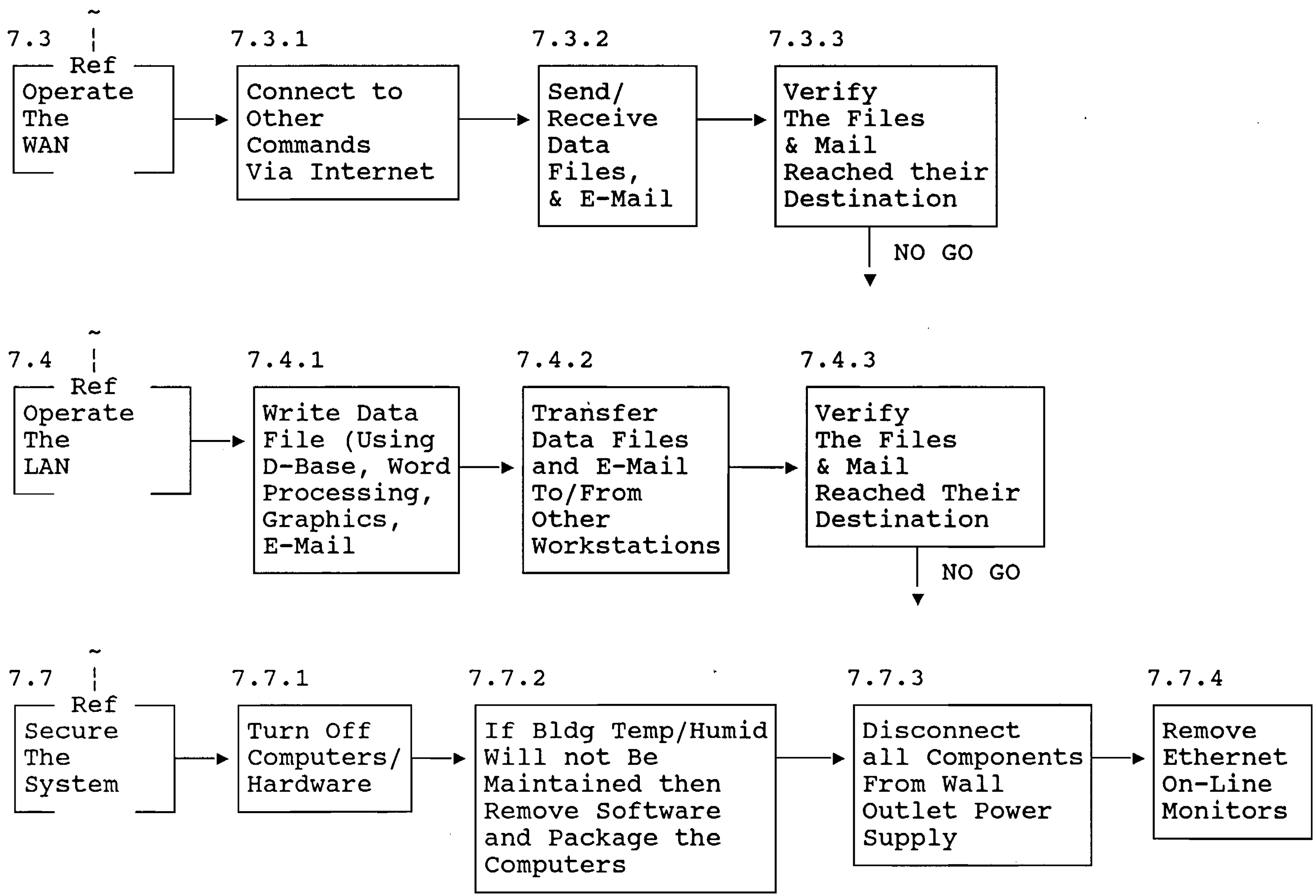
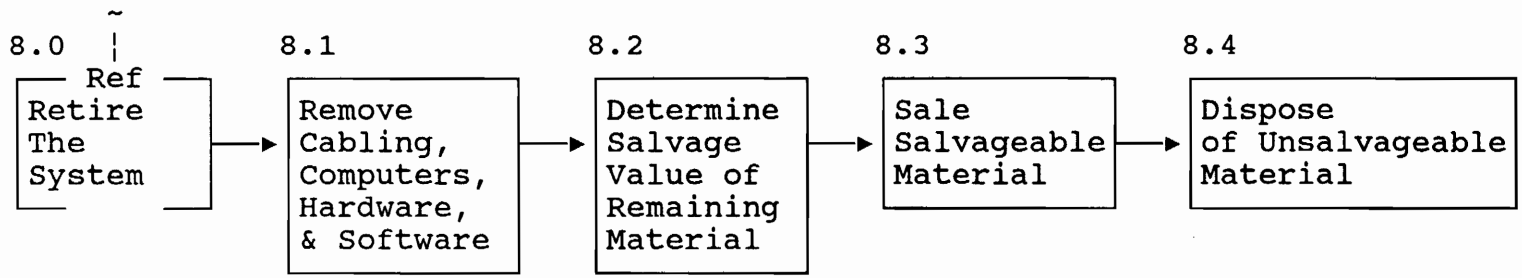
