# NAVAL POSTGRADUATE SCHOOL
## Monterey, California

# THESIS

ANALYSIS AND DESIGN OF A LOCAL AREA NETWORK
INFORMATION SUPPORT SYSTEM FOR THE
MARINE CORPS AIR STATION, YUMA, ARIZONA

By

Samuel L. Jordan

March 1988

Thesis Advisor:                                    J.B. Isett

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This thesis provides an analysis of the organizational information system of the Marine Corps Air Station, Yuma, Arizona. A discussion of academic theory concerning structured systems analysis and design, local area network communications standards, and the characteristics of a local area network provide the theoretical foundation for the analysis and design of a local area network information support system for the Air Station. A survey was conducted to identify the problems and the functional requirements. Based upon this analysis, a local area network information support system is presented as a technologically viable alternative to the current information system. Implementation issues are presented as well as an implementation strategy which can be used to manage the change process. A cost-benefit analysis is presented to demonstrate the economic feasibility of the proposed local area network information support system. Finally, recommendations are presented for the Air Station's Local Area Network committee.

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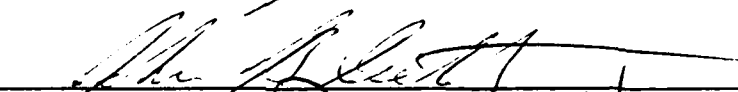
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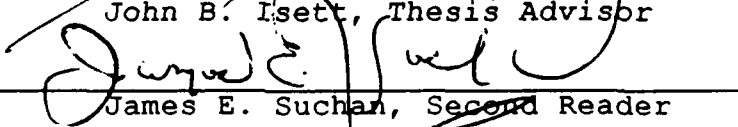
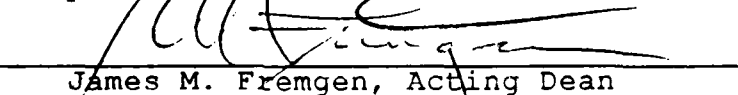NAVAL POSTGRADUATE SCHOOL
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Author: _____
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Approved by: _____
John B. Isett, Thesis Advisor

_____
James E. Suchan, Second Reader

_____
David R. Whipple, Chairman,
Department of Administrative Sciences

_____
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# ABSTRACT

This thesis provides an analysis of the organizational information system of the Marine Corps Air Station, Yuma, Arizona. A discussion of academic theory concerning structured systems analysis and design, local area network communications standards, and the characteristics of a local area network provide the theoretical foundation for the analysis and design of a local area network information support system for the Air Station. A survey was conducted to identify the problems and the functional requirements. Based upon this analysis, a local area network information support system is presented as a technologically viable alternative to the current information system. Implementation issues are presented as well as an implementation strategy which can be used to manage the change process. A cost-benefit analysis is presented to demonstrate the economic feasibility of the proposed local area network information support system. Finally, recommendations are presented for the Air Station's Local Area Network committee.

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# I. INTRODUCTION

## A. CONCEPT

> Businesses and non-business organizations have been
> obliged to adapt more rapidly to a changing environment,
> not only in order to innovate but even to survive.  To do
> this these organizations have increased their investment in
> scientific research, market research, and in computers
> --i.e., in the creation, acquisition and, manipulation of
> information. (Flint 1983:19)

Similarly, the rate of acquisition of microcomputers in
the Marine Corps has grown dramatically in recent years.  The
Marine Corps Air Station at Yuma, Arizona is no exception.
Just two years ago there were fewer than ten microcomputers
in use.  In 1987 alone, approximately one hundred microcom-
puters have been requisitioned and new requests for
microcomputers continue to arrive almost daily.

Requests for local area network capability and informa-
tion concerning other organizations that have implemented
local area networks became the driving factor behind the
establishment of an Ad-hoc Local Area Network committee for
the Air Station (Hedloff 1987).  In response to the
committee's request, this study was undertaken.

Through the synthesis of theory from several disciplines
such as systems analysis and design as well as management and
data communications, this thesis analyzes Yuma's communica-
tion and information requirements.  Based on this analysis,

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a local area network design is developed and an implementation strategy is presented as a feasible alternative to the current organizational information system.

## B. PURPOSE

The primary purpose of this thesis is the application of academic theory to analyze the feasibility of a local area network (LAN) to meet the communication and information needs of the Marine Corps Air Station, Yuma, Arizona. Integrated with the application of academic theory is the development of a network design and implementation strategy which is presented as an alternative to the current organizational information system.

## C. SCOPE

There are several topics closely associated with the development of an automated information system. For example, topics range from the design of distributed databases to security to network management and control. Specific questions concerning these topics include:

1. How are distributed database requirements effectively developed?

2. What are effective security precautions and measures for data and how can they be implemented?

3. What are effective network security measures and how should they be implemented?

4. What is the role of the network administrator in relation to the management and control of the network?

Additionally, the impact of the implementation of such a network upon the current formal and informal communication networks and organizational structures presents a unique opportunity for organizational theorists. The need for the development of specific applications for use within the network are also areas of concern for many of the individual staff officers and may well present further areas of research in software engineering and life cycle management. These and other issues are certainly a concern regarding the implementation of a local area network; however, they are beyond the scope of this thesis.

In defining the scope of this study certain limitations are imposed. These limitations are the result of discussions with the Ad-hoc Local Area Network committee. The first limiting factor is that the implementation of a local area network aboard the Air Station is solely a garrison information system; that is, it is not considered in the light of any possible deployment (tactical employment) of the Air Station. Secondly, the analysis and design is confined to unclassified data traffic. The security of classified material is strictly governed by Department of the Defense, Secretary of the Navy and U. S. Marine Corps instructions. Future requirements for the capability to handle classified material over the network will require further analysis to ensure that the network complies with those directives.

Thus, the central focus of this research is the definition of the functional requirements for a local area network as determined by an analysis of the current information system, the subsequent design of a local area network, and the implementation strategy to meet those needs.

## D. METHODOLOGY

The methodology used in this study consisted of the development of a survey, based upon academic theory, to determine information and communication needs. The survey also captured personal attitudes and opinions concerning the automation of office work and the perceived usefulness of a local area network. Statistical analysis of the data obtained from the survey is performed. The inferences from this analysis provided insight into the tangible and intangible benefits that can be derived from the implementation of a local area network.

Additionally, key individuals in the organizational structure were personally interviewed to supplement the survey and to provide insight into the current information system. A review of current literature and of Marine Corps policy and guidance concerning local area networks and the Marine Corps Life Cycle Management for Automated Information Systems (LCM-AIS) was completed to ensure a solid foundation was established. This foundation allows the combination of

thought from several different perspectives, particularly

current academic research, corporate experience, and

government policy and directives.

## E. ORGANIZATION

The next chapter provides the theoretical framework and

methodological background on the facets of structured systems

analysis and design, data communications, and computer

network analysis and design, with a particular emphasis on

the theory applicable to the design of local area networks.

Chapter III begins with a study of the existing system.

Also, an overview of the business and information system

environments is presented. Information requirements are

identified and discussed in terms of current capability,

current needs, and the future requirements. Inferences from

the statistical analysis of the survey are presented to

validate the information requirements and to identify

tangible benefits to be realized through the implementation

of a local area network.

Chapter IV presents the Marine Corps Air Station, Yuma

local area network design. The chapter continues with a

description of the benefits obtainable from the implementa-

tion of a local area network. A discussion of the implemen-

tation issues for management and a cost-benefit analysis is

presented to demonstrate the economic feasibility of the

network.

Chapter V presents conclusions derived from this
research. Recommendations are presented for consideration by
the Air Station's Ad-hoc Local Area Network committee as an
aid in the decision-making process. Recommendations concern-
ing areas of further research are presented as well to
stimulate interest and thought for both the academician and
the practicing systems analyst.

## II.  SYNTHESIS OF THEORY

### A.  INTRODUCTION

In recent years there has been a dramatic fall in the
cost of hardware processors and memory, combined with
similar cost reductions and technological advances in the
communications field.  The result has been to make computer
networks and interconnected computer systems a viable and
cost-effective solution in many environments.  Users have
recognized the advantages of interconnecting what were
independent computer systems to permit interaction,
cooperation and sharing of facilities.  (Sloman and
Kramer 1987:1)

Davis says that systems analysis and design is "...a
relatively new profession; its methodology is still
evolving." (Davis 1983:8)  In the 1950s, 1960s and the early
1970s computer based systems were developed and managed by
technical computer specialists. With advances in technology,
hardware now plays a smaller role in the development of
computer systems while software development and the applica-
tion of computer resources has become the central focus
(Pressman 1987:1-5).

However, as the emphasis has shifted from hardware to
software and beyond to distributed systems and system
integration, the computer systems manager and the systems
analyst have been required to expand their areas of expertise
to include general management, organizational development,
data communications, information theory, and systems analysis
and design.

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In addition to the technological advances, the view of information as a strategic resource and the expanded role of information technology has led to an expanded role for the information systems manager (Davis and Olson 1985:630).

The Nolan stage theory offers one explanation for the shift in emphasis from the management of computer resources to that of the management of organizational information resources (Davis and Olson 1985:450-455). In the early growth stages the emphasis is placed upon encouraging the use of computer resources. As the organization matures, controls, standards and centralization occur to contain unplanned expansion and to ensure that there are cost-effective criteria established. At maturity, there is an alignment between the information system structure and the organizational structure. The emphasis is placed upon data integrity and the management of the information resources. Also, technological developments have enabled the information systems manager to focus on information resources management "...technologies which in the past could be managed separately are now highly interdependent and should be the responsibility of a single organizational authority." Functional components of the information resources management are shown in Figure 2.1. (Davis and Olson 1985:630-633)

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Computer Operations
Application Development
Technical Services
Processing
Corporate Database
Data Communications
Telecommunications
Voice Communications
Local Area Networks
External Data Services
Office Automation
Word Processing
Intelligent Workstations
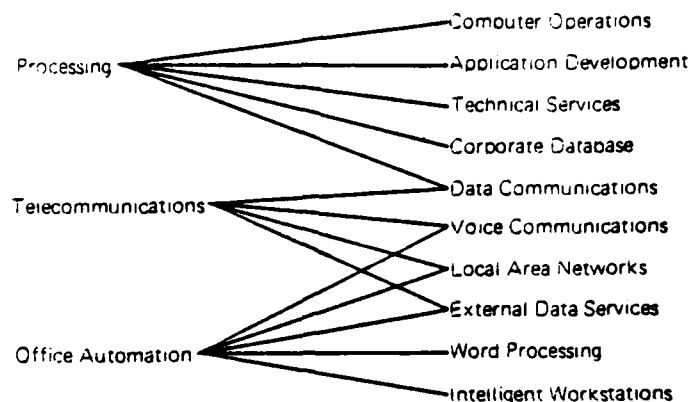
Figure 2.1 Functional components of information
resources management
(Source: Davis and Olson 1985:633)

## B.  STRUCTURED SYSTEMS ANALYSIS AND DESIGN

### 1.  The Management Information System Concept

In 1513 Machiavelli observed:  "There is nothing more
difficult to plan, more doubtful of success, nor more
dangerous to manage than the creation of a new system.
For the initiator has the enmity of all who would profit by
the preservation of the old system and merely lukewarm
defenders in those who would gain by the new one."  (Biggs,
Birks and  Atkins 1980:1)

Although technology has made great strides,

Machiavelli's words continue to hold true for the systems

developer today (Biggs, Birks and Atkins 1980:1).

But what is a system?  There are many different kinds

of systems, such as an educational system, a nervous system,

an ecological system, a computer based system, and a manage-

ment information system.  Some concept of the system is

connoted by the adjective used to describe each of these

systems.  Brabb defines a computer based system as "...a

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combination of elements, their attributes, and their interrelationships, organized in the pursuit of a common objective." (Brabb 1980:38) The American National Standards Committee defines a computer based system as "...a collection of men, machines, and methods organized to accomplish a set of specific functions." (Davis 1983:4) And Pressman defines a computer based system as: "A set or arrangement of elements organized to accomplish some method, procedure, or control by processing information." (Pressman 1987:33) Figure 2.2 depicts the elements of a computer based system. While there is not a single, all-encompassing definition of a computer based system, certain characteristics are common in the definitions presented. Thus, computer based systems are comprised of integrated elements utilizing procedures to accomplish a specific task or function.

The management information system concept provides a framework for organizing the elements of the individual computer based systems used within an organization. Davis and Olson define a management information system (MIS) as

> an integrated, user-machine system for providing information to support operations, management, analysis and decision-making functions in an organization. The system utilizes computer hardware and software; manual procedures; models for analysis, planning, control and decision making; and a database. (Davis and Olson 1985:6)

Conceptually, an MIS can be thought of as a pyramid structure (Figure 2.3), developed to support the primary functions of each level of the organization and management.
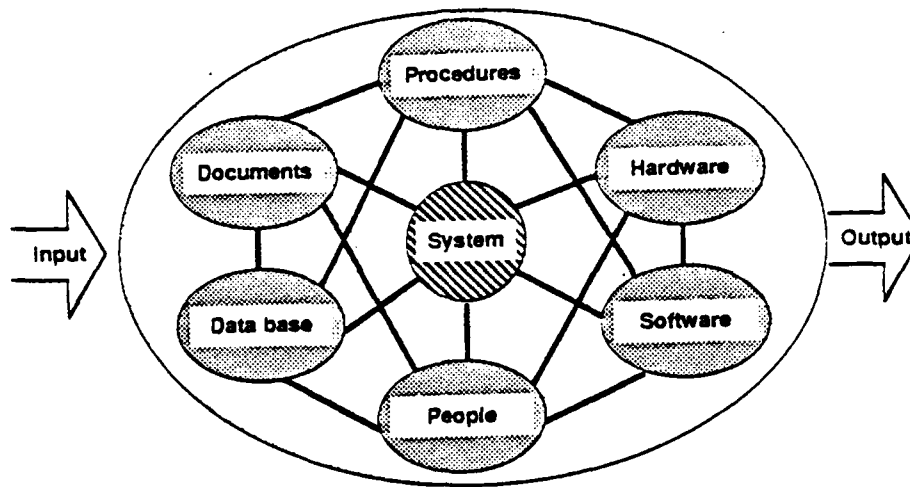
Figure 2.2 Elements of a computer based system
(Source:   Pressman 1987:33)

An organization is comprised of functional subsystems
(Davis and Olson 1985:332); similarly, the MIS should be
viewed "as a federation of functional subsystems" rather than
a single, monolithic structure (Davis and Olson 1985:45).
The functional subsystems require information processing at
each level of the pyramid, i.e., transaction processing,
operational control, management control, and strategic
planning.  Within each functional subsystem there are
applications that are unique to that subsystem.  However,
there will be applications and data which need to be avail-
able across subsystem boundaries.  Thus, the MIS can be
described as unique functional subsystem applications with
unique data requirements combined with common applications

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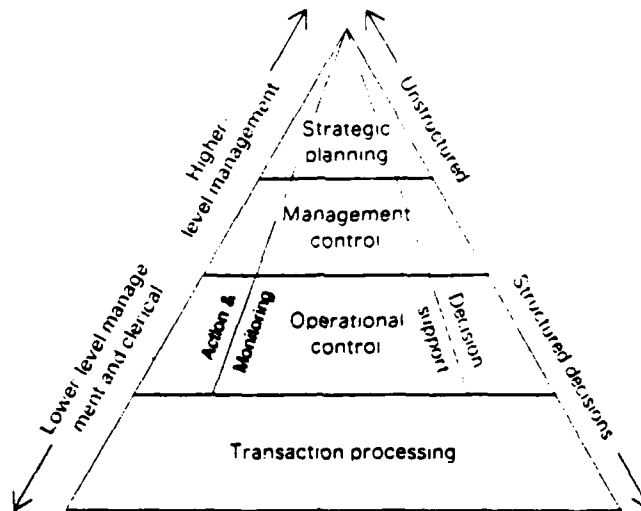
Figure 2.3   The MIS as a pyramid
(Source: Davis and Olson 1985:48)

and data across subsystem boundaries.   The combination of the
functional subsystems into the organizational management
information system is depicted in Figure 2.4.   (Davis and
Olson 1985:41-54)

Thus, the technological advances and the associated
cost reductions in the computer and communication fields
enable the MIS structure to mirror the organizational
structure and, with proper design, to effectively and
efficiently support the goals of the organization.

## 2.   The System Life Cycle Defined

The analysis and design of computer based systems is
married to the system life cycle.   There are various models
of the system life cycle in the literature.   There are
differences in the names and the description of each stage or

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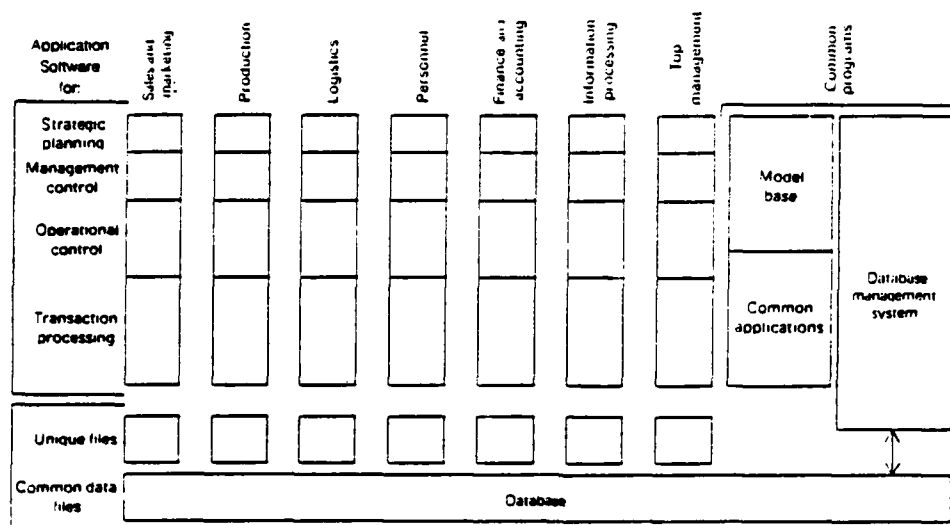
Figure 2.4 The Organizational MIS
(Source: Davis and Olson 1985:46)

phase of the system life cycle depending upon the author's
point of view. For example, Pressman presents three phases
(Pressman 1987:27) while Biggs, Birks and Atkins identify
four phases in the system life cycle (Biggs, Birks and Atkins
1980:45). Similarly, the Marine Corps Life Cycle Management
for Automated Information Systems defines four phases in the
system life cycle (Marine Corps Order P5231.1).

Regardless of the number of phases, the names or the
descriptions presented, there is general agreement on the
logical sequence of actions involved in the systems develop-
ment process. The system life cycle model, also referred to
as the "classical or waterfall model", is used in this
research. The steps in the system life cycle are depicted in
Figure 2.5. The system life cycle paradigm "...demands a

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systematic, sequential approach" (Pressman 1987:20), "...pro-

gressing from step to step in a careful, methodical fashion,

completing a number of well defined exit criteria." (Davis

1983:8) Each step in the system life cycle will be

discussed briefly.

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**Problem definition**

**Feasibility study**

**Analysis**

**System design**

**Detailed design**

**Implementation**

**Maintenance**
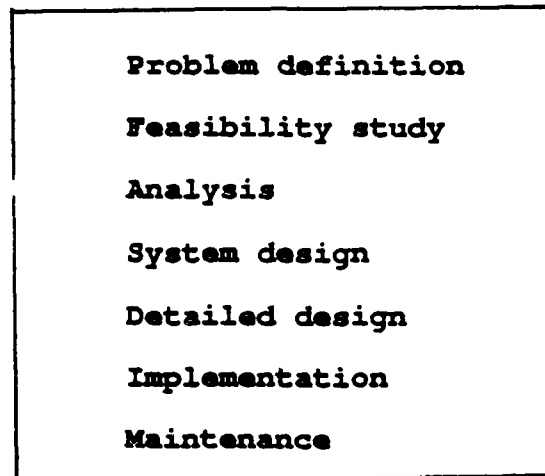
Figure 2.5 Steps in the System Life Cycle
(Source: Davis 1983:8)

### a. Problem Definition

Problem definition begins when the user (e.g.,

clerical personnel, the manager or the executive) perceives

dissatisfaction with the current methods of conducting

business. This is often highlighted by variances from

standards or established measures, such as processing time

(turnaround time), or it can occur with the introduction of

new technology, such as the personal computer. For example,

the user may define the following problem:

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"Here at Albert Ross Marine Insurance, we've increased
our staff by 43 percent in the past two years.  We've also
doubled our policy range and have increased our business by
more than 100 percent.  The cost for all of the extra
clerks and policy supervisors we've taken on is becoming
exorbitant.  I think we need a computer...."
(Page-Jones 1980:23)

Although problem definition is a logical and
intuitive starting place in the systems analysis and design
process, it is often overlooked or misunderstood (Davis
1983:8).  The systems analyst must define the problem in
concert with the user and management.  The user often
describes symptoms and possible solutions to a problem rather
than the actual problem.  In the example, the user has
implied that the workload and the cost of doing business has
increased dramatically due to an expansion of the business;
however, the problem is defined in terms of a possible
solution, that is, "We don't have a computer, I think we need
one."

After the initial investigation into the problem,
the analyst prepares a statement of the scope of the problem
and the objectives.  This written document is reviewed with
the user, management and the analyst to ensure that the
analyst understands the problem and that the scope of the
analysis has been properly defined and agreed upon by all.
If not, the analyst will continue the investigation until the
errors or misunderstandings have been corrected.  (Fitzgerald
and Fitzgerald 1973:54-57; Davis 1983:9)

The statement of scope and objectives is the exit criteria for the problem definition phase. It provides a clear understanding of the problem that is agreed upon by the user, management and the analyst. It provides management with a go/no-go decision point for continuing the analysis and design process. (Davis 1983:8-9)

### b. Feasibility Study

The feasibility study determines whether the problem can be solved, technically, economically and operationally. Its purpose is to:

- Plan the system's project development and implementation activities.

- Estimate the probable elapsed time, staffing, and equipment requirements.