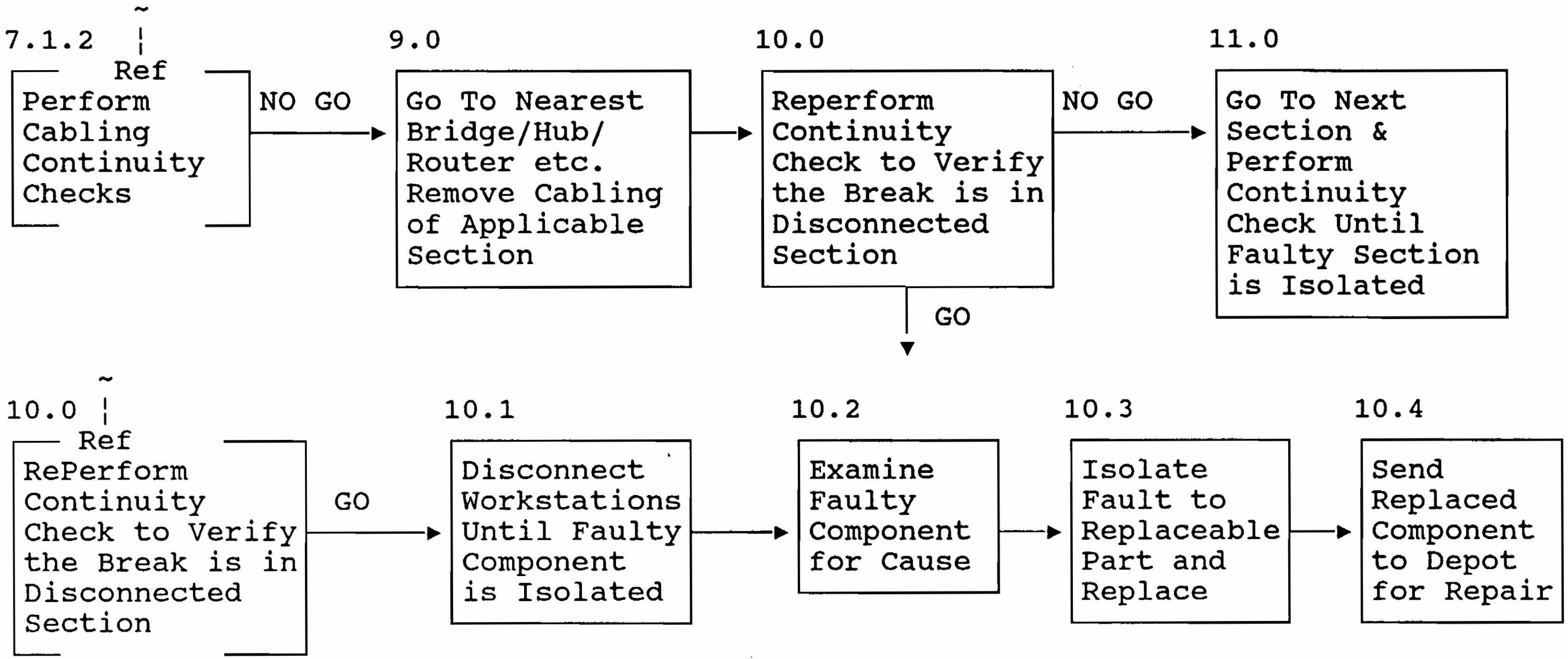


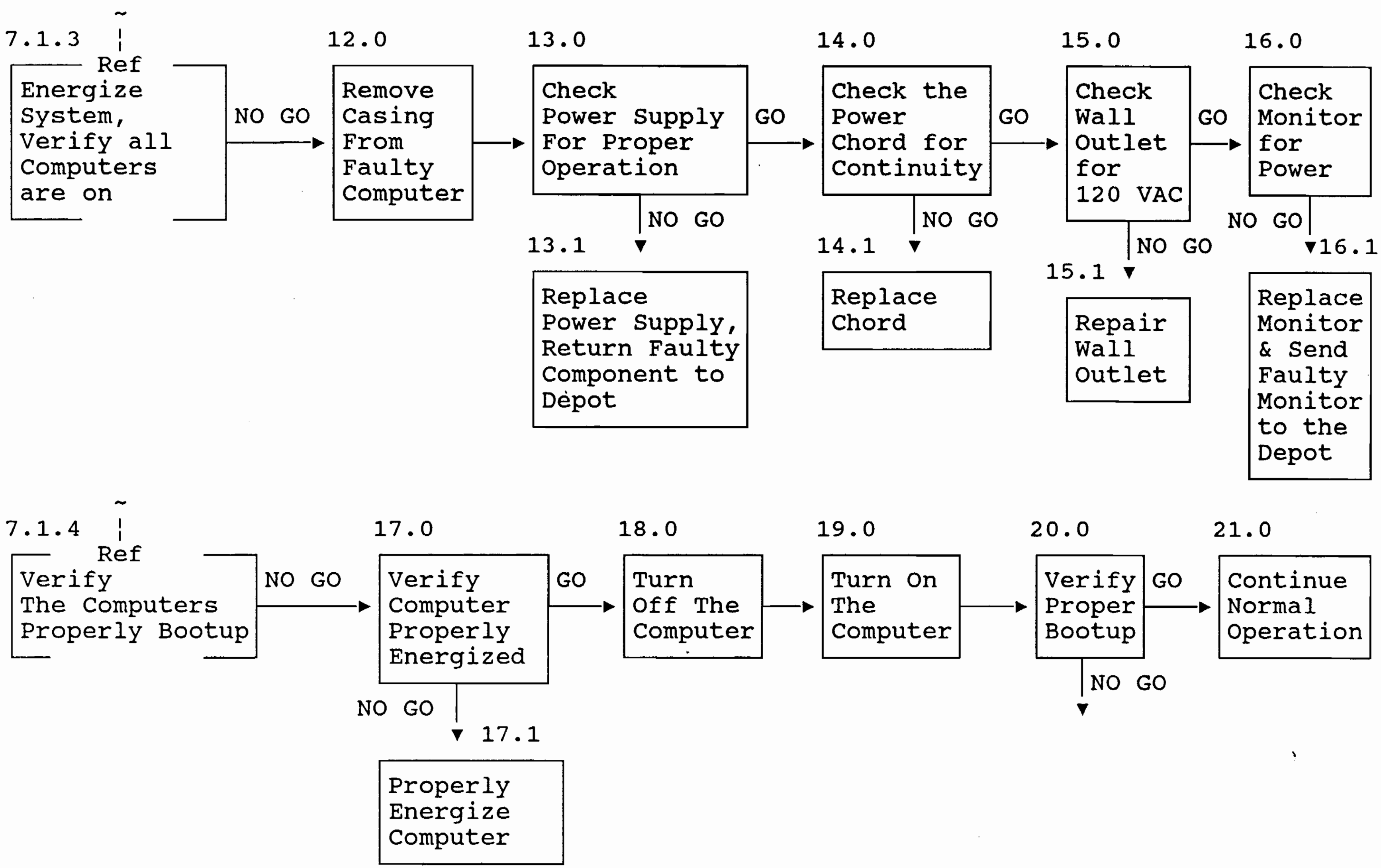
8.0 Retire The System