- Identify the probable costs and consequences of investing in the new system. (Biggs, Birks and Atkins 1980:61)

Davis describes the feasibility study as "a high-level capsule version of the entire systems analysis and design process." (Davis 1983:30)

Using the statement of scope and objectives as input to the feasibility study, the analyst refines the problem definition, narrows the scope of the system and defines the system boundaries and objectives. (Page-Jones 1980:24)

During the feasibility study, the analyst studies the existing system and develops a high level model of the system. Based upon the analyst's understanding of the system, alternative solutions to the problem are developed.

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As the analyst develops possible solutions, the initial
concern is with technical feasibility.  (Davis 1983:31-35)

Technical feasibility considers the technology
that is available to apply to the problem.  Can the problem
be solved with the current state of technology?  Non-existent
technology, whether it is hardware, software, or procedures
cannot be applied to a problem and thus quickly rules out the
solution as an alternative.  (Davis 1983:38-39)

After a technically feasible alternative solution
has been found, the analyst must determine operational
feasibility.  Operational feasibility, often referred to as
political feasibility, asks, "Can we do it here?"  Does the
technically feasible solution fit the organization?  If the
solution requires major organizational change or restructur-
ing or major changes in management policy and philosophy, and
unless these organizational or management changes have been
considered and planned for in consonance with the new system,
then it may not be operationally feasible.  (Davis 1983:39)

Given unlimited resources, all solutions are
economically feasible.  However, resources maybe scarce and,
at any one time, there maybe many projects competing for
those resources.  The costs of the new system must be weighed
carefully against the benefits associated with its implemen-
tation.  The analyst must perform cost/benefit analyses for
the alternative solutions that are technically and

operationally feasible. (Biggs, Birks and Atkins 1980:71-73;
Davis 1983:39)

Once the analyst has developed feasible solutions
to the problem, the analyst presents the feasibility study to
management and the user with a recommended course of action,
the cost/benefit analysis, and a rough implementation plan.
The feasibility study report is the exit criteria for the
feasibility study phase. It presents management with a
go/no-go decision point on whether to continue with the
analysis phase, prioritize the project, or terminate the
project. (Davis 1983:274-279; Biggs, Birks and Atkins
1980:73-74)

c. **Analysis**

If management accepts the findings presented in
the feasibility study, the system life cycle proceeds to the
analysis step. The feasibility study is the primary source
document for the analysis. In contrast to the general
overview presented during the feasibility study, this step
provides an in-depth, detailed analysis of the system.

The objective of the analysis is to develop a
logical model of the system. Using structured analysis
techniques and tools, the analyst studies and documents the
functions and processes of the system. Gane and Sarson
present an excellent examination of the structured analysis
and design methodology and of the tools available to the

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analyst (Gane and Sarson 1979). The tools of structured analysis include data flow diagrams, data dictionaries, and algorithm descriptions.

Data flow diagrams provide a graphic representation of the physical and logical models developed by the analyst. A large, complex system is difficult to understand when considered as a whole. Thus, the data flow diagram is used to partition or decompose the system into subsystems. This decomposition process is used both in the analysis of the existing system and in the development of the new, logical system. (Page-Jones 1980:59; Yourdon 1986:37)

The data dictionary "is an organized collection of logical definitions of all data names that are shown on the data flow diagram." (Yourdon 1986:39) The data dictionary is the repository for information about the data, the inputs and outputs to a process. It contains the definition and use of each data element (atomical form) in an organization. The combination of data elements defines the structure of the data depicted on the data flow diagram (Gane and Sarson 1979:50). Using the data dictionary, the analyst can ensure that data which is used across functional boundaries is consistent.

The description of algorithms is used to understand each function or process within the system study. This description, also called process specification, identifies the way data is transformed during the process and the policy

which governs that transformation (Page-Jones 1980:79). The process specification may be expressed by structured English, decision tables, or decision trees. The purpose of the process specification is to define what must be done in clear, concise, unambiguous terms that the user and management will understand. (Page-Jones 1980:80; Yourdon 1986:40-42)

After the analyst has completed the logical model of the system together with the data dictionary and the process specifications, the model is reviewed by the user and management to ensure that the model reflects the problem. Upon acceptance by the user and management, the system life cycle progresses to the system design step.

### d. System Design

The system design process begins the translation of the functional requirements identified during analysis into working components of the new system. The analyst begins to move from the logical model to the physical (Davis 1983:11).

During system design the analyst develops alternative solutions based upon the detailed analysis. Solutions may vary from improved or alternative manual procedures to implementation of a totally automated system or some combination of both. The analyst attempts to define in general terms how the problem can be solved.

With the information from the detailed analysis, the analyst can refine the resources required as well as a

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tentative implementation schedule. Based on this refined information, the analyst can prepare more accurate cost/benefit analyses for each solution.

The results of the system design step are presented to management and the user. Thus, it provides management with another go/no-go decision point in the system life cycle. A decision by management or the user that the costs of the new system outweigh the expected benefits will result in ending the project. If the project provides the requisite benefits, one alternative will be selected as the high level design which will be used in the detailed design step. (Davis 1983:12)

### e. Detailed Design

The purpose of detailed design is to define each component of the system to the level of detail required for the implementation step (Davis 1983:14). Using the alternative selected in the system design phase, everything except the code is developed (Page-Jones 1980:25). Implementation specifications are developed using structured techniques. These include the development of structure charts, input/process/output charts as well as detailed process specifications. If new hardware is to be implemented, the detailed hardware specifications are developed during this step.

Davis says that "the specifications developed during detailed design are analogous to the engineer's

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blueprints." (Davis 1983:14)  Based on these blueprints, the analyst can begin developing the system test plan and refining the implementation schedule and the cost estimates. The detailed design is verified using formal inspections or walkthroughs.  Errors can be corrected before the detailed design enters the implementation step.  (Davis 1983:255-264; Yourdon 1986:171-185; Page-Jones 1980:294-298)

### f.  Implementation

During the implementation step, the detailed design is used to develop the software programs, new operating procedures, security procedures, system documentation as well as detailed test plans and test programs.

Testing occurs throughout the implementation step beginning with unit or module testing, subsystems testing and continuing to the system test.  Once the system test (often referred to as acceptance testing) is complete, the system enters the final step in the system life cycle.

### g.  Maintenance

The maintenance step encompasses everything associated with the system after it is implemented, such as correcting latent errors that were not discovered during testing, software modification to meet changing requirements as well as enhancements and expansions of the system. Pressman divides the maintenance activities into four categories (Pressman 1987:526-527).  The first is corrective

maintenance. This involves the detection and correction of latent errors. The second category, termed adaptive maintenance, occurs because of changes in the environment, either external or internal. New technology, changes in government regulations, or the addition of a new product line are examples of such changes. The third category is termed perfective maintenance which occurs when users suggest enhancements or modifications to a correctly working program. The fourth maintenance activity, called preventive maintenance, is primarily cosmetic maintenance performed to provide for future benefits in maintenance or reliability.

A system will remain in the maintenance step until the user or management determines that a problem exists, thus beginning the system life cycle process anew.

## 3. The Systems Development Process

The analyst gathers information about the system by collecting and analyzing documents, conducting background research, conducting surveys (sampling) and by conducting interviews. The analyst's primary tool for gathering that information is the personal interview. (Fitzgerald and Fitzgerald 1973:102; Biggs, Birks and Atkins 1980:53-54; Davis 1983:268)

Using the structured systems analysis and design methodology, the analyst employs "a step-by-step approach to system development...." (Davis 1983:8) This methodology implies a "once through" or "straight line" approach to

system development (Figure 2.6). This linear process follows from the assumptions that the analyst, in conjunction with the users and management, can accurately define the problem and the requirements for the new system upfront during the initial steps in the system life cycle (Pressman 1987:21).
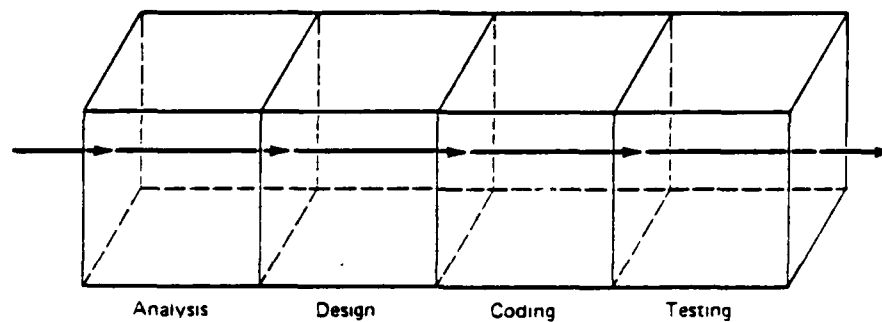


Figure 2.6 The straight line approach to
systems analysis and design
(Source: Gane and Sarson 1979:224)

In reality, systems development rarely follows this sequential approach. The system development process requires an iterative approach because users often define problems in terms of symptoms and solutions, because it is difficult to state all of the system requirements accurately during the early stages of the system development process and because of errors and misunderstandings and miscommunications between the users and the analyst (Pressman 1987:21-22; Gane and Sarson 1979:224-225).

This iterative approach (Figure 2.7) is implemented in the structured analysis and design process through the use

of specific exit criteria at the completion of each step in the system life cycle. The exit criteria, developed by the analyst, is reviewed by both the users and management. This allows the users and management to provide feedback to the analyst to correct errors and misunderstandings, returning to previous steps if necessary and thereby reducing the risk of crucial errors late in the system life cycle or the implementation of a bad system simply because the money has already been spent. At the same time, management is given go/no-go decision points at each step in the development process. This enables management to review each decision to proceed with the development process, to prioritize projects in relation to the business and information systems plan, and to minimize the costs of the development process should management decide to terminate the project. (Gane and Sarson 1979; Page-Jones 1980; Davis 1983)

Thus, while problems exist with the structured systems analysis and design methodology, it does provide the analyst with a set of tools and techniques to use in translating the user's requirements into logical and physical system designs. The iterative nature of the system development process is captured and enhanced during the review of the exit criteria. By defining specific exit criteria, management can exercise greater control over the systems development process.
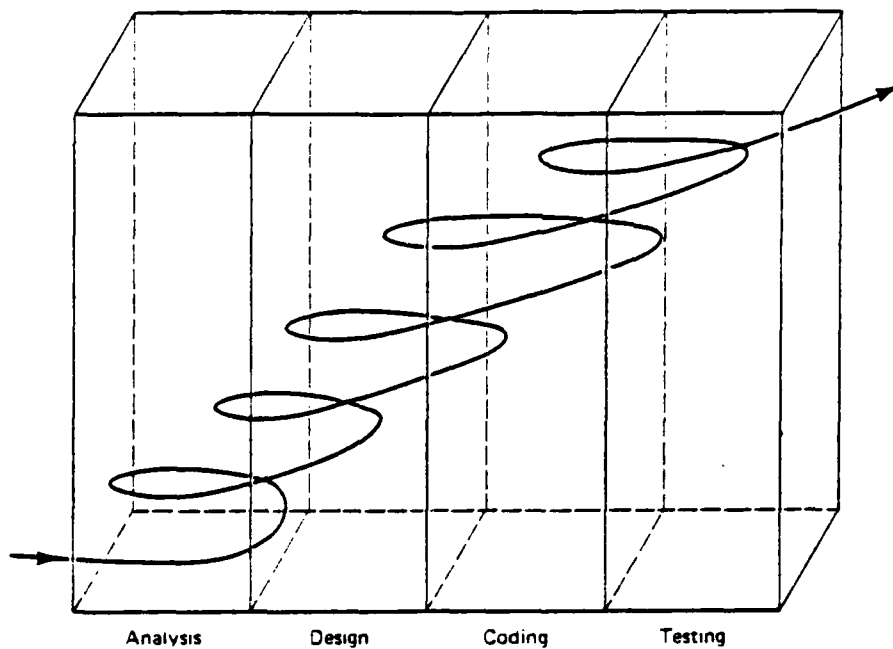
Figure 2.7 The iterative approach to systems
analysis and design
(Source: Gane and Sarson 1979:225)


The management information systems concept and the
structured systems analysis and design provide the systems
analyst with theoretical foundations and methodological
approaches to the systems development process. However, the
systems development process is only one of the functional
components of information resources management as discussed
in Section A of this chapter.

Another functional component is telecommunications.
This includes voice and data communications and local area
networks. The merging of computer and telecommunications

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technologies makes it imperative that the systems analyst has a working knowledge of computer and data communications.

## C.  LOCAL AREA NETWORK COMMUNICATIONS

### 1.  Defining a Local Area Network (LAN)

Numerous definitions of a local area network exist in the literature and in the industry.  Although there is little agreement upon a particular definition, the concept of a local area network does clearly emerge.

One of the earliest efforts to develop a generally accepted definition of a local area network was done by Thurber and Freeman.  They define a local area network in terms of the following properties:

1.  They are owned by a single organization.

2.  They are geographically limited; that is, a local network's backbone spans a distance on the order of only a few miles.

3.  They contain some type of switching technology.

4.  Their transmission rates are usually faster than those of networks covering a broad geographic area. (Thurber and Freeman 1982:222)

Tanenbaum defines a local area network in terms of "a diameter of not more than a few kilometers, a total data rate exceeding 1Mbps, and ownership by a single organization." (Tanenbaum 1981:286)  Similarly, Durr defines the local area network as "a communications system that covers relatively short distances and operates at 1 to 10 megabits per second." (Durr 1987:4)  The U. S. Marine Corps has defined local area

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networks as "user-acquired networks to be utilized within the confines of an office space, building or closely clustered buildings, owned, operated and maintained by the using organization." (U.S. Marine Corps 5239-05:1-5)

These definitions, while not exhaustive, show how they have evolved over time. While there has not been a substantial change in the underlying philosophy concerning the definition of a local area network, there has been an attempt to more precisely define a local area network to differentiate it from wide area and computer networks.

These definitions have certain characteristics in common; sole proprietorship, limited geographic area, and a communication system. Single proprietorship differentiates the local area network from the wide area network where many of the components of the network are owned by different organizations. Because much of the technology applied to local area networks evolved from the wide area and computer network industry, the limited geographic area is similarly imposed to distinguish the local area network from the wide area network (Cheong and Hirschheim 1983:4). The communication system provides for the interconnection of data communicating equipment; autonomous, intelligent devices, such as two or more computers, neither capable of controlling the other, as opposed to a master-slave relationship typical of the mainframe or large computer system with remote terminals, printers or other peripheral (Tanenbaum 1981:2).

Thus, while there is not a universally accepted definition of a local area network, there is general agreement on the concept of a local area network as evidenced by the common characteristics.

2. **The International Standards Organization Reference Model for Open Systems Interconnection**

A central issue in the development of a local area network is that of the communication system. In the early days of computer communications, the concern was only for the interconnection of homogeneous computers. Specialized hardware and software was developed to meet these needs. As new requirements evolved, "a one-at-a-time special-purpose approach" was used to develop communications software. With advances in technology, the communications problem grew as users now wanted to connect heterogeneous devices. (Halsall 1985:135; Stallings 1988:389-390)

These special purpose communications software packages did "...not address the problem of universal interconnectability--open systems interconnection...." (Halsall 1985:136). In the late 1970s, the International Standards Organization (ISO) developed a reference model "to provide a common basis for the coordination of standards development for the purpose of systems interconnection." The results of the work of the ISO is known as the ISO Reference Model for Open Systems Interconnection (OSI). The reference model provides the logical framework for the interconnection of heterogeneous computers. The ISO model is

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not an implementation specification. Rather, it provides the logical and functional framework for the development of protocol specifications. The ISO model uses a layering structure. The seven layers of the ISO model are shown in Figure 2.8. (Sloman and Kramer 1987:28; Halsall 1985:136-137; Stallings 1988:389-390)

As shown in Figure 2.8, the ISO model provides for communications between similar layers of the two systems. Thus, Layer 7 establishes a communication path using an application protocol, with its peer, the other Layer 7. This is defined as the logical peer-to-peer communications. Note that while the Application Layer appears to establish horizontal communications directly with its peer, the actual physical communication flow is implemented vertically. Thus, the Application Layer establishes communication with its peer by requesting Presentation Layer services, through the interface between the layers, continuing down the layers of the model to the Physical Layer. Only at the Physical Layer, through the physical medium, is communication established horizontally. The model does not require that the two systems be directly connected at the physical layer. (Mayne 1986:159; Stallings 1988:391-393)

The layering structure in the ISO model provides for the division of communication process functions. Each layer is tasked with a well-defined set of services that it must provide to the layer above it. Each layer communicates with

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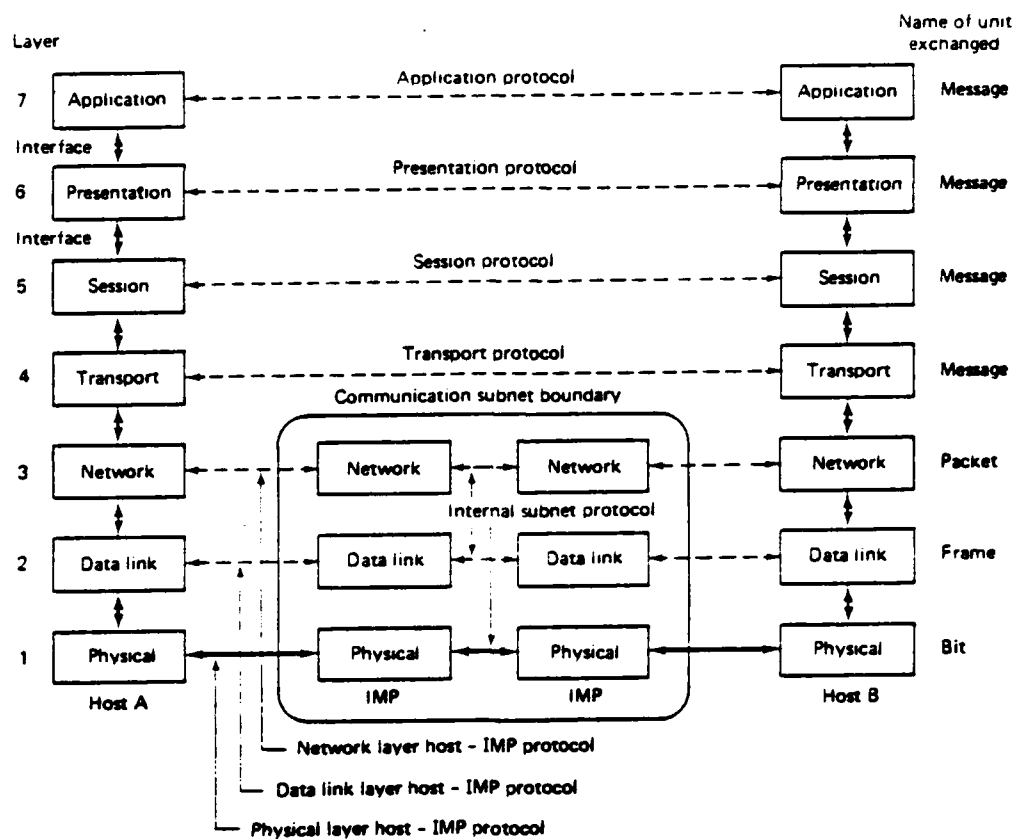
Figure 2.8 The ISO Reference Model for OSI
(Source: Tanenbaum 1981:16)

the layers above and below it through an interface, a service

access point (Stallings 1988:394). Layers 5-7 are generally

referred to as the higher layers. Occasionally, Layer 4 is

included in the higher layers. The higher layer protocols

are normally developed independent of the underlying data

communications facility. The primary focus at this level is

to provide end-to-end services to allow heterogeneous

computers to interact. (Stallings 1988:397)

Layers 1-3 then are the network dependent layers. These layers are concerned with the details of the communications protocols and the data communications network used to link the computers. Layer 4, the Transport Layer, is the go-between. It is often considered as the boundary between the application oriented layers and the communication oriented layers (Sloman and Kramer 1987:30). It masks the higher level protocols from the detailed intricacies of the network dependent layers (Halsall 1985:137).

The **Application Layer**, Layer 7, is the highest layer in the model. The Application Layer is concerned with providing network services to user processes. It provides a means for application processes to access the OSI environment. Examples of Application Layer services include file transfers and electronic mail. (Halsall 1985:137-138; Stallings 1988:398)

Layer 6, the **Presentation Layer** is concerned with the representation of data between the Application Layers. It resolves differences in the way information is represented between two application layers through data transformation. For example, one application uses the American Standards Committee for Information Interchange (ASCII) character set while the other application uses the Extended Binary Coded Decimal Interchange Code (EBCDIC) character set. The Presentation Layer must convert one to the other at each end

before passing the information up to the application layer.
(Halsall 1985:139)

Another function performed by the Presentation Layer
is that of data security.  The Presentation Layer provides
encryption/decryption operations (Halsall 1985:139).

The **Session Layer's** (Layer 5) primary function is to
define the logical user interface with the Transport Layer.
It is the communication manager, responsible for establishing
and maintaining communication paths or channels between two
communicating application processes and for controlling the
dialogue (Halsall 1985:139; Stallings 1988:398).  The Session
Layer provides for the mapping of device names (such as hosts
or printers) to network addresses so that applications can
use names to communicate with the devices (Durr 1987:26).
This allows for the logical representation of the devices
rather than requiring the application to know the actual
physical location or address of the device.