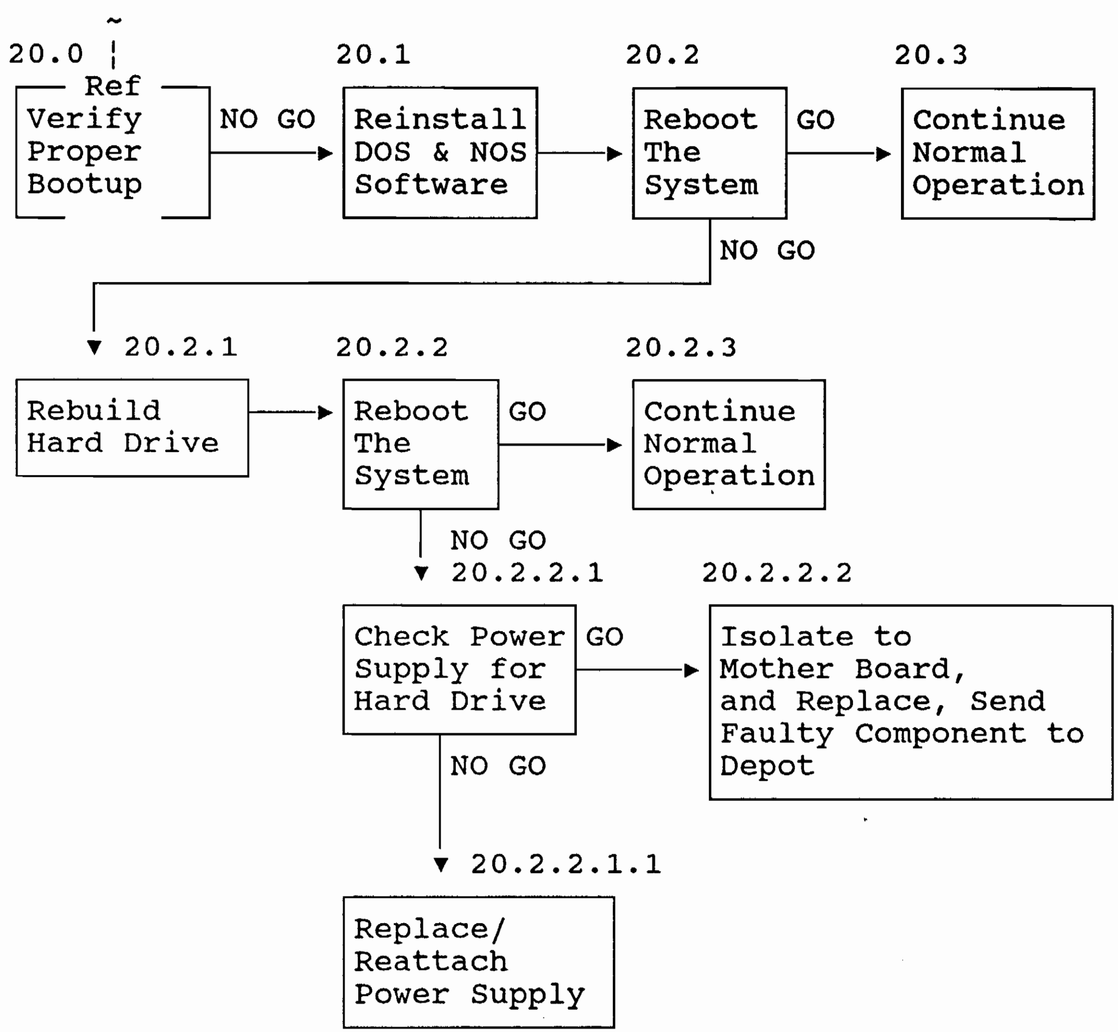
Maintenance Functional Flow



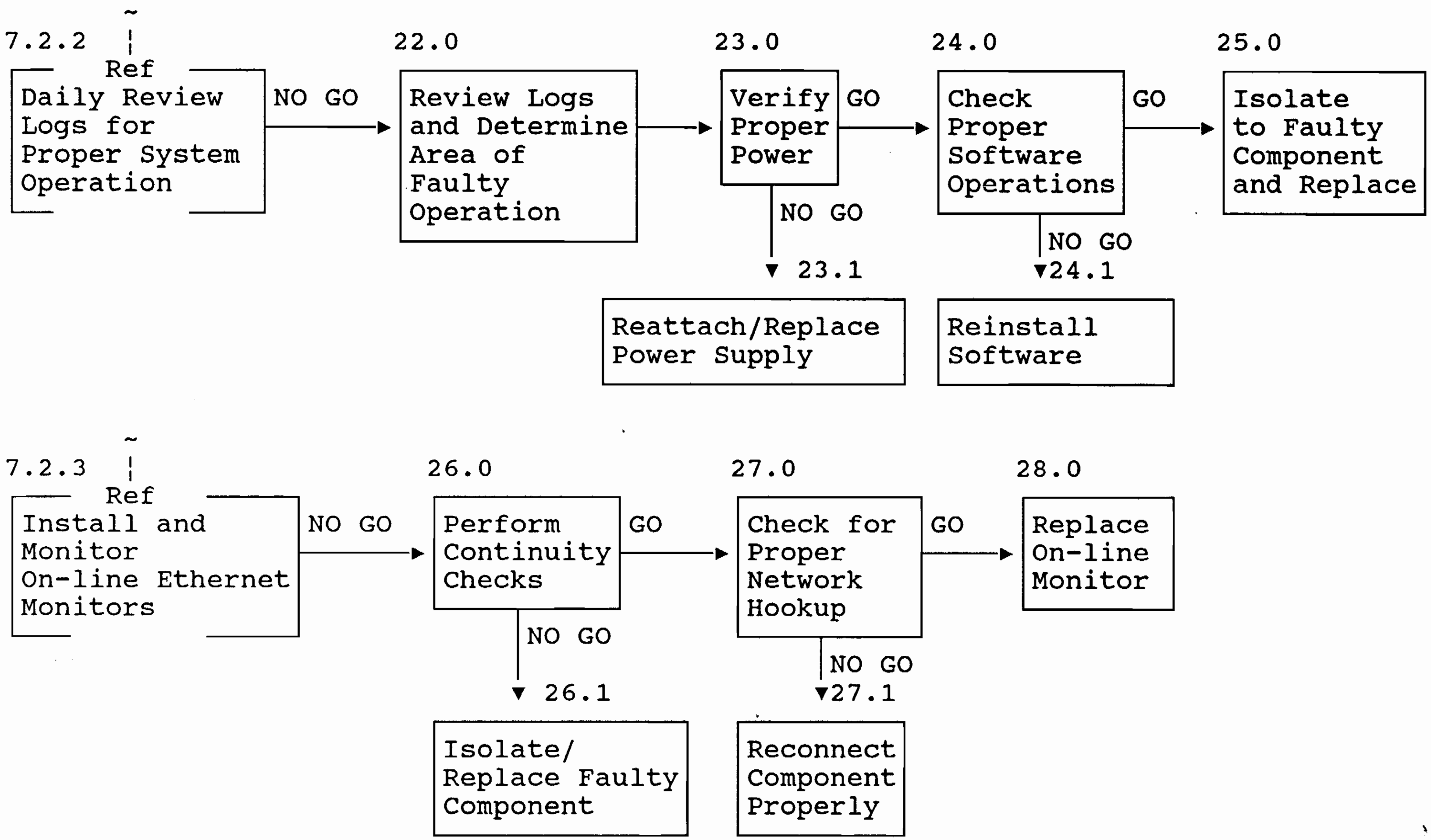