The purpose of the **Transport Layer**, Layer 4, is to
provide reliable and transparent service to the Session Layer
independent of the underlying network type.  This includes
end-to-end error recovery and flow control.  The Transport
Layer defines network addressing and provides for the
management of the logical connections.  (Halsall 1985:140;
Durr 1987:26)

Layer 3, the **Network Layer**, provides for the trans-
parent transfer of data between transport layers.  The

Network Layer includes such functions as routing, switching and network management. It may include some error, flow and sequence control in the transfer of data. The Network Layer performs physical addressing functions compared to the logical addressing performed by the Transport Layer. (Sloman and Kramer 1987:30-31; Stallings 1988:396-397)

The primary service provided by Layer 2, the **Data-link Layer**, is that of error detection and correction. The Data-link layer receives the outgoing message from the Network Layer. The Data-link layer breaks the information frame into packets or blocks for delivery to the Physical Layer. On the receiving end, the Data-link Layer receives the raw bit stream from the Physical Layer, performs packet assembly as well as error detection and, if possible, error correction. If the Data-link Layer can not correct the error, it is responsible for requesting retransmission of the corrupted frames. Thus, the requirement for a local area network to provide relatively error free, reliable service is implemented at the Data-link Layer, although higher layers are still responsible for error control. (Halsall 1985:140; Stallings 1988:396; Hammond and O'Reilly 1986:353)

The lowest layer, Layer 1 in the ISO model, is the **Physical Layer**. The Physical Layer, as the name implies, is concerned with the transmission of the bit streams over the physical connection. It also defines the rules and the protocols for the mechanical, electrical and functional

interfaces between data communications equipment. (Halsall 1985:140; Stallings 1988:396)

Table I presents a summary of the functions and the purpose of each layer in the ISO model.

## TABLE I

## THE ISO REFERENCE MODEL FOR OSI

| | |
|---|---|
| 1. Physical | Concerned with transmission of unstructured bit stream over physical medium; deals with the mechanical, electrical, functional, and procedural characteristics to access the physical medium |
| 2. Data link | Provides for the reliable transfer of information across the physical link; sends blocks of data (frames) with the necessary synchronization, error control, and flow control |
| 3. Network | Provides upper layers with independence from the data transmission and switching technologies used to connect systems; responsible for establishing, maintaining, and terminating connections |
| 4. Transport | Provides reliable, transparent transfer of data between end points; provides end-to-end error recovery and flow control |
| 5. Session | Provides the control structure for communication between applications; establishes, manages, and terminates connections (sessions) between cooperating applications |
| 6. Presentation | Provides independence to the application processes from differences in data representation (syntax) |
| 7. Application | Provides access to the OSI environment for users and also provides distributed information services |

(Source: Stallings 1988:392)

3. **The Institute of Electrical and Electronics Engineers 802 LAN Standards**

The Institute of Electrical and Electronics Engineers (IEEE) has established a local area network standards committee known as the IEEE 802 Standards Committee. The standards developed to date are concerned with the implementation aspects of the three lower layers of the ISO Reference Model. There is an effort to incorporate the IEEE 802 LAN

standards with the ISO Reference Model. Hammond and O'Reilly report that "the ISO has agreed to process these standards for adoption as international standards as they are finalized by the IEEE 802 Committee." (Hammond and O'Reilly 1986:355-356)

Currently, the IEEE 802 standards are divided into six parts. Figure 2.9 depicts the division of the IEEE 802 standards and their relationship to the ISO model. The standards are described as follows:

IEEE 802.1 -- This document defines the 802 standards and their relationship to the ISO model;

IEEE 802.2 -- This defines the common logical link-control protocol;

IEEE 802.3 -- This defines the standards for a bus topology that uses the Carrier Sense Multiple Access/Collision Detection access method;

IEEE 802.4 -- This defines the standards for a bus topology that uses the control token access method;

IEEE 802.5 -- This defines the standards for a ring topology that uses the control token access method,

IEEE 802.6 -- This defines the metropolitan area network (MAN).

As indicated in Figure 2.9, there is no direct correspondence between the ISO model and the IEEE 802 standards. However, the standards developed for the lower layers "encompass essentially all that is needed for network access." (Hammond and O'Reilly 1986:358) While the standards are not complete nor fully implemented, they provide direction for the development of the hardware and software

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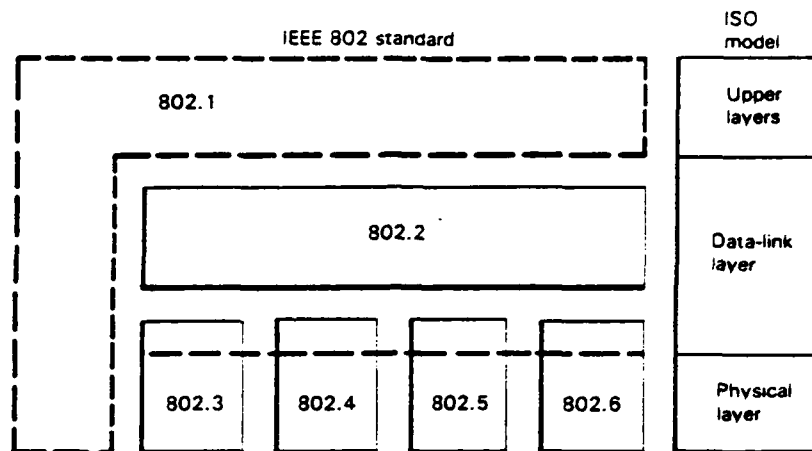
Figure 2.9   The IEEE 802 LAN Standards and
the ISO Reference Model
(Source: Hammond and O'Reilly 1986:356)

architecture for local area networks.  The conformance to
these standards will simplify the analysis, design and
selection process for the systems analyst.  (Hammond and
O'Reilly 1986:355-374; Stallings 1988:12-14)

## D.   LOCAL AREA NETWORK CHARACTERISTICS

Just as no one attribute can describe a person in detail,
no one characteristic can fully convey the concept of a local
area network.  Each characteristic must be considered,
independently and jointly, to design an appropriate network.
A local area network is characterized by (1) its topology
(both physical and electrical), (2) its transmission medium,
and, (3) the protocol used to access the transmission medium
(Halsall 1985, Stallings 1984).  Figure 2.10 is an overview

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of the characteristics of a local area network.  Each of
these characteristics will be considered in further detail.
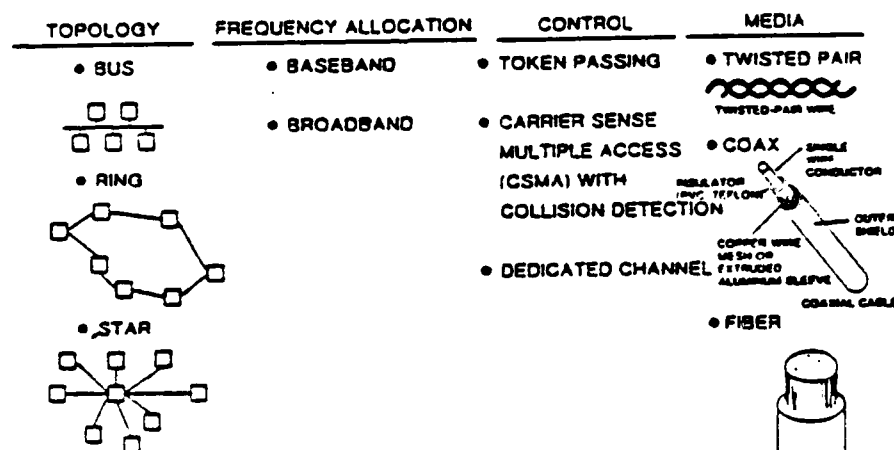


Figure 2.10 Network Characteristics
(Source: Robinson 1987:6)

## 1.  Network Topology

Network topology refers to both the physical and
electrical layout of the network, the way in which the
devices (referred to as data terminal equipment [DTE] or
nodes) are interconnected.  Two nodes can be directly
connected to each other, which is referred to as a
point-to-point link.  This is known as the mesh topology and
it has proven infeasible for both wide area network and local
area network purposes.  Figure 2.11 depicts such a network
for two to five nodes.  The reason that the mesh topology is
infeasible for a local area network is that as the number of
nodes (N) increases, the number of full-duplex links required
is $N(N - 1)/2$.  This would require $(N - 1)$ input/output ports

which would quickly exceed the capabilities of the microcom-
puter. Additionally, the cost and amount of the physical
medium required for these connections is prohibitive.
(Stallings 1988:193-194)



(a) 2 Stations

(b) 3 Stations

(c) 4 Stations

(d) 5 Stations
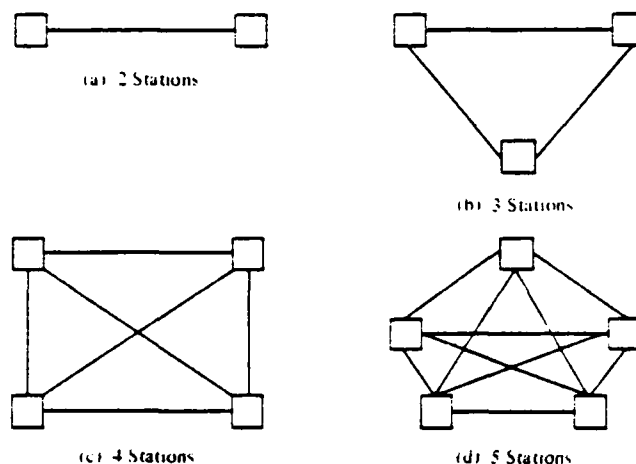
Figure 2.11   Mesh Topology (Point-to-Point link)
(Source: Stallings 1988:194)

In terms of the local area network three basic
topologies are used: (1) star, (2) ring and (3) bus.   The
following sections will describe each of these, with their
relative advantages and disadvantages discussed in terms of
reliability, expandability, and performance.   Each of these
topologies can be used independently or combined to develop
more complex topologies to meet the requirements of the
organization.

a.   **The Star**

As the name implies, in the star topology
network, each node is connected by a point to point link to a

single central control node or hub (Figure 2.12). Any communication between two nodes must be sent first to the control node, processed and forwarded to the receiving node. The telephone central switch is an example of such a network.
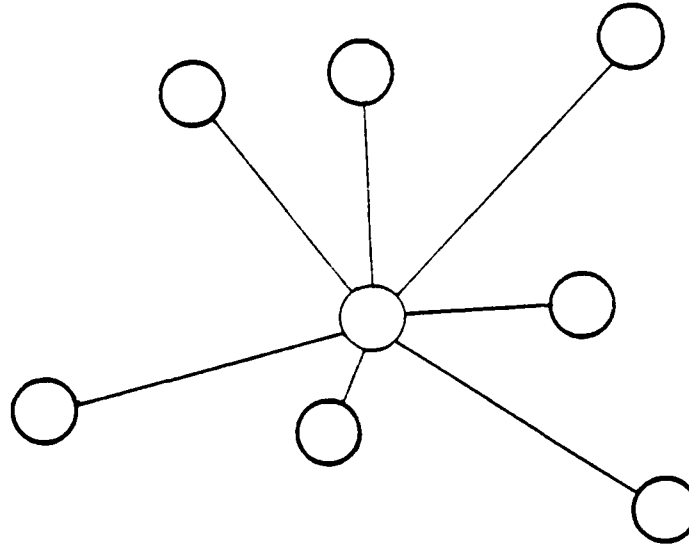


Figure 2.12 Star Topology
(Source: Katzan 1983:63)

The star network has several advantages. It is simple to design, implement and control. Because of this simplicity, development costs are usually lower than other designs. In terms of reliability, the failure of any single node will not interrupt network service, with the exception of the central control hub. Additionally, the identification and maintenance of network problems are relatively simple. (Rosenberg 1978:3)

Expansion and changes to the network simply
require the addition or removal of the point-to-point link
between the node and the control node.  Thus, a node can be
added or deleted from the network without disturbing the
normal flow of network operation.  Similarly, the addition of
other control nodes can expand the size of the network
creating a distributed or multistar topology.  Figure 2.13
illustrates the multiple levels of such a network.

The major disadvantage of the star topology is
that failure of the central control node will completely
disrupt network services unless there is complete redundancy
at each critical point.  Also, the star is medium intensive
and it will need more cabling or wire than the other
topologies. (Flint 1983:84-85)
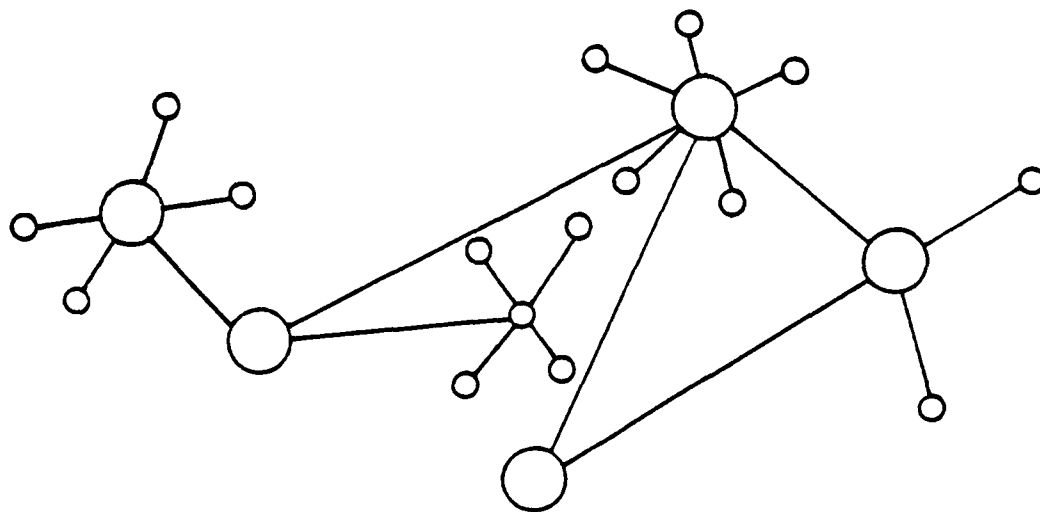
Figure 2.13 Multistar Topology
(Source: Katzan 1983:65)

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### b. The Ring Topology

In the ring topology, every node in the network is connected to the two logically adjacent nodes on its sides with a point-to-point link to form a complete circle or closed loop (Figure 2.14). The design of the ring is an attempt to overcome the reliability problems of the star topology.
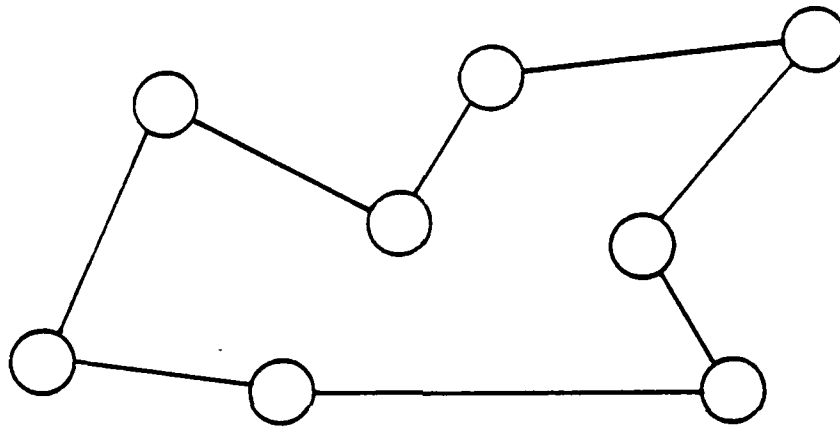
Figure 2.14 Ring Topology
(Source: Katzan 1983:67)

Communications on a ring network are generally unidirectional and must pass through all nodes between the sender and receiver. Each node must know its own address and be capable of receiving the transmission, decoding the address and subsequent retransmission of the message if the address is not its own. Each node acts as an active repeater, thus, distributing the control function of the central node of the star network.

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An advantage of the ring is the decentralization
of the communication control function.  Closely associated to
this is the direct point-to-point communications link.
Because each node is actively involved in the communication
process, error control is enhanced and greater distances can
be covered than with some other topologies such as the bus.
Also fault isolation and recovery are simpler to implement
than on the bus topology.

The ring is not without its problems.  A break in
the point-to-point link can disrupt the entire network until
the problem can be isolated.  Similarly, the failure of a
single node can disable the network.

Expansion of the network is more detailed than
that of the star, but it is still relatively simple.  Adding
a node requires identifying topologically adjacent nodes,
breaking the ring, inserting the new node, completing the
ring and identifying the new address to the neighboring
nodes.

In general, however, the benefits outweigh the
problems and the ring provides excellent performance on
networks with a small number of nodes. (Stallings 1984:91-92)

### c.  The Bus Topology

Typically with the bus topology, a single
physical medium is routed throughout the office, department,
or building in a linear manner without repeaters or switches

(Figure 2.15).  In this sense, the communications network is the transmission medium.
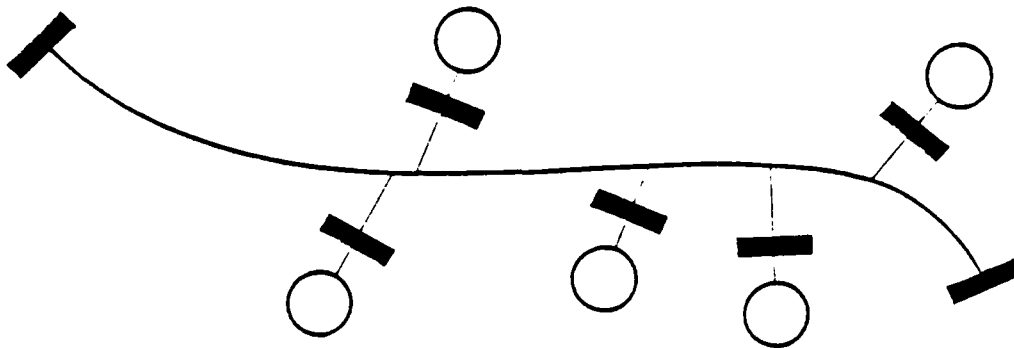


Figure 2.15 Bus Topology
(Source: Katzan 1983:69)

In contrast to the active repeaters in the ring network, the bus is a passive system.  Each node accesses the bus through a direct physical attachment (tap).  As in the ring, each node must know its own address; however, rather than pass the message from node to node, the bus requires that the node continually "listen" to the network for all transmissions addressed to it.  To transmit a message, a node broadcasts the message onto the bus.  Broadcast transmission means that all nodes that are active on the network hear the message and that the message is propagated the entire length of the bus.

Expanding the bus network does not interrupt network services.  Because the bus is passive, any node can be added, deleted or moved to any location on the bus without

disrupting the network as contrasted with the ring. Similarly, the failure of a node or several nodes will not generally disrupt the network. A break or failure of the transmission media may either result in two disjoint networks or the loss of all stations beyond the break. Although network service is degraded, there is not a total disruption of network service. However, the passive nature of the network makes fault isolation and recovery more difficult than that associated with the ring network.

Thus, the topology of a local area network is based upon the way in which the nodes are connected to the network. The topology of a local area network is interdependent upon the transmission media and the access and transmission methods employed. The combinations of these characteristics impart unique advantages and disadvantages to each topology. The choice of a specific topology must be determined based upon these factors as well as the intended use of the network and the physical location of the nodes to be connected to the network. Figure 2.16 summarizes the characteristics of the network topologies.

## 2.  **Transmission Media**

The transmission media provides the actual physical connection between any of the nodes attached to the network. Local area networks have been developed using a variety of transmission media and frequency allocation. Transmission media include infrared, radio and satellite, as well as

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microwave. Because the local area network is limited in its geographic coverage, such media as satellite is not required. The primary media used for a network is: (1) twisted-pair wire, (2) coaxial cable and (3) optical fiber cable.

### a. Twisted-pair Wire

Twisted-pair wire (shielded or unshielded) is simply two wires, usually copper, that have been twisted together; analogous to the common telephone wire. A twisted-pair wire is shown in Figure 2.17a. The wire is commonly used for low-speed transmission operating in the range of 300 to 9,600 bits per second although data rates up to one megabits per second can be achieved over short distances (less than 100 meters) with appropriate line drivers and receiver circuits. The wire is twisted to provide better "noise immunity"--spurious noise signals from other electrical signal sources caused by electromagnetic radiation (Halsall 1985:79-81). Twisted-pair wire is easily constructed, which is reflected in its low cost. It is small in size and it is the easiest media to install and maintain.

Twisted-pair wire is not without its limitations. A phenomenon known as the "skin effect" is a major limiting factor. As the bit rate of the transmitted signal increases, the current flowing in the wires tends to flow only on the outside surface of the wire, thus using less of the available cross section. This has the effect of increasing the electrical resistance of the wires for higher frequency signals

| Net | Connection | Interface | Expansion | Failure Impact |
|-----|-----------|-----------|-----------|----------------|
| Star | Single central hub. All other nodes are radially connected to the hub. | All data is sent to the central hub to distribute. | Easily expanded up to the maximum capacity of the central hub, without disrupting the network. | Only the failed node is affected unless the central hub fails which results in total network failure. |
| Ring | Stations are physically connected to two adjacent stations in a closed loop. | Transmission is unidirectional. Data is passed to every station between sender and receiver. | Expansion is fairly simple, but requires bringing the network down. | Failure of a single node will bring down the network unless that node can be bypassed. |
| Bus | All stations are connected to the transmission media. | All data is broadcast onto the network. Each station must "listen" for its address. | Can be easily expanded because of its passive nature. | Node failure has no impact on the network. A break in transmission media may or may not disrupt the entire network. |

Figure 2.16 Network Topologies Compared

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which in turn causes more attenuation of the transmitted

signal. Apart from the skin effect, at higher frequencies,

there is an increasing amount of signal power lost due to

radiation effects. Low speed, loss of power over distance

and its susceptibility to electromagnetic and radio inter-

ference may effectively eliminate twisted-pair wire from

consideration as a transmission media where a high data rate,

a low error rate and a high degree of reliability are

required. (Cheong and Hirschheim 1983:11-15; Halsall

1985:81)

### b. Coaxial Cable

Coaxial cable minimizes the limitations of the

twisted-pair wire. Coaxial cable has a central conductor

running concentrically (coaxially) inside a non-conducting

insulator (dielectric) which is covered by a solid or woven

outer circular conductor and finally covered by an insulat-

ing, protective outer casing as shown in Figure 2.17b (Katzan

1983:83-84).

Because of the configuration of the coaxial

cable, the center conductor minimizes the skin effect and the

loss of signal power. Also, the center conductor is effect-

ively shielded from external interference signals. Coaxial

cable is capable of various data rates depending upon the

signalling scheme that is used. However, "coaxial cable is

manifestly suitable for signal bandwidths up to several

hundred megahertz, which implies data rates up to numbers in

(a) Twisted pair.
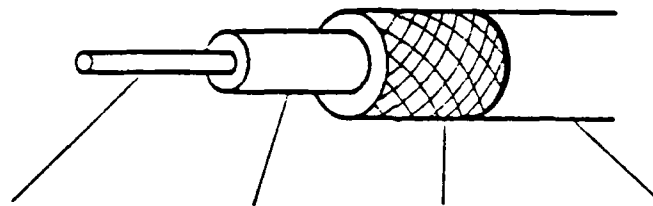
**Conductor**   **Insulation**   **Mesh or Sleeve**  **Protective Cover**

(b) *Coaxial cable strand.*

Cladding    Jacket Cover

Core    Light Rays
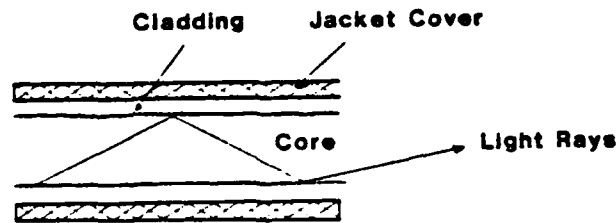
(c) Optical fiber cable.

Figure 2.17 Transmission Media
(Source: Katzan 1983:83-84)

the order of a hundred megabits per second." (Potter 1985:199)

Coaxial cable is operated using either "baseband" or "broadband" techniques. Table II highlights the differences between the baseband and broadband transmission techniques.

Baseband is defined as one that uses digital signaling. The signal occupies the entire spectrum of the cable, thus only one signal is on the cable at a time so that frequency division multiplexing (FDM) can not be used (i.e., multiple signals divided by signal frequency sharing the cable). Transmission is bidirectional which dictates a bus topology. Data rates of one to ten megabits per second can be achieved over a limited distance of approximately 2500 meters. (Stallings 1984:76, Potter 1985:202)

Broadband coaxial cable has a high bandwidth, uses analog signalling and frequency division multiplexing. Broadband cable can carry many signals at a time with each signal being carried at a different frequency. The data rate of a broadband cable is about half that of the baseband rate; however, because the cable can be divided into separate channels many more signals can be carried at one time. Broadband components rely heavily on the cable antenna television (CATV) technology. The broadband signaling is unidirectional and because it uses an analog signal, greater distances can be covered (up to 50 kilometers) easily

## TABLE II

## COAXIAL CABLE TRANSMISSION TECHNIQUES

| Baseband | Broadband |
| --- | --- |
| Digital signaling | Analog signaling (requires radio frequency modem) |
| Entire bandwidth consumed by signal no FDM | FDM possible -- multiple channels, video, audio |
| Bidirectional | Unidirectional |
| Bus topology | Bus or tree topology |
| Distance: up to a few kilometers | Distance: tens of kilometers |

Source: (Stallings 1984:75)

exceeding the geographic limitations of a local area network. (Summers 1985:225)

Coaxial cable, whether baseband or broadband, can easily provide high data rates, low error rates, a high degree of reliability and the flexibility required for a local area network. The broadband transmission technique increases the cost of a network because radio frequency modems must be used as well as other components from the CATV industry, such as the frequency translation unit (headend). Baseband techniques are less costly than the broadband method, but both are more expensive than twisted-pair wire;

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however, the benefits of coaxial cable often outweigh the cost difference.

### c. Optical Fiber Cable

Optical fiber transmission carries data in the form of a fluctuating beam of light in a glass fiber rather than an electrical signal in a piece of wire. The construction of the optical fiber cable is shown in Figure 2.17c. Since the transmission is in the form of a light wave, optical fiber cable is immune to electromagnetic interference and noise, cross-talk, and electrical shorts. Additionally, it is immune to electronic eavesdropping; and because the physical tapping of the cable is difficult, physical security is greatly enhanced when compared to either twisted-pair wire or coaxial cable. Data rates of 100 giga ($10^9$) bits per second over 100 kilometers can be attained; however, data rates of several hundred megabits per second are typical (Finley 1987:224).

Optical fiber uses either laser semiconductors or light emitting diodes as the source of the light wave. Using optical couplers, the cable can operate in any of the topologies described. Optical fiber cable is currently best suited for point-to-point connections where there is a need for a high information capacity and data rate, immunity to electromagnetic interference, and a high degree of security is required. (Jackson 1986; Stallings 1987)

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As with the topologies, there is no single
transmission medium that is best.  Each media has particular
advantages and disadvantages, whether it be cost, ease of
installation and maintenance or data rates and security.
Each particular network application must be considered in
context to determine the type of media to implement.
Table III presents a comparison of the transmission media
discussed.

## TABLE III

### TRANSMISSION MEDIA

| CHARACTERISTICS | TWISTED PAIR WIRE | BASEBAND COAX | BROADBAND COAX | FIBER OPTIC CABLE |
|---|---|---|---|---|
| BANDWIDTH (Hz) | 100 K - 1 M | 10 M - 50 M | 300 M - 400 M | UNLIMITED |
| COMPLEXITY OF CONNECTION | 1 | 2 | 4 | 5 |
| COMPONENT AVAILABILITY | WIDELY AVAILABLE | LIMITED | WIDELY AVAILABLE | VERY LIMITED |
| COMPONENT COST | 1 | 2 | 4 | 5 |
| RELATIVE MEDIUM COST | 1 | 3 | 2 | 5 |
| STATE OF TECHNOLOGY | MATURE | DEVELOPING | MATURE | EMERGING |
| SCALE | 1           2           3           4           5<br>VERY LOW                                    VERY HIGH | | | |

(Source: Robinson 1987:9)

## 3.  Network Access Protocols

Any topology that uses a shared cable must employ
some means of regulating access to that cable.  In the star
topology, access is regulated by the central control hub.

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With both the ring and the bus topology, there is a single logical path connecting the nodes of a network. To ensure that each node accesses and shares the medium in an equitable manner, a network access protocol (or discipline) must be imposed upon the network. There are two primary protocols used in local area networks. They are: (1) Carrier-Sense Multiple-Access with Collision Detection (CSMA/CD), and (2) Control Token. CSMA/CD networks are used solely for the bus topology while the token protocol can be used with either a bus or ring.

### a. CSMA/CD

CSMA/CD access method is often referred to as the "listen while talk" method. Figure 2.18 shows a typical CSMA/CD Bus network and the necessary components to attach the data terminal equipment to the network. Referring to the bus topology, all nodes are connected to a single cable which is used to transmit all data between any of the nodes. In this sense, the media is said to be multiple access, each node has access to the cable. A node prepares the data for transmission and broadcasts the data onto the cable. Since the cable is a shared media and the broadcast is bidirectional, every node connected to the network "hears" the transmission.

It is possible that two nodes may transmit data at the same time, resulting in the collision of the two transmissions and the subsequent corruption of each

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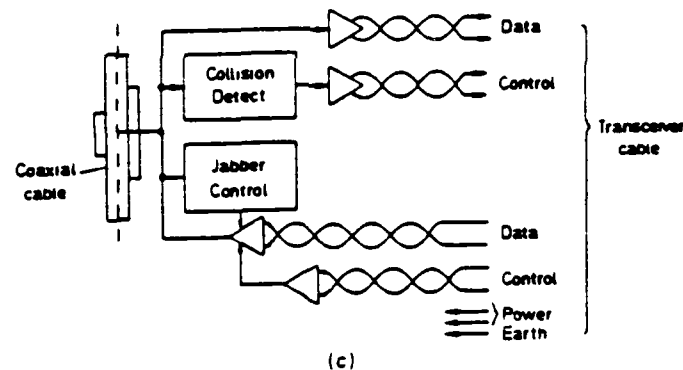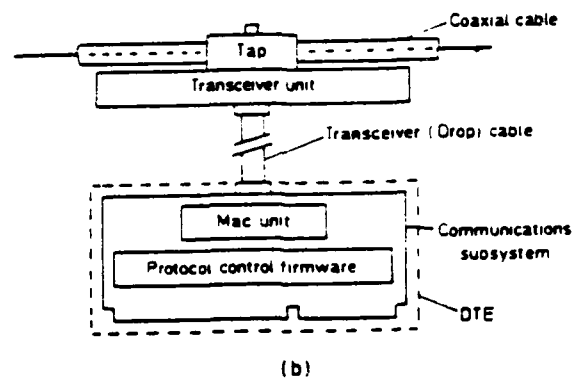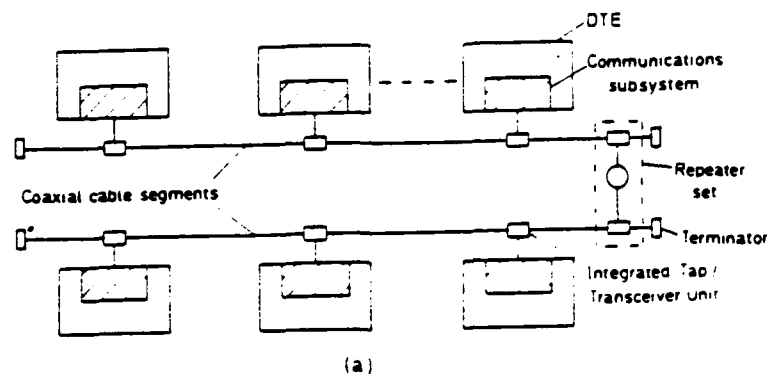
Figure 2.18 CSMA/CD Bus network components:
            (a) cable layout; (b) DTE interface;
            (c) transceiver schematic
            (Source: Halsall 1985:214)


transmission.  A collision window is defined as "the maximum

time during which a collision can occur after the line goes

quiet." (Sloman and Kramer 1987:179)  In the worst case,

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"for a 10 Mbps baseband coaxial cable network with a maximum of 2.5 km between any transmitter and any receiver, this is equal to 512 bit times" or approximately 51 microseconds (Sloman and Kramer 1987:179; Halsall 1985:217). To reduce the possibility of collisions, the node "listens" to the cable (Carrier-Sense) to determine if there is traffic already on the network. If the node senses a carrier signal, it defers transmission until the cable is free of traffic. It is possible, however, that two nodes may sense the cable at the same time and determine that the cable is free of traffic and begin transmitting simultaneously, again resulting in a collision.

To account for this possibility, the node listens to the cable while it transmits its data. If the transmitted signal differs from the monitored signal, the node assumes that a collision has occurred (Collision Detection). When the node detects a collision, it enforces the collision by transmitting a "Jam Sequence" for a short period of time, thus ensuring that any node involved in the collision is aware that a collision occurred. The nodes involved further wait a short randomly selected time interval before trying to retransmit its data. The timeout intervals are multiples of the collision window. An exponential backoff algorithm is used to calculate the timeout period. The exponential backoff algorithm calculates a "random time period which is biased by a count of the number of collisions which have

occurred and is seeded with the station address to make sure the algorithms in two stations do not get synchronized. Wait time is random in the range 0 to $2^k$ slots (45 microseconds to 45 milliseconds) where k is the maximum number of retries." (Sloman and Kramer 1987:179; Halsall 1985:208-209; Stallings 1984:111-119; Tanenbaum 1981:288-306)

Access to the media using CSMA/CD is probabilistic and dependent upon network loading. The lighter the load on the network, the fewer collisions. Other factors such as propagation delay (the time it takes for the first bit of a transmission to propagate to all parts of the network) and throughput also affect the performance of the CSMA/CD access protocol. With high data rates, network loading tends to be low and since a node transmits only if the network is inactive, the probability of a collision occurring is in practice quite low (Halsall 1985:209).

### b. Control Token

The control token or simply token access method can be used in either the ring or bus topology. Access to the shared medium is granted by possession of the token. In its simplest form, a control token is passed from node to node. A node may transmit data by capturing the token. Once the node has completed its transmission, it must pass the token on to the next node in the ring.

The sequence of operation is as follows:

1. a logical ring is first established, which links all the DTEs connected to the physical medium, and a single control token is created;

2. the token is passed from DTE to DTE around the logical ring until it is received by a DTE waiting to send a frame(s);

3. the waiting DTE then sends the waiting frame(s) using the physical medium and then passes the control token to the next DTE in the logical ring. (Halsall 1985:209)

Since control of the network is distributed between each node on the network, each node is responsible for initialization and recovery of both the connection of the logical ring and from the loss of the token. Even though each node is capable of performing these functions, only one node at a time is responsible for recovery and re-initialization.

The token access method can be used with a bus physical topology. The requirement is to establish a logical ring. Figure 2.19 shows the ring and bus physical topology and the logical topology that has been established. In part (a), the logical ring is synonymous with the physical ring. In part (b), the physical topology is a bus, but the electrical topology is that of a ring. Thus, the logical ring is established in the bus. Note that DTE H is not a part of the logical ring. As such, DTE H is capable of receiving only since it can never capture the token. Another aspect of the token access method is that priorities can easily be established with the token.

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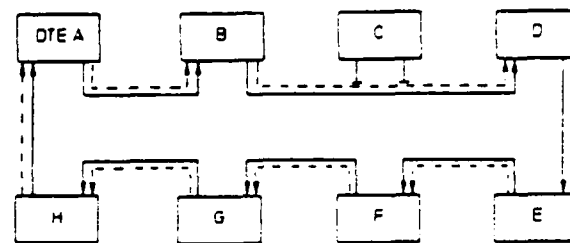
Note (i) ——— = physical medium, – – – – = logical ring
(ii) DTE C assumed switched off and hence in bypass mode

(a)
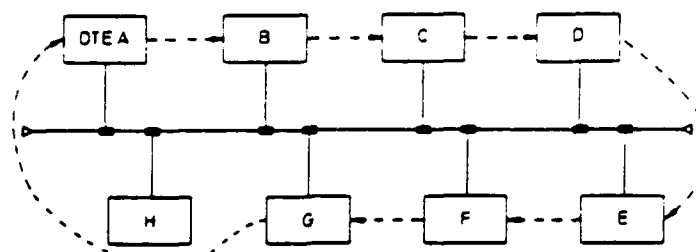


Note (i) —●— = physical medium, – – – ● = logical ring
(ii) DTE H not part of logical ring and hence is receive only

(b)

Figure 2.19    Control token access method:
(a) Token Ring; (b) Token Bus
(Source: Halsall 1985:210)

In contrast to the CSMA/CD method, the token access method is deterministic in that there is an upper bound to the amount of time that any station must wait before it can transmit its data.  In this sense the token access method without priority assignments ensures that every DTE has the opportunity to transmit without the concern of collisions.  (Stallings 1984:125-126)

Hammond and O'Reilly provide a complete discussion concerning the performance analysis of both the CSMA/CD and the token access protocols (Hammond and O'Reilly 1986). Performance analysis has been and continues as the central theme for many researchers. Tobagi and Hunt have reported the performance analysis of CSMA/CD (Tobagi and Hunt 1987) while Bux has evaluated the performance of CSMA/CD, token controlled and several other access protocols (Bux 1987). In general, however, the user is not concerned with network performance per se. Durr says that "token passing and contention are of little importance from the end user's point of view. Neither scheme has a consistent performance advantage." (Durr 1987:39) Feldmeier reports that "traffic measurements on the ring show that traffic was similar to that found on the Ethernet...and that network applications, rather than the physical network, determine the data traffic." (Feldmeier 1986:243) The user's concerns focus on three things:

> Firstly, has his or her system--office workstation for example--got the necessary hardware to allow the system to be physically connected to the network; secondly, does the system have the appropriate software to allow the services supported by the network--electronic mail, file archiving etc.--to be accessed; and thirdly, is the access time to these service within acceptable limits. Providing these conditions are met, the user is not concerned with the type of underlying LAN which is being used to access these services. (Halsall 1985:242)

## 4. **Analysis of Alternatives**

There is not a single networking approach that can meet all telecommunications needs. Given that the user is

less concerned with the underlying architecture and more
concerned with the operational capabilities, the network
designer must have a knowledge of the characteristics and
capabilities of the various topologies and protocols in order
to determine whether a particular local area network design
will meet the requirements of the users. The network should
fit into the existing environment and it must meet the user's
functional requirements. Because the user is only concerned
about the services of the network, the network should be
transparent to the user. (Ginsburg and Rappaport 1986:96)

With the introduction of the ISO Reference Model for
Open Systems Interconnection and the IEEE 802 local area
network standards, hardware standards now exist which
simplify the selection process. Choosing equipment which
conforms to those standards, the network planner can develop
a hierarchical system with a limited number of different
network types. This will keep the management and maintenance
of the network within reason while ensuring compatibility
with future hardware procurement. (Stallings 1986:91)

The topology of a network should reflect the physical
layout of the microcomputers that will be attached to the
network. The physical media of the network should provide
adequate capacity to meet current needs, and there should be
excess capacity planned into the network to ensure that it
can meet tomorrow's needs as well. Similarly, the access

method used should reflect the user's requirements for reliability, performance, and response time.

## E. SUMMARY

Advances in technology, declining costs of computer and telecommunications resources, and a shift in emphasis from the management of computer resources to that of information resources management are major factors in the merging of traditionally separate technologies. The merging of the functional components of information resources management (data processing, telecommunications, and office automation) has required the broadening of the technical expertise of the systems analyst.

Thus, this chapter presented the theoretical foundations of structured systems analysis and design, data communications, and network analysis and design. The management information system concept enables the systems analyst to view the organizational information system as a federation of functional subsystems. This view allows the systems analyst to align the MIS structure with that of the organization. The structured systems analysis and design methodology provides the systems analyst with the conceptual foundations and the tools and techniques necessary to systematically analyze a problem, moving from the current physical system to the new conceptual system and ultimately designing a new physical system. The iterative nature of the systems

analysis and design methodology is captured in the system life cycle model through the management, user, analyst review of the exit documents prior to proceeding to the next step.

Local area network communications standards, the ISO Reference Model and the IEEE 802 LAN standards, were discussed. The development of these standards will simplify the selection process for the systems analyst. With an understanding of the users' requirements, the organizational structure, and the style and philosophy of management, the systems analyst can match the characteristics and capabilities of the topologies and protocols as well as the physical medium of a local area network design to the organization, thereby ensuring that the users' current and future requirements are met.

The synthesis of theory from this multi-disciplinary approach is the basis for the methodological framework used in this research.

# III. RESEARCH APPROACH AND ITS APPLICATION TO THE MARINE CORPS AIR STATION, YUMA, ARIZONA

## A. METHODOLOGICAL FRAMEWORK

Knowing how to operate large machines or to build elegant systems that provide the most efficient hardware or software is only part of the information problem. The real issue is how to solve business problems by making information work for the people who need it.

The starting point is understanding how information capabilities are received by and delivered to the end users. To do this requires a knowledge of the business --how it operates and what the important issues are. (Chorafas 1980:ix)

In the analysis and design of a local area network, "the most difficult element may be obtaining the requirements of current and anticipated network users." (Held and Sarch 1983:366) Establishing the requirements for a local area network differs somewhat from the requirements analysis of application software development. Traditional structured analysis identifies the system of interest and attempts to decompose it into smaller and smaller subsystems until each is a single process. The analysis determines the data inputs to the process and the subsequent outputs from that process in order to develop the specific application.

However, the focus here is on the organizational information system. As such the level of specification is much more general relative to that associated with the development of application software (Davis and Olson 1985:460).

Thus, this multi-disciplinary approach serves as the foundation for the strategy used in this research. Given the objectives of the feasibility study and the macro-level view of the organizational information system, the specific steps in the strategy are:

1. Study the existing system.

2. Determine user requirements.

3. Develop alternative solutions.

4. Analyze the cost-effectiveness of the alternatives developed.

To understand how the Air Station operates and what is important to it requires an understanding of the environment, the goals and objectives of the organization, and how it accomplishes its mission. This is the purpose of studying the existing system and the first step in the feasibility study.

Through the study of the system, the analyst gains an insight into how the current system operates, how it is supposed to operate, and what the users expect of the system. Armed with this knowledge, the analyst begins to elicit and identify the users requirements.

The study of the existing system is divided into two areas: the business environment and the information systems environment. By studying these two areas the analyst can determine the degree to which the two systems are aligned with the mission and goals of the organization.

## B. THE BUSINESS ENVIRONMENT

### 1. Environmental Overview

The Marine Corps Air Station (MCAS), Yuma is located in the southwestern corner of Arizona near the California and Mexico border. It has been the home of fixed wing training squadrons for many years. As such, it is the last training command for the aviators before they join an operational aircraft squadron. There are two extensive bombing ranges within fifty nautical miles of the Air Station which are capable of handling all classes of aviation ordnance. The Air Station is directly responsible for the planning, scheduling, and coordination of those ranges to include rocket, gunnery, and bombing targets. The proximity of the Air Station to these bombing ranges makes the Air Station extremely popular with Marine and Navy aviation squadrons from across the United States. The Air Station is also the home of the Marine Aircraft and Weapons Tactics Squadron 1 (MAWTS-1) which conducts several Weapons Tactics Instructor (WTI) courses each year as well as other courses in aircraft weapons tactics and employment.

Because of the mild winter climate, the extremely high degree of visibility throughout the year and the central location of the Air Station in relation to the bombing ranges, the Air Station is home to many transient squadrons throughout the year. This results in a constant state of coordination, planning, and supervision regarding the

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administration and the command and control of the Air
Station.

## 2. **Mission**

The formal mission of the Air Station is:

To maintain and operate facilities and provide services
and materiel to support operations of a Marine Aircraft
Wing, or units thereof, and other activities and units as
designated by the Commandant of the Marine Corps in coor-
dination with the Chief of Naval Operations. (Marine Corps
Air Station, Yuma, Arizona, Station Order P5451.1D:1-3)

"Facilities" include station real property, build-

ings, station housing, grounds, garrison mobile equipment,

airfield pavements, utilities (sewage, water, electrical, and

telephone) and other shore facilities. Specific taskings

include the inspection, maintenance, repair, and operation of

all real property.

"Services and materiel" include such things as

airfield operations (air traffic control), crash and fire

services, search and rescue operations, weather service,

operation of the aviation fuel farm, ordnance storage, issue,

and disposal services, and aircraft maintenance, and the

necessary materiel to accomplish those services.