Maintenance Functional Flow (continued)



Maintenance Functional Flow (continued)



Maintenance Functional Flow



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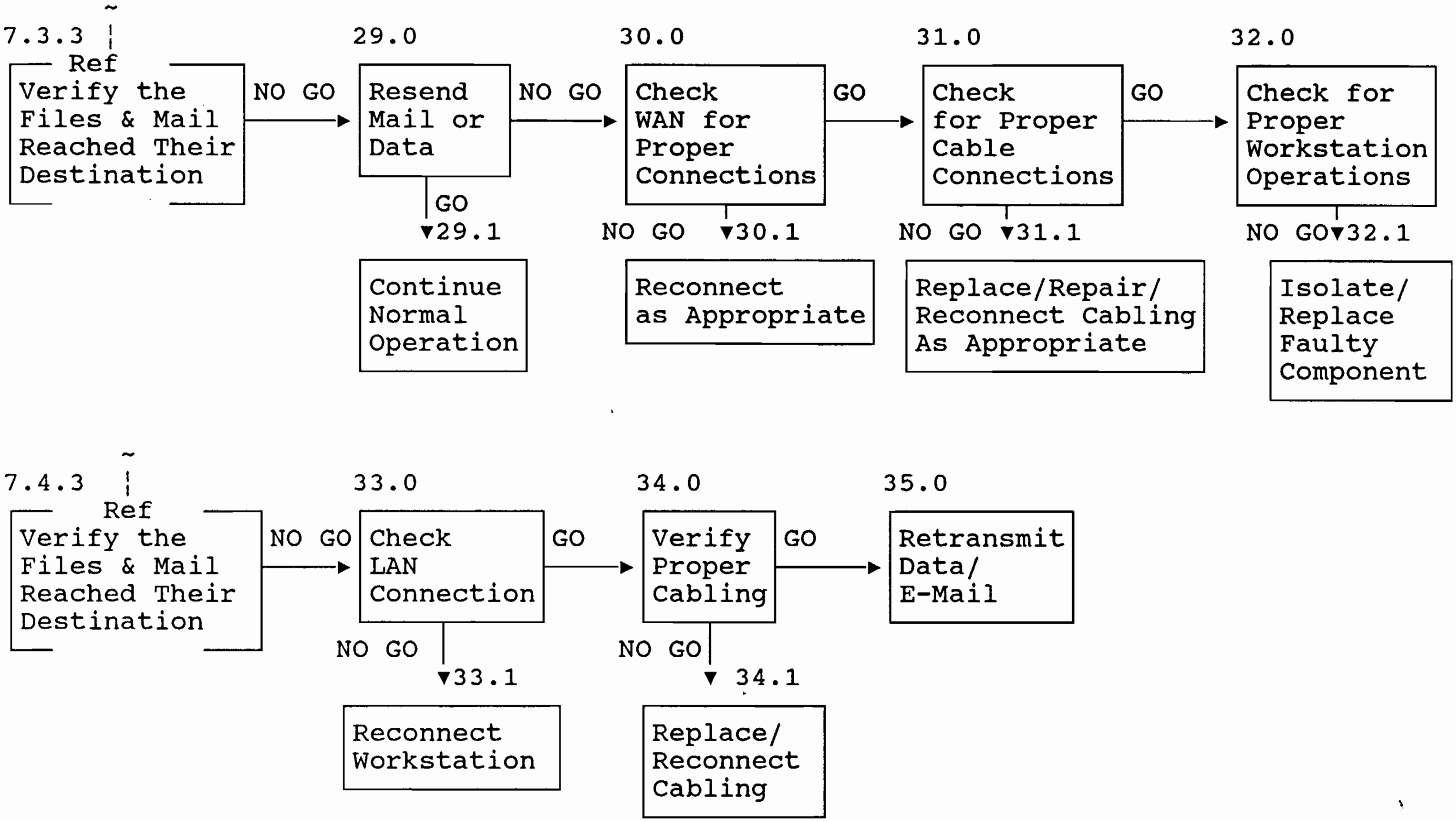

VITA

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