"Activities and units" include both tenant units as

well as the station units necessary to accomplish its

mission. Also, those activities and units "as designated by

the Commandant of the Marine Corps in coordination with the

Chief of Naval Operations" include Marine and Navy units from

as close as the Naval Air Station (NAS), Lemoore, California

to as far away as the Marine Corps Air Station at Cherry Point, North Carolina.

Thus, the mission of the Air Station is wide ranging and complex. In order to accomplish its mission, the Air Station must capture, process, and disseminate a diversity of information ranging from the construction and maintenance of real property to the coordination and support required to host interservice aviation units. This complexity of command and control necessitates the close coordination of information and communication within and between the functional subsystems of the organization.

### 3. Organization

#### a. Higher Headquarters

The Air Station is subordinate to the Commander, Marine Corps Air Bases, Western Area (COMCABWEST) located at the Marine Corps Air Station, El Toro, California. Because of the geographic separation between the Air Station and its next higher headquarters, there is a certain amount of complexity introduced into the administration of the Air Station which would not exist if the commands were collocated.

#### b. The Marine Corps Air Station, Yuma

The organization of the Air Station reflects a traditional, functional hierarchy, which is readily apparent from the organizational charts. Specifically, there is a well-defined hierarchy of authority, narrow span of control,

supported by a formal chain of command and a centralization

of authority and decision-making. (Hampton, Summer and

Webber 1982:504-514; Davis and Olson 1985:333-335)  The

organizational structure is depicted in Figure 3.1.

A description of each of the functional subsys-

tems and the tasks performed by those subsystems is provided

in Appendix A.

## C. THE INFORMATION SYSTEMS ENVIRONMENT

In the analysis of any system, whether it is a particular

function or as in this case an organization, it is necessary

to study the existing system (Davis and Olson 1985:275).

This section provides a description of the data processing

functions and the extent and purpose of the microcomputer

assets.  Additionally, known changes that will impact the

organization and its information system are presented as well

as the results of the local area network survey.

### 1. Current Data Processing Capabilities

An inventory of computing equipment revealed that

there are several automated systems in place as well as many

"stand alone" microcomputers in use throughout the Air

Station.

The Automated Services Center is the primary focal

point for data processing services.  The center is equipped

with an IBM 4361, a Burroughs B1955 and an NCR COMTEN 3650.

The IBM 4361 is primarily used as remote job entry (RJE)

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                    ┌─────────────────────────┐
                    │  Commanding Officer     │
                    └─────────────────────────┘
┌──────────────────┐                              - - - ┌──────────────────┐
│  CO, H & HS      │                                    │  CO, MAWTS-1     │
└──────────────────┘                                    └──────────────────┘
┌──────────────────┐                                    Administrative
│  CO,  SOMS       │                                    control only
└──────────────────┘
                    ┌─────────────────────────┐
                    │  Executive Officer      │
                    └─────────────────────────┘

     ┌─────────┐   ┌─────────┐        ┌─────────┐   ┌─────────┐
     │  S-1    │   │  S-4    │        │ Supply  │   │ Services│
     └─────────┘   └─────────┘        └─────────┘   └─────────┘

     ┌────────────────┐              ┌────────────────┐
     │  Comptroller   │              │  Facilities    │
     │                │              │  Management    │
     └────────────────┘              └────────────────┘

  ┌──────────┐  ┌──────────────┐   ┌──────────┐  ┌──────────────┐
  │ Adjutant │  │ Inspector/   │   │ Chaplain │  │ Management   │
  │          │  │ CP & L       │   │          │  │ Engineer     │
  └──────────┘  └──────────────┘   └──────────┘  └──────────────┘

  ┌──────────┐  ┌──────────────┐   ┌──────────┐  ┌──────────────┐
  │ Aviation │  │ Civilian     │   │ Staff    │  │ Safety/      │
  │ Safety   │  │ Personnel    │   │ Judge    │  │ Occupational │
  │ Officer  │  │ Manager      │   │ Advocate │  │ Health       │
  └──────────┘  └──────────────┘   └──────────┘  └──────────────┘

  ┌──────────┐        ┌──────────┐        ┌──────────────┐
  │ Provost  │        │ Public   │        │ Family Service│
  │ Marshall │        │ Affairs  │        │ Center       │
  └──────────┘        └──────────┘        └──────────────┘
```

Figure 3.1 MCAS, Yuma Organizational Chart
(StaO P5451.1D:2-7)

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system to the Regional Automated Services Center (RASC) at Camp Pendleton, California.

Similarly, the Burroughs B1955 is a remote job entry system to the Regional Automated Services Center at the Marine Corps Air Station, El Toro, California for the Navy supply system, the Uniform Automatic Data Processing System for Stock Points (UADPS-SP). Figure 3.2 depicts the data processing systems under the purview of the Automated Services Center.
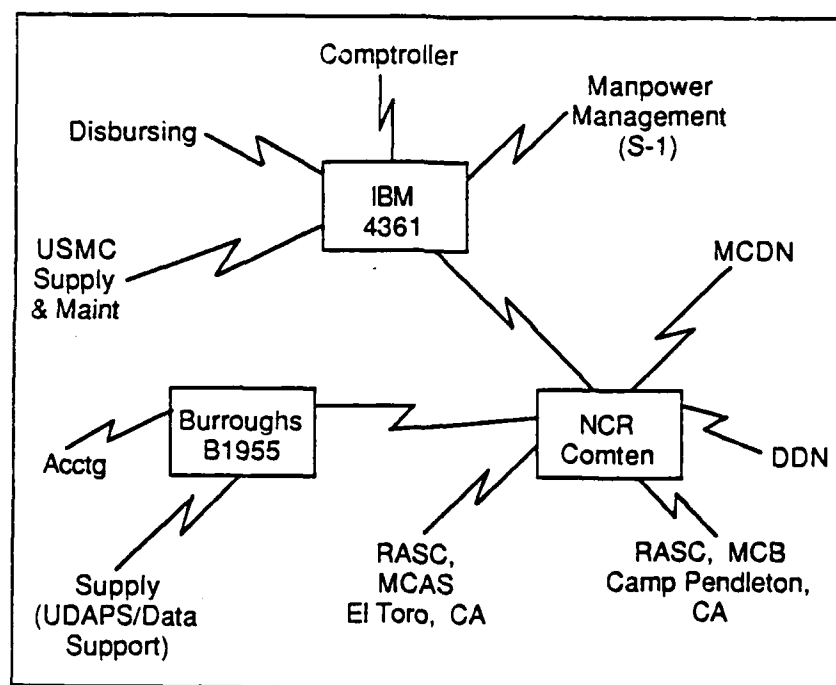


Figure 3.2 The Data Processing System

Although the Automated Services Center is small in size and the scope of its operations are limited, it is experiencing the transition from data processing to that of

information management and the support of end user computing. The view of information as a strategic resource and the expanded role of information technology has led to an expanded role for the information systems manager (Davis and Olson 1985:630).

The Marine Corps has adopted the concept of information resources management and has established Information Resource Centers within the Automated Services Centers. Thus, in conjunction with its traditional role of centralized data processing, the Automated Services Center is assuming a greater role in the organizational information system with respect to the functional components of the information resources management.

The Information Resources Center is tasked with providing end-users with hardware and software training and consulting, technical assistance in requirements analysis, economic analysis and vendor evaluation to help the end-users apply information resources to their problems. As such, Information Resources personnel generally act as teachers and consultants to the end-users, not as application programmers. (Davis and Olson 1985:427-428)

## 2. Changing Horizons

During fiscal year 1987 and 1988, the training squadrons are being decommissioned and the Marine Aircraft Group 13 (MAG-13), a Fleet Marine Force (FMF) operational aircraft group, is being relocated to Yuma from the Marine

Corps Air Station, El Toro, California. With the transition
from the training command environment to that of supporting a
tactical Marine Aircraft Group, there is a tremendous amount
of new construction aboard the Air Station. Current con-
struction plans include a new building for the Automated
Services Center. It is expected that the Automated Services
Center will relocate during late 1988 or early 1989. Also,
the Instructional Television section of the Training and
Audiovisual Support Center will probably relocate during 1988
to provide space for the squadrons of the aircraft group.
This move is important because of its impact upon the current
cable television network and cable plant.

Several new automated systems are planned for the
near future for many of the departments of the Air Station.
The Burroughs system is scheduled to be replaced by a Tandem
NS-TXP. The new system will replace the Burroughs terminals
located in the UADPS/Data Support Division and Accounting.
During this upgrade, the supply software system, UADPS-SP,
will be replaced by the Stock-Point Logistics Integrated
Communication Environment (SPLICE) program. This upgrade is
expected during the early part of 1988. The Traffic Branch
is scheduled to receive the Wang VS-85 Transportation
Management System during the summer of 1987. The Wang VS-85
is being implemented throughout the Marine Corps to provide a
standard transportation management system. The Traffic

Branch has already completed the site preparation necessary in anticipation of the system being delivered.

The terminals in the Disbursing division are being replaced by Headquarters, U. S. Marine Corps with Zenith Z-248s. The reason for this upgrade is that it will provide a local processing capability while maintaining the sharing of financial data from the central database at the Marine Corps Finance Center at Kansas City. Additionally, the COMPAQ 286 in the Comptroller's office will eventually provide connectivity to the Standard Accounting and Budgeting Reporting (SABR) system, a joint Headquarters, U. S. Marine Corps and Marine Corps Finance Center financial system.

The Naval Aviation Logistic Command Management Information System (NALCOMIS) is scheduled to be introduced to the Air Station in direct support of the tactical aircraft group. The implementation of the system as a local area network is currently under study. The system is scheduled to be phased in beginning in the summer of 1987 through the summer of 1988; however, no decision concerning the implementation of the system as a local area network has been reached.

In addition to NALCOMIS, the Wing headquarters located at the Marine Corps Air Station, El Toro, California is currently implementing its own microcomputer based local area network. The network will eventually connect all of the Group commanders with the Wing commander. With the

relocation of the Marine Aircraft Group 13 to the Air Station at Yuma, this network will evolve from a local area network into a wide area network. Since the group is a tenant organization, there will be minimal impact upon the organizational information system. However, since the Air Station is tasked with providing support and facilities to the tenant organizations, the major impact will be upon physical facilities.

Thus, there are myriad factors impacting the definition of the functional requirements for an organizational local area network information system. New construction, new systems, upgrading of established systems, and office automation, combined with the increasing trend in end-user computing must all be weighed carefully to ensure that the users' requirements are correctly defined.

### 3. The Local Area Network Survey

A survey was conducted to gather data about the current information system and personal attitudes concerning the automation of information tasks. The survey was designed to sample a large cross section of personnel aboard the Air Station to obtain a fair representation of the population. The specific objectives of the survey were:

- To obtain quantitative data about the current information processing requirements;

- To obtain qualitative data concerning how well the current system is meeting the information processing requirements;

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- To determine attitudes and opinions concerning the automation of the information processing requirements, and;

- To determine the extent to which a local area network information support system could improve the efficiency and effectiveness of the current system.

To meet these objectives, the surveys were distributed to a cross section of personnel in 26 departments aboard the Air Station. The surveys were targeted to the key managers at the middle and upper levels as well as the individuals responsible for the everyday information processing tasks such as typing, filing, and distribution of information.

Table IV lists the departments and the quantities of surveys distributed to each. The quantities were determined by the relative size in terms of personnel and the degree of specialization within a particular department. In total, 214 surveys were distributed. There were 192 returned of which 189 were usable. This resulted in a completion rate of 88 per cent. Three surveys were rejected because they could not be identified by rank, billet or unit. Appendix B presents an abbreviated version of the actual survey.

Table V provides a breakdown by rank and category, i.e., military or civilian. There were 17 military ranks and 11 civilian grades represented. Additionally, there was a total of 108 military respondents and 81 civilian respondents to the survey.

## TABLE IV

### MARINE CORPS AIR STATION, YUMA
### SURVEY DISTRIBUTION SCHEME

| Department | Quantity Distributed | Quantity Returned |
|---|---|---|
| Station Headquarters | 4 | 2 |
| Aircraft Intermediate Maint Dept | 7 | 7 |
| Chaplain's Office | 2 | 1 |
| Communication-Electronic Office | 8 | 7 |
| Civilian Personnel | 3 | 3 |
| Comptroller | 22 | 21 |
| Dental | 4 | 1 |
| Facilities Management | 20 | 19 |
| Food Services | 4 | 1 |
| Ground Safety | 3 | 3 |
| Headquarters & Headquarters Sqdn | 6 | 5 |
| Management Engineer | 4 | 4 |
| MAWTS-1 | 7 | 7 |
| Medical | 4 | 4 |
| Military Police | 11 | 7 |
| Resident OIC for Construction | 4 | 4 |
| Public Affairs | 5 | 5 |
| S-1 | 16 | 16 |
| S-4 | 6 | 4 |
| Services Dept | 15 | 13 |
| Staff Judge Advocate | 8 | 8 |
| Station Adjutant | 2 | 2 |
| Station Inspector | 2 | 1 |
| Station Training | 8 | 6 |
| Station Operations & Maint Sqdn | 12 | 11 |
| Supply | 27 | 27 |
| Unknown | | 3 |

Total: 26 Departments     214     192

Completion Rate: (189 + 214)*100 = 88.3177%

## TABLE V

## CATEGORY AND RANK BREAKDOWN

| Military | | | | Civilian | |
|---|---|---|---|---|---|
| Officer Rank | No. | Enlisted Rank | No. | Grade | No. |
| LtCol | 4 | SgtMaj/MGySgt | 7 | WS-14 | 1 |
| Maj | 5 | MSgt | 9 | GS-12 | 2 |
| Capt | 15 | GySgt | 15 | GS-11 | 8[*] |
| 1stLt | 4 | SSgt | 19 | GS-10 | 4[**] |
| 2ndLt | 1 | Sgt | 11 | GS-9 | 8 |
| CWO-4 | 1 | Cpl | 5 | GS-8 | 2 |
| CWO-3 | 2 | LCpl | 2 | GS-7 | 7[***] |
| CWO-2 | 6 | PFC | 1 | GS-6 | 6[****] |
| WO-1 | 1 | | | GS-5 | 16 |
| | | | | GS-4 | 7 |
| | | | | GS-3 | 12 |
| | | | | Unknown | 8 |
| Total: | 39 | | 69 | | 81 |

| | | | |
|---|---|---|---|
| * | includes 2 WA-11s | *** | includes 1 AS-7 |
| ** | includes 2 WS-10s | **** | includes 1 WA-6 |

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A statistical analysis of the data obtained from the surveys was performed. The statistical analysis is based upon the fact that X has a sampling distribution which is approximated by a normal distribution. This assumption is based upon the central limit theorem which says that:

1. the sampling distribution of the sample mean is asymptotically normal,

2. the mean (expected value) of the sample means is equal to the mean of the original population from which we are sampling, and

3. the variance of the sample mean is a well-defined function of the variance of the original population from which we are sampling. (Smith and Williams 1976:247)

Additionally, the Law of Averages (also known as the Law of Large Numbers) states that "if the sample size is large, the probability is high that the sample mean is close to the mean of the parent population." (Anderson and Sclove 1986:284)

The survey asked for three different types of responses. One type of question required the individual to provide a numerical response. Another type asked the individual to select a single answer from a list of answers, and the last type asked the individual to select all answers that were applicable.

There were eighteen questions which asked for numerical responses. Nine questions elicited one answer from among several possible choices, and there were seven

questions that allowed the individual to select all that were applicable.

For those questions where numerical responses were provided, the responses were summed and means, variances and standard deviations were computed. To ensure that the sample mean is representative of the population mean, confidence intervals were constructed. The confidence level was arbitrarily established as 0.95. This means that there is a 95 per cent certainty that the population mean falls within that interval.

In the second case, the underlying assumption was that each possible answer in the list was equally likely to have been chosen. Thus, if x represents the total number of choices for each question, then the probability of a particular answer being selected is given by $\frac{1}{x}$, denoted by $p_o$.

However, "conclusions drawn from statistical inference are subject to errors due to sampling variability." (Anderson and Sclove 1986:347) To account for this sampling variability and to validate the conclusions drawn from this set of data, one-tailed hypothesis testing was performed. The hypothesis tested in each case, referred to as the null hypothesis ($H_o$) was that the observed probability p (the actual response to the survey) was equal to the hypothesized probability $p_o$ (the expected response--1/x). The alternative hypothesis ($H_1$) which represents the negation of the

null hypothesis was that the observed probability p was greater than the hypothesized probability $p_o$. The alternative hypothesis means that the actual response to the survey was significantly different from the anticipated response. Based upon the results of the hypothesis testing, conclusions drawn from the statistical inferences are confirmed or denied. For example, consider the experiment of tossing a fair coin. The hypothesized probability $p_o$ is 1/2, i. e., the coin is equally likely to land on a head or on a tail. Thus, the null hypothesis is that the coin is fair ($H_o:p = 1/2$) while the alternative hypothesis is that the coin is not fair ($H_1:p > 1/2$). If, during the conduct of the experiment, the observed probability is 3/4 then the null hypothesis is rejected and the alternative hypothesis is accepted. Thus, one concludes that the coin is not fair. There is always the possibility of rejecting the null hypothesis when it is true. This is often referred to as the risk, or level of significance. To limit the probability of making this type of an error, the level of significance used was 0.05. This means that there is a five per cent chance of rejecting the null hypothesis given that the null hypothesis is true. The null hypothesis was accepted when the observed p was less than $p^*$ and statistical significance was denied, that is, the observed probability was not significantly different from the hypothesized probability. (Smith and Williams 1976:316-331)

The remaining seven questions provided for multiple responses. A tally was used to sum the number of responses. The purpose of these questions was to determine current information processing techniques. Additionally, these questions provided insight into personal attitudes toward the current information system and the proposed introduction of a local area network information support system.

Specific statistical analysis formulas which were used are provided in Appendix C. Inferences were drawn from this analysis and are discussed below.

### a. Information Communication and Distribution

To meet the differing needs for information in the organization, the information must be disseminated. The dissemination process can take the form of verbal communications such as meetings or through the distribution of physical media such as a memorandum or a letter.

A primary tool for verbal communications in an organization is the telephone. Table VI summarizes the results of the survey regarding telephone communications aboard the Air Station. There is a general perception aboard the Air Station that incoming telephone calls require more time than outgoing telephone calls. Given a seven hour workday, individuals spend approximately 26 percent of each work day on incoming telephone calls, while approximately 21 percent of each work day is spent originating telephone calls.

**TABLE VI**

**TELEPHONE COMMUNICATIONS**

| | Minutes per Day | | |
| | Incoming | Outgoing | Total |
|---|---|---|---|
| Intra-<br>Department | 43.57 | 32.87 | 76.44 |
| Higher<br>Headquarters | 16.02 | 13.02 | 29.04 |
| Inter-<br>Department | 49.43 | 41.52 | 90.95 |
| Total | 109.02 | 87.41 | 196.43 |

In a study of management information system executives, Ives and Olson found that managers spend approximately ten percent of their time on telephone communications (Davis and Olson 1985:261-262). Nickerson cites a study conducted by H. Mintzberg in 1973 which indicates "that managers spend about 95 percent of their time in activities that can be classified as communication; the bulk of this time (about 75 percent) is spent in meetings and on the phone, and the remainder reading and writing." (Nickerson 1986:217) Of the time spent in meetings and on the phone, Mintzberg distributes 69 percent of the time to meetings and the remaining six percent to telephone calls.

The telephone communications aboard the Air Station are significantly beyond these ranges. This is

indicative of the amount of communication required to support the training environment, and of the coordination necessary to host the numerous aircraft squadrons which deploy to the Air Station throughout the year.

The interactive nature of the telephone is disruptive to the work routine. Additionally, "telephone tag", the problem of actually getting through to the required person, further taxes the telephone communication system aboard the Air Station. In recognition of this problem, the Air Station telephone system provides an automatic callback feature. While this reduces some of the aggravation and stress associated with telephone tag, it does not eliminate the disruptive nature of the telephone system nor does it provide any better access to information.

In general, "managers operate in an interruption-driven environment and have very little actual control over the flow of events." (Davis and Olson 1985:261) Barcomb indicates that for the typical manager, at least 30 minutes of nonproductive time per day can be attributed to shadow functions. Additionally, unscheduled interruptions amount to "136 minutes or 28 percent of the average eight-hour working day." (Barcomb 1981:12-13)

> Bair (1978) estimates that managers lose roughly half an hour a day to shadow functions (making phone calls that fail to connect, getting meetings under way, and so on). He estimates further that effective use of computer mail systems could save as much as two hours of the labor of nonclerical office workers per day.... (Nickerson 1986:218)

While the telephone system provides for the verbal communication of information, the distribution of paper output aboard the Air Station is primarily a manual process. Table VII portrays the methods used in the manual distribution of the information.

**TABLE VII**

**INFORMATION DISTRIBUTION**

| Method | Intradepartment | Interdepartment |
|---|---|---|
| Personally delivered | 36% | 24% |
| Guard Mail | 22% | 32% |
| Designated "Runner" | 14% | 16% |
| Other | 28% | 28% |
| Time required | 5-8 hrs/wk | 6-9 hrs/wk |

Most of the documents distributed within a department are personally delivered. This is indicative of the time that an individual is away from their desk and telephone. This absence compounds the telephone tag problem. Additionally, the delivery of documents is not a primary responsibility, thus, the effectiveness and efficiency of the individual are reduced.
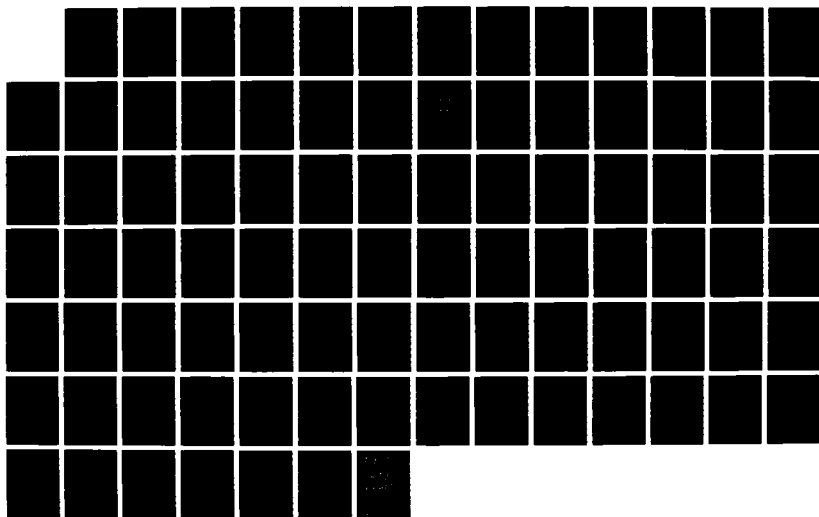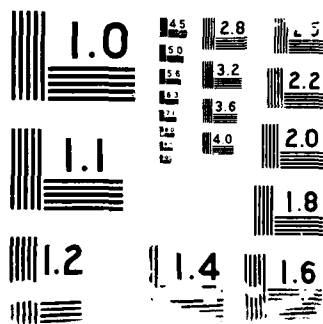
A combination of methods is used to distribute paper output external to the office. Guard mail is the primary distribution method, followed by personal delivery. The guard mail is a manual delivery system internal to the Air Station which functions to distribute information within and between departments. A guard mail "runner" is generally a Marine Lance Corporal (E-3) or Private First Class (E-2). The "runner" responsibilities are usually additional duties which supersede the individual's regular duties.

The survey reports that a runner makes 15 to 20 trips per week to pick up and deliver paperwork and, on average, each trip requires 26 to 35 minutes. Therefore the runner is not available to perform primary duties or for training approximately 7.5 to 10 hours per week. Because of this, the runner's primary duties must be distributed to other personnel, become a backlog of unfinished work, or require "overtime" to accomplish the assigned duties.

Generally, people are satisfied with the methods employed to distribute information; however, some employees are dissatisfied with the guard mail system. Even though there is general satisfaction with the distribution methods, the survey indicates that approximately 10 to 15 per cent of the paper output misses a deadline primarily due to the distribution system. Again, the guard mail system was identified as a primary cause. The missed deadlines cause additional burdens to be placed on the information system.

Telephone queries concerning the status of the information such as: Has it been completed? Is it being delivered? Why is it late? add to the disruption of the work routine. And the proverbial reply is: It's in the guard mail! This causes additional administrative stress within and between departments and adds to the perception of an increasing workload. Additionally, the survey reports that six to ten percent of all paperwork placed in the distribution system is lost. Here to, the guard mail system was singled out as contributing to the problem.

The introduction of a local area network which provides an electronic mail capability will not replace the current forms of information distribution or the telephone communication system. It will, however, supplement these other forms and improve the overall information communication and distribution functions. Through electronic mail, the communication within and between the functional subsystems can become more structured and planned. Electronic mail will allow an individual to respond to a message when it is convenient to do so, reduce interruptions, improve the ability to control the work flow, and give the message a better, more thoughtful response (Tapscott 1982:22-23; Barcomb 1981:81-83). An electronic mail capability will also provide an automatic record of messages sent, received, and answered thereby improving the audit trail and reducing the quantity of lost or misplaced documents (Nickerson 1986:174).

Barcomb reports that gains ranging from 19 to 25 percent can be obtained in managerial productivity through the proper application of electronic mail as an alternative to the current methods of information communication and distribution (Barcomb 1981:13).

Chorafas presents the following example of the application of an electronic mail system:

Manufacturers Hanover Trust, seeking ways to streamline its channels of internal communications, found the electronic mail system it installed in 1980 to be of great value. A management estimate indicates that about 19 percent of the user base is senior management, 28 percent is professional, and 53 percent is middle management. Currently there are some 2400 users sharing over 1000 terminals on the system. The biggest savings come from the elimination of phone calls, followed by the elimination of many paper memos and meetings.

It is hard to measure the productivity added by using wide-ranging electronic mail, but many users have estimated, through surveys, that the system saves 30 to 40 min/day (minutes per day). Multiplying that by the number of employees and by the average pay, one derives an estimated savings of millions per year in time alone, for a 2000- to 3000- people company. (Chorafas 1984:41)

As indicated by the survey, the Air Station anticipates similar savings in the dissemination of information as well as the productivity gains associated with the application of electronic mail. Specifically, 61 percent indicated that an electronic mail capability would be a benefit. The survey indicated that 8 to 11 hours per week could be saved through the use of electronic mail, primarily through the reduction of telephone calls, written correspondence, and meetings.

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### b. Information Production

Productivity gains and cost reductions are the most visible in the area of word processing. This is attributed to the fact that the output can be seen, measured or weighed. Similarly, the secretary-typist's performance can be measured, i. e., typing speed, number of errors per page and so on. Thus, productivity can be measured directly. However, the secretary-typist's costs amount to little more than six percent of the total labor costs. While the productivity gains in information production are tangible, they are only the "tip of the iceberg." (Tapscott 1982:20-21; Nickerson 1986:217)

Table VIII summarizes the survey results regarding the word processing function aboard the Air Station. Once a document is composed it must then be keyed into the memory typewriter. The survey indicated that most of the individuals type the document themselves. Thus, a typed document goes through at least three iterations: composition by hand, typing, and conservatively 22 percent of the time it must be retyped because of changes to the content.

Even though information production costs account for a small percentage of the total business costs, automation of the word processing tasks provide tangible benefits. A local area network which provides a personal computer with a word processing capability will improve the current methods of information production. A word processing capability will

## TABLE VIII

## WORD PROCESSING

| | |
|---|---|
| Primary method of composition | Pen and Paper |
| Primary method of typing | Memory Typewriter |
| Time spent typing | 11.5-16 hours/wk |
| Time spent retyping due to changes or errors | 1.5-2 hours/wk |
| Percent of retyping due to changes in content | 22-31% |
| Percent of retyping due to typing errors | 11-18% |

eliminate repetitive typing through the use of a comprehensive text editing capability. Additionally, there is no longer any requirement for hardcopy output until the final version of the document has been approved. Barcomb suggests that word processors "are most useful in the production of:

- Documents that are heavily revised

- Documents that are reissued after initial distribution

- Documents that contain forms or frequently used sections of text

- Lengthy documents of all kinds, for these usually require extensive editing.

Enormous production gains of 200 and 300 percent are possible when operators perform minimal keying in the revision of previously stored material." (Barcomb 1981:53)

As evidenced by the survey, 72 percent of the respondents consider their administrative paper workload to

be increasing relative to the previous year and that 49 to 59 percent of their workload is of a wholly standardized format or includes standard paragraphs. Examples of standardized documents are endorsements to temporary duty orders, inter-service support agreements, work requests, supply requisitions and legal documents. Through a combination of the word processing capability and electronic mail, the Air Station anticipates a substantial increase in productivity, similar to the examples presented.

### c. Information Management

"Automated means of filing and indexing...documents is becoming essential and must be coupled with the means of searching for and retrieving the required information." (Martin 1978:117)

The survey indicated that most paperwork is maintained in personal files and a central office file and that it takes approximately 6 to 9 hours per week to maintain the filing system. Additionally, between 2 to 4 hours per week are spent searching for missing or misplaced files.

Barcomb reports that

...some 35 percent of all filed papers are never retrieved; 90 to 95 percent are never accessed after the first year. Moreover, office studies show that 1 to 5 percent of all documents are misfiled, and that the average cost of a misfiled document is between $50 and $75. (Barcomb 1981:104-105)

Including an electronic filing and retrieval function in the local area network will provide for the rapid and accurate access to information stored in the local area network information system. Given appropriate security

precautions, information may be accessed regardless of the physical location of the user or the information. The electronic filing and retrieval system will not necessarily increase the percentage of information accessed; however, it will reduce and possibly eliminate the misfiling of documents thereby reducing the administrative costs associated with a filing system.

The following benefits were identified during the survey as obtainable from the implementation of a local area network information support system:

a. reduction in paper-based files;

b. reduction in lost information;

c. reduction in file searching time;

d. quicker access to documents and information.

In addition to these benefits Barcomb includes storage efficiency through shared access, portability of files, and time transparency as well as geographic transparency for access (Barcomb 1981:105).

### d. General Perceptions

Overall, 80 percent of the respondents said that a local area network that provided them with a personal computer and access to the application software which included the functions of word processing, electronic mail, and electronic filing and retrieval would be a benefit. Also, 80 percent of the respondents indicated that they would

use the local area network information support system if it were implemented.

The local area network incorporates computer technology to help people manage information. Intelligent workstations which automate labor intensive, error-prone tasks enable the individual to work smarter, not harder. The local area network is the communications component which links together multiple components within the organization in such a manner that information, once entered, can be processed and available or disseminated within the organization with a maximum of technological assistance and a minimum of human intervention (Barcomb 1981:2).

### 4.  **The Current Information System**

Brabb says that "the information system of an organization obviously reflects the structural organization of the firm." (Brabb 1980:41)  It follows then that the organizational information system consists of a similar hierarchical organization of integrated, functional information subsystems.  Within the Air Station, each functional information subsystem maintains its own information which can support or augment the information needs at the next higher level in the hierarchy as well as provide information to other subsystems outside of its formal hierarchical organization.

The Air Station's current organizational information system can be described as an aggregation of functional

information subsystems which reflect the structural hierarchy of the organization. Data is captured at the lowest levels of the information subsystems, processed, stored and transmitted manually as required or directed to others within the functional subsystem and between functional subsystems.

The primary method of information processing is still heavily dependent upon manual methods; however, many departments are beginning to automate their information processes. While the rate of automation is increasing, as evidenced by the quantities of microcomputers being requisitioned each month, there is neither a strategic nor tactical plan at the organizational level for the management of these resources. Also, there is no communication system for the interconnection of the data communications equipment within or between the functional subsystems which currently use microcomputers. Thus, the capture, processing, dissemination, storage and retrieval of information is still heavily dependent upon the manual organizational information system.

## D. DEVELOPING FUNCTIONAL REQUIREMENTS

In the process of developing the functional requirements for a local area network, the first step requires the characterization of the network. Is the network to be an application such as office automation or is it to be a communications utility? (Flint 1983:297)

The question may seem simplistic in view of the definition of a local area network as a communication system for interconnecting a collection of autonomous computers. However, it is an important distinction that must be made. A local area network characterized as an application system, such as a decision support system, implies that the application software is an inherent and necessary part of the network. If the implementation of such a network occurs only as a communications utility, then the user requirements have not been met and the wrong system has been installed.

For the Air Station, the answer to the above question is that the local area network is primarily to be considered as a communication utility. Since the current information system is largely a manual system, it could be argued that the local area network should be characterized as an office automation application system. However, the automation of the office has already been adopted as evidenced by the implementation of specific systems and the increasing number of requisitions for microcomputers, so that the focus is now on establishing communications between computing equipment within and between functional departments.

Overall requirements defined for the local area network are that (1) it meets current data needs as well as future growth requirements, (2) it provides reliable and effective service, (3) it provides flexibility to accommodate the changing environment of the Air Station such as the

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relocation of an office or the rearrangement of the office furniture, (4) it uses Department of the Defense standard end-user-computing equipment (EUCE) and off-the-shelf hardware and software, (5) it does not require extensive work on the facilities and (6) it has available the capability to access other networks. (Durr 1987:21; Flint 1983:37-41; Hopper, Temple and Williamson 1986:9-13; Cheong and Hirschheim 1983:11-16; Meisner 1980:151)

After the above requirements were identified, further analysis of current data needs revealed that while the application point of view has been considered, a great deal of application development is still required within the functional departments. For example, the Community Planning and Liaison Officer requires a database query application to interface with the Geographic Modeling System to aid in the management of the Air Installations Compatible Use Zone (AICUZ). The Community Planning and Liaison Officer is the Station commander's representative to the civilian community regarding land development and environmental matters within and around the Air Station to include the flight path and the bombing ranges.

Since the Community Planning and Liaison Officer deals with the civilian community concerning land development, much of the correspondence produced must be reviewed by the Staff Judge Advocate. Similarly, the Community Planning and Liaison Officer must coordinate with the Environmental

Engineer in the Facilities Management department on environmental matters.

In the case of the Community Planning and Liaison office, functional requirements include a database management system, a word processing capability, a file transfer and document review, or "chop" capability, with at least two other departments as well as the need for electronic messaging to obtain information prior to, during, and subsequent to document preparation.

As in the above example, each department was evaluated to determine functional requirements such as word processing as well as interdepartmental communications requirements. As discussed in Chapter II, there are differing information needs at the different levels within the organizational hierarchy: transactional, operational and strategic. In determining the information requirements the focus was not on the specific requirements as such, but at the macro level or organizational level, resulting in emphasis on the interaction between the functional departments. Also, given that the network is being considered as a communications facility, the emphasis was placed on interdepartmental requirements in general, such as the interaction described between the Community Planning and Liaison Officer, the Staff Judge Advocate and the Environmental Engineer.

The results of the analysis are presented in Table IX which is a matrix of information and communication

interaction between the functional departments within the Air Station. The matrix, though, is not all-encompassing. One task that the Comptroller performs is the coordination of the planning, execution and evaluation of the budgeting process. In order to accomplish this task for the Air Station, the Comptroller has 27 Fund Administrators (FA) that are intimately involved with the budgeting process throughout each fiscal year. While there is almost daily communication between the Budget Division, the Comptroller and the Fund Administrators, this information and communication requirement is considered incidental to the organizational system under analysis.

Similarly, Table IX highlights the commander's need for current information which dictates a strong information and communications network with the executive and special staffs and the subordinate commanders.

Functional requirements for word processing, project management or database management vary in priority by functional department, depending upon the specific task. However, at the organizational level, the functional requirements in order of priority are (1) electronic mail, (2) word processing, (3) database management and, (4) spreadsheet.

TABLE IX

## INFORMATION AND COMMUNICATION INTERACTIONS

| FROM \ TO | CO | XO | H&HS | SOMS | S-1 | S-4 | SUPPLY | COMPT | FAC MGT | ADJUTANT | CP & L | MGT ENGR | CPO | SJA | PMO | PAO | ASC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO |  | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | O |
| XO | X |  | X | X | X | X | X | X | X | X | X | X | X | X | X | X | O |
| H&HS | X | X |  |  | X | X |  |  |  | O |  |  |  | X | X | X |  |
| SOMS | X | X |  |  | X | X |  |  |  | O |  |  |  | X | X | X |  |
| S-1 | X | X | X | X |  | X |  | O | X | X |  | X | X |  |  | X | X |
| S-4 | X | X | X | X | X |  | X | O | X |  |  | X |  |  |  |  |  |
| SUPPLY | X | X | O | O |  | X |  | X | X |  |  | X | X |  |  |  | X |
| COMPT | X | X |  |  |  |  | X |  | X |  |  |  | X |  |  |  | X |
| FAC MGT | X | X | O | O | X | X | X | X |  |  |  | X | X | X | X |  |  |
| ADJUTANT | X | X |  |  | X |  |  |  |  |  |  |  |  |  |  | X |  |
| CP & L | X | X |  |  |  |  |  | X |  |  |  |  | O | X |  |  | X |
| MGT ENGR | X | X | O | O | X | X | X | O | X |  |  |  | O |  |  |  |  |
| CPO | X | X |  |  | X |  | X | X | X |  |  |  |  |  |  |  |  |
| SJA | X | X | X | X | O |  |  | O | X |  | X | O | O |  | X |  |  |
| PMO | X | X | X | X | O |  |  |  |  |  |  |  |  | X |  | O | X |
| PAO | X | X | X | X | X |  |  |  |  | X |  |  |  |  |  |  |  |
| ASC |  |  | O | O | X | O | X | X |  |  |  | X |  |  | X |  |  |

X = two way information and communication flows

O = primarily one way information and communication flows

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## E. CONCLUSION--THE NEED FOR CHANGE

The Air Station is a complex organization composed of functional subsystems integrated into the whole. Command, control and administration of the Air Station requires close coordination of information and communication within and between the functional departments of the organization.

More and more of the manual processes are being automated. Advances in technology, a reduction in the cost of microcomputers, and an increasing acceptance of office automation has led to an increasing number of microcomputers being employed aboard the Air Station. Even so, the organizational information system is still primarily a manual system. Information is transmitted personally or through the guard mail in the form of paper documents. Communications within and between departments rely upon the telephone system and the guard mail. As the survey indicated, there is a great amount of time devoted to the production of information, i.e., the retyping of documents. The distribution of information consumes approximately one day per week. Similarly, the filing system requires one day per week, thus reducing the amount of time available to spend on primary tasks. The implementation of a local area network will not magically do away with the requirement for paper documents or a filing system. Nor will the implementation reduce the requirements for information and communications. However, a local area network will improve intra and interoffice

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communications, will provide a framework for the structure of the organizational information system, and will provide the expansion and flexibility necessary to meet the future information and communication requirements of the Air Station.

Durr says that "networking is a communications mechanism that ties the isolated PC into the organization." (Durr 1987:15) A local area network will provide the interconnection between these isolated, autonomous information subsystems within and between the functional departments of the Air Station. Properly designed, a local area network can easily meet the functional requirements identified above and improve the coordination and flow of information across the organization.

The next chapter discusses the design of the organizational local area network information support system.

# IV. LOCAL AREA NETWORK DESIGN

## A. INTRODUCTION

With the declining cost of the microcomputer and the increased productivity realized in the automation of office tasks, the microcomputer is the workstation of choice (Durr 1987:17). Even so, the inability of the microcomputers to communicate prevents the effective distribution of information within the organization.

Studies of the distribution of information within organizations show that "90% of all information is distributed within half a mile and in excess of 75% is distributed within 600 feet" (Cheong and Hirschheim 1983:9) and that "roughly half of the data generated within a department is distributed within that department only." (Stallings 1986:91) Similarly, Katzan describes a rule of thumb that can be used with the information distribution process as the 80/20 rule--80% of the information within a department is generated and used within that department while only 20% of the information is received from or sent outside of the department.

To improve the distribution process and to enhance local communications, "the local area network is the system which permits the efficient communication of information among intelligent entities (i.e., persons and software) in a local environment." (Katzan 1983:1)

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As such, the local area network is the glue which will cement the components of the departmental information systems with that of the organization so that the importance of the local area network will continue to grow in supporting the organizational information system.

However, to support the organizational information system, the network must be designed with an understanding of the user's requirements and the characteristics and capabilities of such a network.  A misunderstanding or misconception in any one of these areas may well result in the right solution to the wrong problem. (Bradley 1984:1-12; Flint 1983:297; Held and Sarch 1983:366)

## B.  THE YUMA LOCAL AREA NETWORK INFORMATION SYSTEM

There are basically two approaches to consider when designing an organizational local area network. One approach is to design a single, monolithic network connecting each of the buildings and providing connectivity to each of the devices.  A second approach entails the development of sub-networks (one for each functional department) and providing an organizational backbone local area network to provide the communication network for interdepartmental communication. (Stallings 1986:91)

There are several advantages to the second approach that are not shared with the design and implementation of a single organizational network.  Multiple networks improve

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reliability by partitioning the network into self-contained

segments which support modularity and provides flexibility.

Performance generally declines as the number of devices

increases and the physical length of the network grows. By

designing and implementing departmental subnetworks, the size

of the departmental network is small relative to the organi-

zation's size. By establishing subnetworks and providing

internetwork connectivity, performance can be improved by

ensuring that intranetwork traffic exceeds internetwork

traffic. A key advantage in the multiple network concept is

that the security of data can be enhanced beyond that of a

single network. Multiple networks prescribe multiple levels

of security. (Stallings 1984:295)

Additionally, an organization is itself a system made up

of many subsystems and ultimately, all organization systems

are linked (Barcomb 1981:5). Champine says that

> ...perhaps the most important feature of the distributed
> data system is that it allows the structure of the EDP
> system to be the same as the natural organization
> structure....The resulting close integration of the EDP
> system and the organization can enhance productivity and
> enable persons responsible for each function to have
> control of and easy access to the EDP capability necessary
> for them to carry out their responsibilities effectively.
> (Champine 1978:164)

Considering the geographic dispersion, the functional

specialization and the user's requirements for reliability,

expandibility, security and performance, the second approach

is used in the design of the local area network for the Air

Station. This hierarchical design also fits well with the

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MIS concept of a federation of loosely coupled functional subsystems. Figure 4.1 depicts the logical view of the network design.
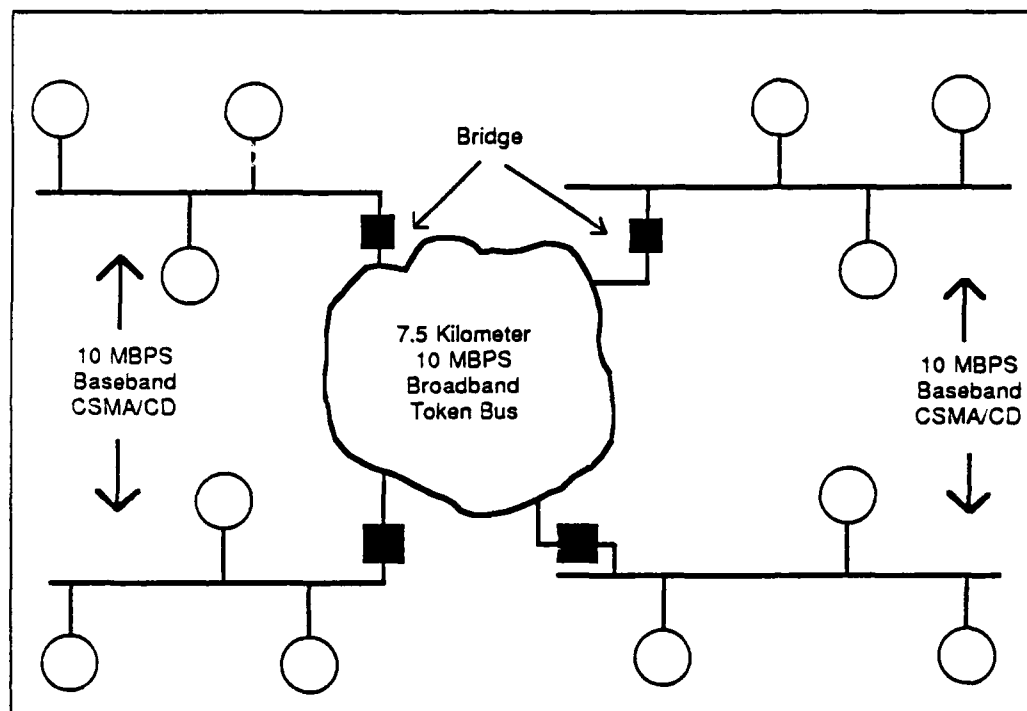


Figure 4.1 Conceptual Network Design

During the analysis, eight of the 26 functional departments were identified as requiring subnetworks. These eight departments are listed in Table X. Each of these subnetworks should employ baseband coaxial cable as the transmission medium. Because the physical distribution of microcomputers is dispersed throughout the offices, departments, and buildings of the Air Station, the topology selected for the

**TABLE X**

**DEPARTMENTAL SUBNETWORKS**

| Department | Topology | Transmission Media | Access Protocol |
|---|---|---|---|
| 1. CPO | Bus | Coax cable | CSMA/CD |
| 2. Disbursing | Bus | Coax cable | CSMA/CD |
| 3. Fac Mgt | Bus | Coax cable | CSMA/CD |
| 4. Headquarters | Bus | Coax cable | CSMA/CD |
| 5. IRC | Bus | Coax cable | CSMA/CD |
| 6. PMO | Bus | Coax cable | CSMA/CD |
| 7. SJA | Bus | Coax cable | CSMA/CD |
| 8. Supply | Bus | Coax cable | CSMA/CD |

subnetwork is the bus. Because a high percentage of the processing and user interaction will still take place through stand alone applications, the intradepartment network load is categorized as typically short, bursty traffic which leads to the selection of the CSMA/CD access protocol. Baseband coaxial cable is selected as the physical medium because of the ease of installation, high data rates, ease of expansion and potential for high capacity. Additionally, analysis of the current twisted-pair cable plant used in the telephone system indicates that it is nearly 80 percent utilized. To dedicate any of this cable plant to a data network would further degrade telephone service. For example, a department

or building would be required to forfeit two telephone numbers to support a data network capability. Appendix E contains the hardware and software requirements for each subnetwork.

Because interdepartmental communications may be as high as 50 percent and there is a current requirement for a video capability, a broadband backbone network, using token control access, is selected as the organizational local area network design. Figure 4.2 is the physical organizational network design. The backbone network provides connectivity for each of the departmental subnetworks, integrating the functional information systems into the organizational information system. The broadband coaxial cable integrates the data and video requirements and provides multiple channels with a high data rate which easily covers the geographic distances between the departments, provides the excess capacity and the expansion capability to meet future growth requirements. As reported by Dineson and Picazo, broadband is easily justified:

> Research and government facilities are generally large enough to justify the presence of broadband, based on distances, buildings, and required services. The numbers of distributed terminals, computers, and subsystems found in these installations are generally such that high-density communications is not a consideration for the future--it was needed 10 years ago. (Dineson and Picazo 1983:64)
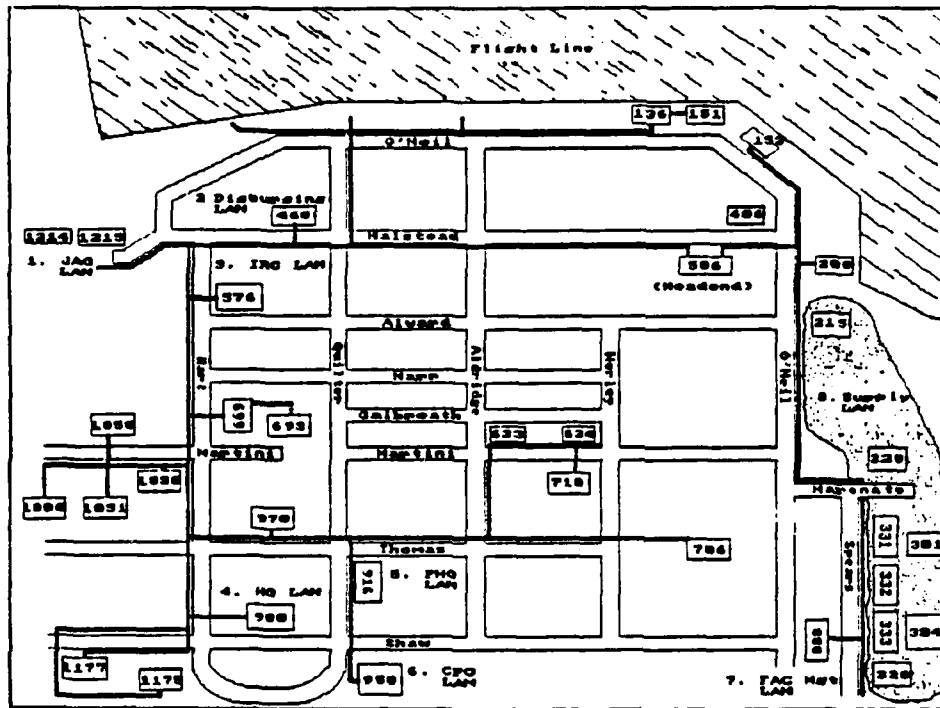
Scale: 3/4" = 400 ft

Figure 4.2 Physical Network Design

## C. LOCAL AREA NETWORK BENEFITS

Numerous benefits can be derived from the implementation of a local area network. The following list describes some of the major benefits of a local area network (Barcomb 1981:7).

- Optimizing staff
    Enhance human capabilities
    Conserve human resources
    Compensate for manpower shortages
    Minimize drudgery

- Increase productivity
    Improve accuracy
    Speed up throughput
    Speed up turnaround

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- Gain competitive edge
    Improve timeliness of information
    Improve decision-making
    Conserve natural resources

- Increase scope of control
    Enhance individual and organizational flexibility
    Make information portable

- Decrease expenses
    Reduce capital investment in structures
    Reduce or cap off payroll costs

The implementation of a local area network will also affect the organization. From the organizational perspective, "the capability to integrate personal computers through a local area network encourages continuity and compatibility so that administrative chores can be systematized." (Durr 1987:15) For example, the task of backing up files in the stand alone configuration is the responsibility of the user. If there are several users assigned to a particular personal computer, the task is often either overlooked or duplicated. With a local area network, the task can be assigned to a network administrator or automated in the file server.

However, the local area network is not without its problems. Table XI presents the organizational effects, both positive and negative, that a local area network may have on several areas. Just as the positive effects of a local area network can be maximized through careful analysis and design, so must the negative effects be minimized through this same analysis and design coupled with strategic and tactical information systems planning and a commitment from management. By ensuring that the local area network is

## TABLE XI

## ORGANIZATIONAL EFFECTS

| Affected Area | Positive Effects | Negative Effects |
|---|---|---|
| Work quality | Wider data accessibility; fewer "lost" items.<br>Wider participation in creating and reviewing work | Indeterminate or mediocre data quality; reduced independence and initiative |
| Productivity | Increased work load handled by more powerful office-systems equipment | Greater resources used to perform inconsequential work |
| Employee changes | Improved skill levels in current staff<br>More challenging work<br>Reduced status distinctions | Fewer jobs for marginal performers<br>Less personal interaction<br>Insufficient status distinctions |
| Decision-making effectiveness | Quicker availability of relevant facts<br>Greater analytic capability<br>More people involved in hypothesis building and testing | Factual component of decision making becomes too high<br>"Forest and trees" problem could encourage "group think" |
| Organizational structure | More effective decentralization | Decentralization can get out of control |
| Costs | Overall cost reduction | Overall cost increase; soft benefits used as justification |
| Total impact | Permits the planning of new business approaches | Creates increased complexity and poorly functioning dependence relationships |

Source: (Stallings 1984:6)

designed in consonance with the information system plan, data quality and data integrity can be assured through the use of well-defined data dictionaries. Similarly, proper alignment of the information system plan with the business plan will minimize the negative effects of decentralization on the organization. The analysis and design must consider the complexity of the organization as well as the complexity of the design to ensure that the local area network information system mirrors the organization and supports the mission of

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the organization. Only through a conscious effort by the system designer and management can the negative effects be minimized and the realization of the benefits and the positive effects be obtained.

In general, the Air Station will realize benefits directly related to both the automation of tasks and the implementation of a local area network. Overall, benefits obtainable across the Air Station include:

- Capability to meet the increasing administrative workload while maintaining the current manpower staffing levels.

- Capability to offset personnel shortages by providing the tools for the worker to work smarter, not harder.

- Job enrichment through the introduction of new technology.

- Increased productivity through improved document preparation, management, and distribution techniques.

- Reduced turnaround of documents, requisitions and interdepartment correspondence which results in increased throughput and ultimately improved morale of personnel directly affected by the information system.

- Improved timeliness of information affecting personnel, pay and allowances, and management.

- Improved decision making ability based upon more current, up-to-date information with quicker, better access to information.

- Capability to access information irrespective of the physical location of the user and the information.

- Reduction in equipment procurement costs realized through planning an integrated information system and resource sharing contrasted to the piece-meal procurement of stand-alone systems.

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Giuliano adds that

> If new information technology is properly employed, it can
> enable organizations to attain the following objectives:
>
>   1 a reduction of information "float", that is, a decrease
>   in the delay and uncertainty occasioned by the
>   inaccessibility of information that is being typed, is
>   in the mail, has been misfiled or is simply in an
>   office that is closed for the weekend;
>
>   2 the elimination of redundant work and unnecessary tasks
>   such as retyping and laborious manual filing and
>   retrieval;
>
>   3 better utilization of human resources for tasks that
>   require judgement, initiative, and rapid communication;
>
>   4 faster, better decision-making that takes into account
>   multiple, complex factors; and
>
>   5 full exploitation of the virtual office through
>   expansion of the workplace in space and time.
>   (Giuliano 1985:310-311)

Realization of the full benefits will only result from
careful planning and the integration of the subsystems with
that of the organization.

## D.  IMPLEMENTATION ISSUES FOR MANAGEMENT

### 1.  System Design and Management

Information is a resource which must be managed.
The design and implementation of an information system is a
change process affecting the organization in total.  To
effectively implement change, it must be managed also.
The local area network design presented in this research
provides the Air Station with a new, technologically
advanced, information system.  (Beckhard and Harris 1987:13;
Tichy 1983:17)

The process of managing the design, implementation, and subsequent use of the local area network information system can be described in terms of pre-implementation, implementation and post-implementation management. A common function to each of these stages is that of planning. Cheong and Hirschheim write:

> Successful implementation depends on a match between user needs and systems design. This match is achieved through assessment of organizational and individual variables affecting implementation outcomes. Such an assessment requires extensive planning. (Cheong and Hirschheim 1983:118)

To effectively accomplish the planning required, Champine recommends combining the technical functions with the management functions. By establishing a central control committee or group comprised of these two functions, management has ready access to technical expertise while strategic and tactical planning is provided to the technical function. Additionally, this group should be augmented with a representative (the subnetwork administrator) from each department under consideration to assist the central control group in defining current and future user requirements. Barcomb also recommends a central coordination effort. In contrast to Champine's strategy, Barcomb suggests forming a new, separate planning and control group. This group is established from current organizational assets and is permanent in nature.

This control group receives guidance from an upper management steering committee. The steering committee should

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be tasked with developing organizational policy and strategic plans. The planning and control group carries out the organizational policies, ensuring departmental compliance with the organizational goals. The control group can be expected to develop corporate expertise and thus provide analysis and design talents to the departments within the organization. It can also act as the focal point in the procurement and implementation process.

Given the manpower constraints within the Air Station, Barcomb's strategy is the most difficult of the two strategies to implement. However, as the Information Resource Center expands to provide information resource management, a logical extension would incorporate the central control group, properly staffed, within the Information Resource Center. Champine's strategy can be implemented relatively quickly as an ad-hoc committee to develop organizational standards and then allowing the departmental user to define requirements, procure and implement systems which comply with the standards established by the committee. The concern with Champine's strategy as it affects the Air Station is that the technical expertise is not available, resulting in inadequate or improper formulation of organizational standards.

Regardless of the specific planning and control group strategy used, certain billets are considered essential to the successful implementation of the local area network

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information system. These billets are: (1) a project manager, (2) assistant project manager, (3) network administrator, (4) assistant network administrator, and at least one subnetwork administrator from each department in the organizational network.

The project manager and the assistant project manager should be tasked with overall strategic network planning and management. Network management includes network operation and control, network monitoring, fault management resource control, testing, user support, job management, and the planning and execution of major changes in the network topology (Brookes, Johnson and Thomas 1984:155). These individuals should be the focal point for the organizational network and provide organizational continuity.

The network administrator should be tasked with the day to day operations of the Air Station's network, the backbone network. This individual should be the point of contact for the subnetwork administrators. Included in the day-to-day operations are requests for access to specific networks, security coordination between the various departments, and the central coordinator of the organizational network.

An individual from each department with a subnet should be appointed as the subnetwork administrator. This individual should be responsible for the day-to-day operations of the subnetwork, such as maintenance,

trouble-shooting, local security both physical and electronic, and provide training and assistance to the user. This individual acts as the point of contact for the Air Station network administer.

Stampler (1986) provides a detailed discussion concerning the requirement to establish particular billets directly related to the design and implementation of local area networks. Additionally, job descriptions for network management personnel are presented. Also Molloy discusses the management of a large, diverse network in a university environment. Molloy presents many of the problems encountered in managing large, multiple networks. Solutions and lessons learned highlight the requirement to include each subnetwork administrator as a member of the central network planning and control group (Molloy 1986:124-131).

## 2. **Information Systems Planning**

After the network management group has been established, a comprehensive information resources plan must be developed. This master information system plan should be aligned with the strategic plans of the organization. Because the resources of an organization are constrained, the master plan aids in resource allocation and implicitly in the setting of priorities. (Barcomb 1981:20)

The master information system plan typically is divided into two major components--a strategic component and a tactical component. The strategic component is a

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long-range plan of three to five years at a minimum. The tactical component is a short-range plan of one year. (Davis and Olson 1985:447)

The strategic plan should establish command policy regarding the design and implementation of information systems. It should provide the general goals and objectives of the organization in this regard. Thus, it becomes the functional action plan for the organization as a whole.

Developing the strategic plan requires answering three questions: Where are we (what is our current position)? Where do we want to go (what are our goals)? And how do we get there (what direction or plan will we follow)? (Katzan 1983:164; Barcomb 1981:21) Answering these questions establishes the framework for all detailed information system planning (Davis and Olson 1985:447). It must be stressed that the master information system plan must be flexible and subject to review, evaluation and adjustment to keep it aligned with organizational objectives and technological advances. Dorros presents nine network planning principles. A central theme of these principles is the alignment of the network plan with the business and information system and the capability of the plan to be robust enough to meet environmental uncertainties (Dorros 1986:2-4). Up to this point, this study has answered the first two questions.

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## 3. Implementation Strategy

The "Three Ps: Prototype, Pilot, and Production" is a strategy used in information systems implementation (Barcomb 1981:23). This concept answers the last question: How do we get there?

The prototype-pilot-production concept is a phased implementation strategy which seeks to minimize cost while risk is high. With this strategy, implementation begins on a small scale with incremental increases until the system is fully implemented.

There are specific advantages achieved with this phased implementation strategy.

- Cost is minimized when risk is high. As cost increases during the life cycle risk decreases.

- Weaknesses and problems can be discovered and assessed during prototyping. Adjustments to the system can be made before full scale production.

- Phased implementation develops the critical mass necessary to see the change process through to fruition.

- It enhances the progression along the organizational learning curve prior to the production phase.

The local area network design for the Air Station is particularly well-suited for the prototype, pilot, production strategy. The design of the subnetworks and the backbone as separate, independent networks facilitates a phased implementation.

Specifically, the prototype, pilot and production phases are:

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1. **Prototype**: Install the Information Resource Center network. This will be the training platform for the Air Station. Also, install the Staff Judge Advocate network. Evaluate and correct problems. Train pilot phase users.

2. **Pilot**: Install Headquarters network, Civilian Personnel Office network, Disbursing network and the first phase of the Supply network. Continue evaluation of proto-type networks and continue network training for current and production network users.

3. **Production**: Install Facilities Management network, Provost Marshall's Office network and complete the Supply network. Install backbone network, continue training.

This implementation strategy provides flexibility in planning, organizing and managing. The implementation can proceed as quickly as desired or as slow as necessary because of the excellent evaluation, feedback, and adjustment process inherent in the strategy. As network needs are identified by other departments not included in this initial study, the central planning and control group can evaluate their requirements against the master information system plan which is the foundation for detailed information system planning. In this manner the benefits of technology can be implemented in a controlled, standardized environment ensuring connectivity and compatibility with the current information systems, and yet still provide the flexibility to capitalize on newer technology.

### 4. Cost-Benefit Analysis

This cost-benefit analysis demonstrates the cost effectiveness of new technology implemented as a local area network information support system. This analysis also

provides a frame of reference for the management of the Air

Station upon which a go/no-go decision can be made to pursue

the design and implementation of a local area network. Actual

costs will vary from these figures because of the contracting

process and the possibility of purchasing from an established

contract.

Considering the fact that there are numerous projects

competing for scarce dollars at any one time, the cost-

benefit analysis aids in the decision-making process of

resource allocation. Because many of the subnetworks include

costs for microcomputers, software, and other peripherals as-

sociated with the stand-alone operation of the microcomputer,

cost savings and cost avoidances include tangibles associated

with the automation of tasks as well as the benefits obtained

from the improved communications capabilities introduced by

the local area network.

Appendix F presents the data used to determine cost

savings. In many cases, not only is productivity improved,

thus realizing a cost savings, personnel turnover will also

be reduced thereby avoiding additional training costs. Also,

the need to hire additional personnel to fill the current and

projected billets required to meet the increasing

administrative workload will be obviated.

The implementation of the organizational local area

network proposed in this study should result in the following

annual dollar savings or expense avoidance:

| | | |
|---|---|---:|
| 1. | Information Production | $161,698.53 |
| 2. | Information Distribution | $56,837.68 |
| 3. | Information Management | $72,882.12 |
| 4. | Facilities Management estimate | $31,100.00 |
| | Total Annual Savings = | $322,518.33 |

As indicated in Appendix E, the initial investment in the network, not including annual operating costs, is $1,008,700.00. Because the net present value methodology explicitly and systematically weighs the time value of money, it is the best method to use for long-range decisions (Horngren 1981:308). The useful life of the network is set at five years for computational purposes. The discount rate used is ten percent. Table XII shows the net present value calculations. The analysis yields a positive net present value of $213,870.10 indicating that the investment is desirable.

## TABLE XII

## NET PRESENT VALUE ANALYSIS

| Cash Flows | Present Value of $1, Discounted @ 10% | Total Present Value |
|---|---|---|
| | | ($322,518.33, 1987 Dollars) |
| Annual Savings: | | |
| Year 1 | 0.9091 | $293,201.41 |
| Year 2 | 0.8264 | 266,529.14 |
| Year 3 | 0.7513 | 242,308.02 |
| Year 4 | 0.6830 | 220,280.01 |
| Year 5 | 0.6209 | 200,251.63 |
| Present Value of future inflows | | $1,222,570.10 |
| Initial outlay | | 1,008,700.00 |
| **Net Present Value** | | $213,870.10 |

An additional method of determining the desirability of an investment is the payback model. The payback or payoff is the length of time required to recoup the initial investment. The formula for the payback model is:

$$\text{Payback period} = \frac{\text{Investment Cost}}{\text{Annual Savings}}$$

Applying the payback model yields:

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$$\text{Payback period} = \frac{1{,}008{,}700.00}{322{,}518.33} = 3.12 \text{ years}$$

Thus, in approximately three years, the full investment will be recovered through the savings generated.

By combining the net present value analysis with the results of the payback model, it is further demonstrated that the local area network information system is a cost effective alternative to the current information system.

## V. CONCLUSIONS AND RECOMMENDATIONS

### A. SUMMARY

The purpose of this thesis was to demonstrate the application of academic theory using the Marine Corps Air Station, Yuma, Arizona as a case study. The synthesis of theory from structured systems analysis and design, management, organizational theory, as well as data and computer communications provided the foundations for the multi-disciplinary approach used in this research.

Using the structured systems analysis and design systems life cycle as a model, a strategy was developed to conduct a feasibility study. The methodology included studying the current organizational system, defining the user's requirements, developing alternative solutions to the problem, and analyzing the cost-effectiveness of the alternatives developed.

The user's requirements were determined through personal interviews, background research, and a survey. The survey was developed to identify needs and to capture personal perceptions concerning the automation of tasks and the degree to which the current information processing and communication needs were unfulfilled.

Having defined the functional requirements, an alternative information system was presented in the form of a

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hierarchical or layered organizational local area network information support system. Implementation issues were presented and an implementation strategy was developed as one possible approach for the management of organizational change. Finally, a cost-benefit analysis was conducted using both the net present value method and the payback method to demonstrate economic feasibility of the local area network.

## B. CONCLUSIONS

There is no single, all encompassing methodology designed specifically for the analysis, design and implementation of a local area network. Similarly, there is no single local area network design which will meet every need of an organization. With an understanding of the philosophies underlying structured systems analysis and design, data and computer communications and local area network design, an appropriate strategy can be developed.

Applying the life-cycle model and the management information systems concept, a local area network can be designed to meet the needs of the functional subsystems while integrating this design into the organizational information system. By designing a federation of functional subsystems, the organizational information system will fit the structure of the organization and, through planning, the design will be aligned with the organizational business and information systems plan.

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The local area network technology is maturing. With the introduction of standards at both the hardware and software levels, these standards will enhance compatibility and connectivity, thereby reducing the complexity of design, selection, implementation and management.

The Marine Corps Air Station, Yuma, Arizona is a complex organization composed of highly specialized functional subsystems. The integration of these diverse subsystems place heavy demands on the organizational information system. The complexity of the organization and its information system requires both a strategic and a tactical information system plan. The Air Station's information system planning has been non-existent. Changes in the Air Station's information system have been evolutionary. New systems and changes to the current system have been implemented piece-meal with no thought given to the organizational information system. Automation has been encouraged, however, there is no overall direction, guidance or plan tieing the functional subsystems into the organizational information system. The Air Station has realized its lack of information systems planning. The formation of the Ad-hoc Local Area Network committee is the first step towards developing an organizational information systems plan.

Although many offices are beginning to automate, the Air Station's information system is primarily a manual system. The demand for information within and between the functional

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subsystems has overburdened the telephone system. As
indicated in the survey, telephone communications consume an
inordinate amount of time each day. Similarly, the informa-
tion production, management, and distribution systems are
technologically obsolete and overburdened. Documents are
composed by hand, keyed into a memory typewriter, and then
the hardcopy of the document is edited. Corrections are
rekeyed beginning the process anew. The manual filing
systems require one day per week to maintain while one-half
day per week is required for searching for lost or misplaced
documents. Information distribution takes the form of
personally delivered documents followed by the use of the
guard mail system, both labor intensive and neither a primary
responsibility.

The local area network information support system concept
presented in this thesis is one alternative solution to meet
the functional requirements of the organizational information
system. The local area network design will not replace the
current, manual organizational information system. It will,
however, supplement the current information system, improving
the production, management, and distribution of information
through the functionality of word processing, electronic
mail, and a database management system. Additionally, intra
and interoffice communications will be enhanced through the
functionality of electronic mail, thereby reducing the burden
on the telephone system and improving the manager's ability

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to control the flow of work. The local area network informa-tion support system will provide a framework for the struc-ture of the organizational information system and will mirror the structure of the Air Station. Additionally, the local area network information support system proposed is technically and operationally feasible and economically viable.

The prototype-pilot-production implementation strategy provides one alternative strategy for the management of change in a complex organization. This is an appropriate strategy for the Air Station. This strategy will minimize organizational risk when capital investment is high. It provides the evaluation and feedback mechanism necessary for continuing management control and approval. The evaluation and feedback loop of the prototype-pilot-production strategy will enhance the organization's ability to capitalize on the local area network learning and experience curve.

Through proper planning the overall cost of the local area network information support system will be reduced. Strategic and tactical information systems planning will result in improved analysis, thereby reducing the amount of redundant hardware and software. The modular design of the Air Station's network will meet the organization's require-ments for reliability, flexibility, security and ease of expansion. Additionally, the modular design conforms with the management information systems concept of the integration

of the functional subsystems within the organizational information system.

## C.  RECOMMENDATIONS

The following recommendations are presented for the consideration of the Ad-hoc Local Area Network committee in regards to the local area network information support system proposed in this thesis.

Develop the strategic and tactical information system plans in consonance with the Air Station's mission, goals and objectives.  After developing the organizational information systems plan, implement the local area network information support system presented in this research using the prototype-pilot-production strategy presented in this thesis.

Establish a central network control group to define command policies and standards and to establish priorities for the expenditure of capital funds.  Encourage local determination of requirements, procurement and installation of systems meeting command policies and standards.

Establish command billets as suggested by Stampler to provide organizational continuity.  Develop measures against which manpower requirements can be evaluated with respect to the automation of the information system.  Adjust manpower requirements as needed.

Designate the Information Resource Center as the organizational technical network control center.  All network

upgrades should be performed on this network first as a testbed. Phase the changes into the network as a whole from this network.

Ensure that a network administrator is appointed for each subnetwork within the organizational information system network. Organize a network administrator's standing committee. There should be a free flow of information between the subnetwork administrators as well as with the organizational network administrator. As Molloy pointed out many problems encountered with a network have occurred before. The network administrator's standing committee will be able to draw upon organizational experience to resolve many of these problems.

Encourage the establishment of special interest groups and network user's groups to enhance the change process and to ensure user acceptance of the new system.

A decision by the Air Station to continue with the systems development process will present numerous areas for further research. These include network performance, network management and security, distributed data processing design, implementation, and management as well as software engineering in the development of application software.

From an organizational perspective the Air Station may provide a unique opportunity to study the evolution of the organizational structure, the formal and informal communication networks as well as the strategic and tactical planning system and the management of change.

In particular, further research is required to develop an appropriate methodology for the analysis and design of the organizational information system which employs or is considering the employment of a local area network. Additionally, standards and measures need to be developed to evaluate the cost-effectiveness of implementing a local area network. Better measures to evaluate the productivity of managers, particularly in the area of communications and time management need to be developed to answer the questions of efficiency and effectiveness of the communications utility provided by a local area network and ultimately the productivity of the manager.

# APPENDIX A

## MARINE CORPS AIR STATION, YUMA, ARIZONA
## ORGANIZATIONAL HIERARCHY STRUCTURE

**DESCRIPTION:** This appendix presents the organizational structure of the primary staff of the Marine Corps Air Station, Yuma, Arizona. A synopsis of the tasks of each of these functional subsystems is presented. A complete description of each subsystem, its tasks, duties and responsibilities can be found in Marine Corps Air Station, Yuma, Arizona Station Order P5451.1D.

S-1

Tasks:   To provide management and budgetary planning of
military and civilian personnel to ensure efficient use
of manpower resources.   Exercises staff cognizance over
military personnel, civilian personnel, family
services, drug and alcohol and data processing.   This
includes:

1. Reviewing and monitoring manpower requirements
   including the Fleet Assistance Program.

2. Supervises the assignment, reassignment,
   transfer and reclassification of personnel.

3. Providing electronic and automated data
   processing services.   (StaO P5451.1:4-3)

```
                        +-----------+
                        |    S-1    |
                        +-----------+
                              |
     +------------+-----------+-----------+------------+
     |            |                       |            |
+-----------+ +-----------+ +-----------------+ +-----------+
| Automated | | Family    | | Manpower        | | Drug      |
| Services  | | Service   | | Utilization     | | and       |
| Center    | | Center    | | ----------      | | Alcohol   |
+-----------+ +-----------+ | Military        | +-----------+
                            | Personnel       |
                            +-----------------+
```
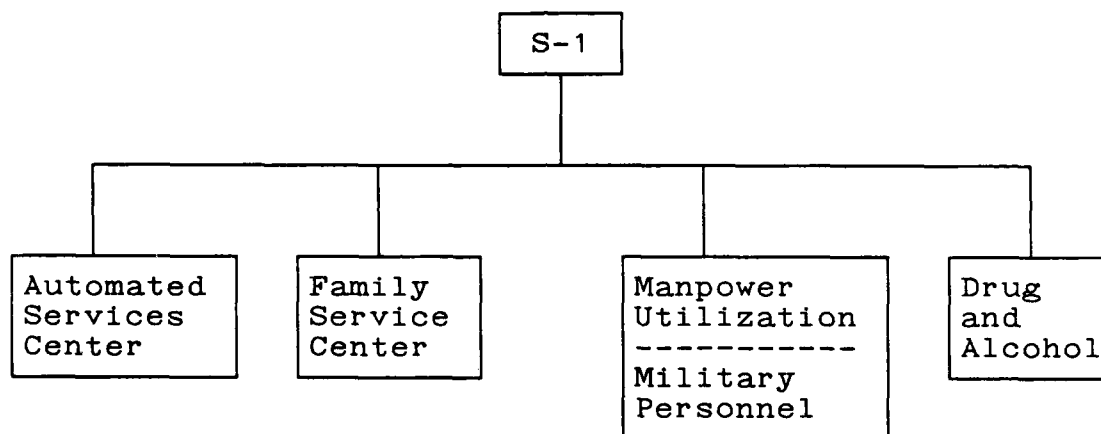
S-1 Organizational Structure
(StaO P5451.1:4-4)

S-4

Tasks:   Plans, coordinates and supervises all aspects
of the Station's facilities.   This includes the
billeting of all bachelor permanent personnel and all
transient personnel.   (StaO P5451.1:5-3)

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```
                    ┌─────────┐
                    │   S-4   │
                    └────┬────┘
              ┌──────────┴──────────┐
        ┌─────────────┐      ┌─────────────┐
        │  Billeting  │      │   Armory    │
        │  Division   │      │  Division   │
        └──────┬──────┘      └─────────────┘
        ┌──────┴──────────────────┐
   ┌─────────┐   ┌─────────┐   ┌─────────────┐
   │   BOQ   │   │   BEQ   │   │  Billeting  │
   │ Branch  │   │ Branch  │   │    Fund     │
   └─────────┘   └─────────┘   └─────────────┘
```
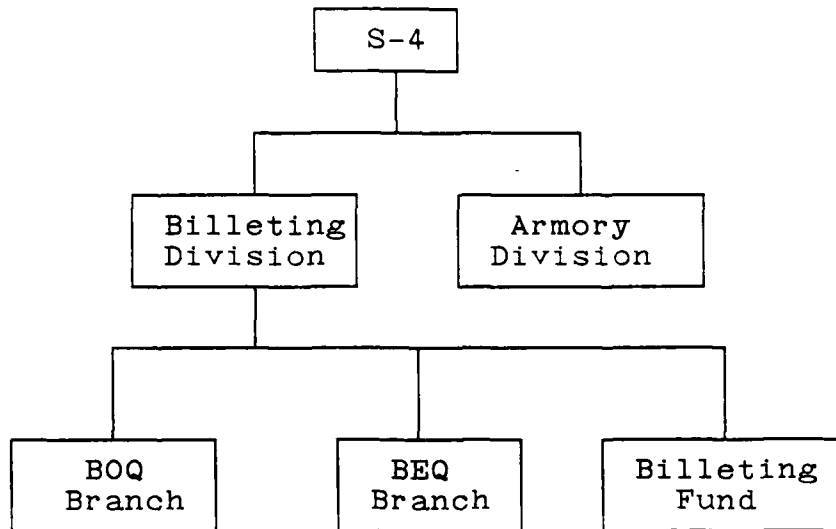
S-4 Organizational Structure
(StaO P5451.1:5-4)


## Comptroller

Tasks:  Responsible for maintaining an integrated
system for the financial management of the resources of
the Air Station.  Coordinates budget planning,
execution and evaluation.  (StaO P5451.1:6-3)

```
                ┌──────────────┐
                │ Comptroller  │
                └───────┬──────┘
      ┌───────────┬─────┴─────┬───────────┐
 ┌──────────┐ ┌──────────┐ ┌──────────┐ ┌───────────┐
 │ Internal │ │ Budget & │ │Accounting│ │Disbursing │
 │  Review  │ │Progress/ │ │ Division │ │ Division  │
 │ Division │ │Stats Div │ │          │ │           │
 └──────────┘ └──────────┘ └──────────┘ └───────────┘
```
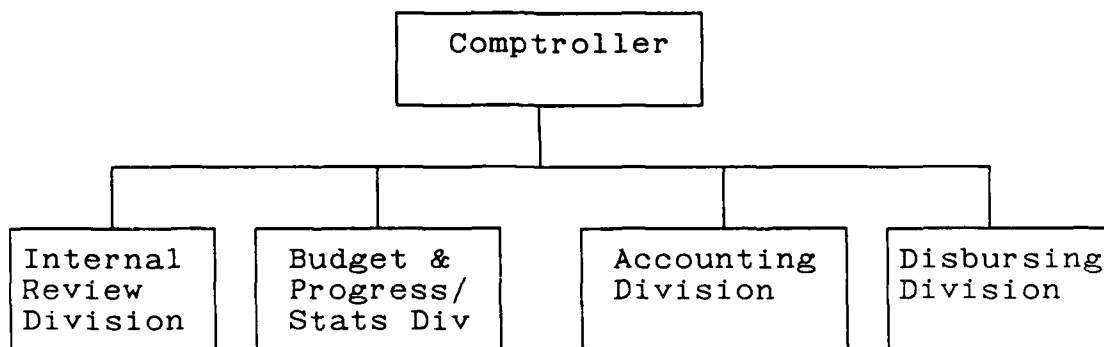
Comptroller Organizational Structure
(StaO P5451.1:6-6)


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## Supply

Tasks:  To provide full supply support and services to the Air Station and to all tenant aviation activities. Provides traffic management services to include household goods.  Responsible for the management of Marine Corps Property items.  Also provides linen services for the Air Station, tenant and transient units.  (StaO P5451.1:7-3)

```
                    ┌──────────────┐
                    │   Supply     │
                    │   Officer    │
                    └──────┬───────┘
                           │
              ┌────────────┴─────────┐
              │     Assistant        │
              │  Supply Officer      │
              └──────┬───────────────┘
                     │         ┌──────────────────────┐
                     │─────────│   Supply Chief/      │
                     │         │ Military Personnel   │
                     │         └──────────────────────┘
     ┌───────────┬───┴─────────┬──────────────┬──────────────┐
┌─────────────┐ ┌───────────┐ ┌─────────────┐ ┌───────────┐
│ Management  │ │  Supply   │ │  Material   │ │  Marine   │
│ Planning    │ │  Support  │ │ Management  │ │  Corps    │
│ Division    │ │  Division │ │  Division   │ │ Property  │
│             │ │           │ │             │ │ Division  │
└─────────────┘ └───────────┘ └─────────────┘ └───────────┘
```
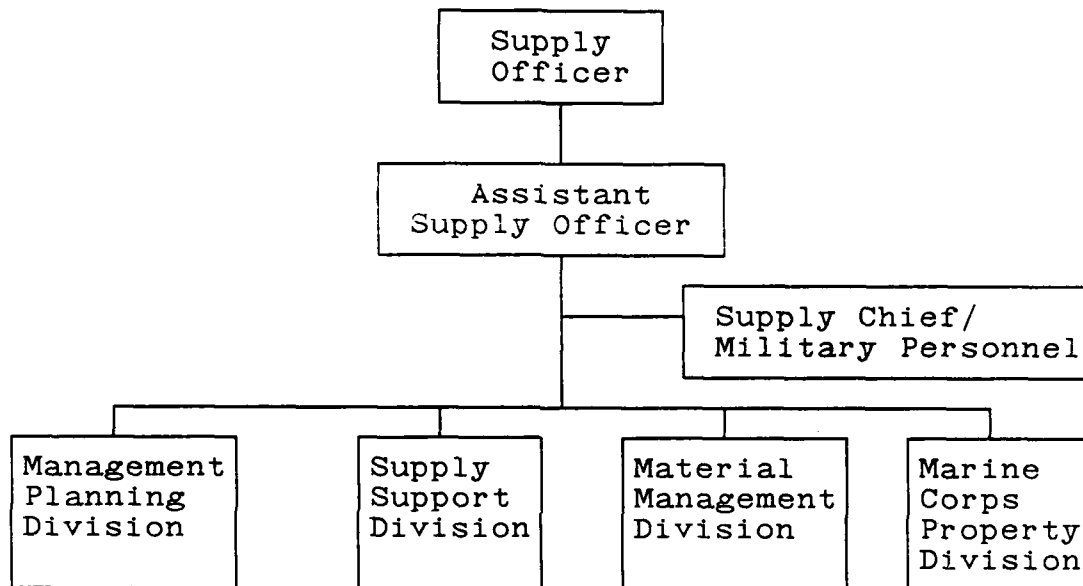
Supply Organizational Structure
(StaO P5451.1:7-10)

## Facilities Management

Tasks:  Responsible for the construction, maintenance, repair and operation of public works and public utilities; maintenance and operation of family housing; and maintenance and repair of garrison mobile equipment; coordinates environmental issues.  (StaO P5451.1:8-3)

```
                    ┌──────────────────────────┐
                    │   Facilities Management   │
                    │       Department          │
                    └──────────────────────────┘
                                 │
   ┌───────────────────┐        │        ┌───────────────────┐
   │   Environmental   │────────┼────────│  Administrative   │
   │     Engineer      │        │        │     Division      │
   └───────────────────┘        │        └───────────────────┘
                                 │
        ┌──────────────┐        │        ┌──────────────┐
        │    Plans     │────────┼────────│   Housing    │
        │   Officer    │        │        │   Division   │
        └──────────────┘        │        └──────────────┘
                                 │
   ┌───────────────────┐        │        ┌───────────────────┐
   │   Engineering     │        │        │  Transportation   │
   │     Division      │        │        │     Division      │
   └───────────────────┘        │        └───────────────────┘
                                 │
┌──────────────────────┐        │     ┌──────────────────────┐
│     Maintenance      │        │     │    Maintenance and   │
│  Control Division     │        │     │  Utilities Division  │
└──────────────────────┘              └──────────────────────┘
```
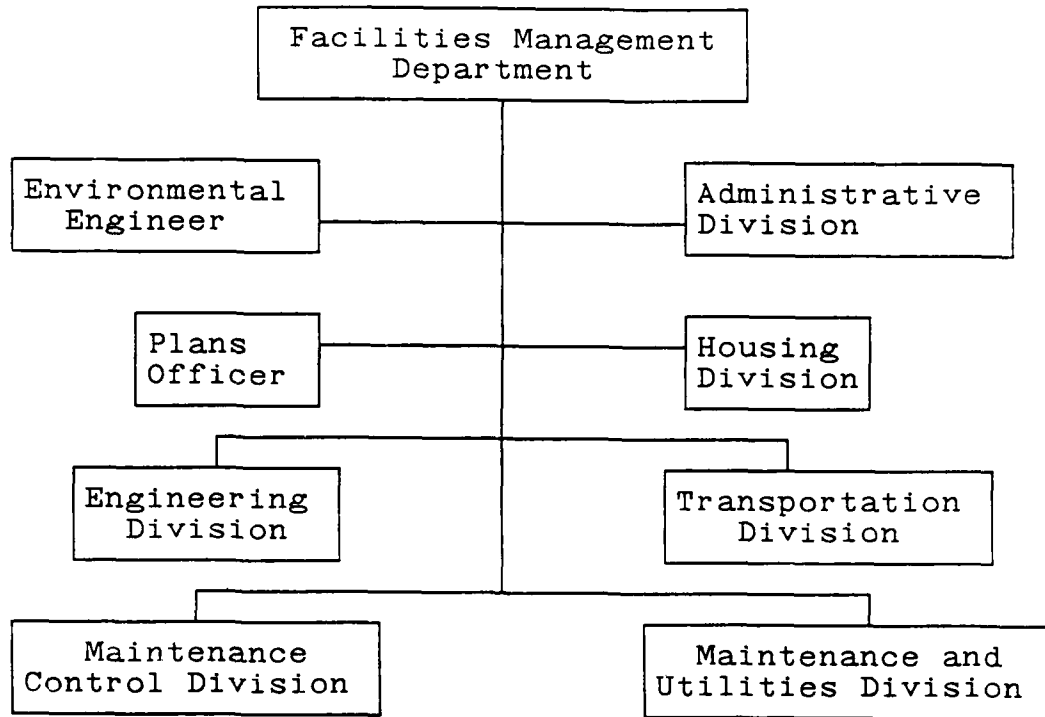
Facilities Management Organizational Structure
(StaO P5451.1:8-6)

LOCAL AREA NETWORK INFORMATION
SUPPORT SYSTEM SURVEY


**DESCRIPTION**: Appendix B contains an abbreviated version of
the Local Area Network Survey. The survey was conducted to
gather data about the current information system and personal
attitudes concerning the automation of information tasks.
The survey was designed to sample a large cross section of
personnel aboard the Air Station in order to obtain a fair
representation of the population.

Marine Corps Air Station, Yuma, Arizona
Local Area Network Information Support System
Survey

---

This survey is being used to collect data about your

current information requirements, office automation equip-

ment, and the procedures for collecting, processing and

managing that information at your installation.  Your

responses to this survey will help determine the feasibility

of implementing a local area network information support

system.

The study is being conducted at the U. S. Naval Post-

graduate School, under sponsorship of the Commanding Officer,

Marine Corps Air Station, Yuma, Arizona.

Instructions:

1.  Where numerical answers such as hours per day or
    percentage of time are requested, your best
    estimate is sufficient.

2.  It will take you about 20 to 25 minutes to complete
    the survey.  Please take your time to consider each
    question carefully.


Rank_____/MOS_____/Billet_____


Unit_____

    (For example, H&HS S-1)

Questions

## I. Telephone Communications

1. About how much time each day do you think you
   spend on <u>incoming</u> telephone calls:
   a. From within your office/section?
      Minutes:_____
   b. From your department head/immediate superior?
      Minutes:_____
   c. From higher headquarters located aboard the Air
      Station within your formal chain of command?
      Minutes:_____
   d. From sections/organizations located aboard the
      Air Station which are outside of your formal
      chain of command?  Minutes:_____

2. About how much time each day do you think you spend
   on <u>outgoing</u> telephone calls:
   a. Within your office/section?
      Minutes:_____
   b. To your department head/immediate superior?
      Minutes:_____
   c. To higher headquarters located aboard the Air
      Station within your formal chain of command?
      Minutes:_____
   d. To sections/organizations located aboard the Air
      Station which are outside your formal chain of
      command? *Minutes:*_____

3. What percentage of your outgoing calls (listed in
   question 2) go through:
   a. On the first try?_____%
   b. On the second try?_____%
   c. On three or more tries?_____%

## II. Information Production:

1. Which of the following methods do you use to produce
   typed output? (Please circle all that apply.  Please
   indicate the primary method used.)
   a. Personal computer with printer
   b. Dedicated word processor with printer
   c. Memory typewriter
   d. Electric typewriter
   e. Manual typewriter
   f. Not applicable

2. How do you most often compose written documents?
   a. Hand written (pen and paper)
   b. Typewriter
   c. Word processor
   d. Personal computer with word processing capability
   e. Not applicable

3. Who types the written document for you?
   a. Admin clerk/typist    c. I do
   b. Secretary             d. Other personnel

4. After the document is typed, what percentage of documents require retyping because:
   a. You make changes to the content_____%
   b. There are too many typing errors_____%
   c. Not applicable

5. Do you compose or type documents for the signature of another?    YES         NO

6. If yes, what percentage of documents require retyping because the person who signs the document makes changes to the content?

   _____%

7. Estimate the average number of hours you spend each week typing.
   _____(Hrs/wk) Not applicable

8. What percentage of the time that you spend typing is on retyping revised documents?
   _____%     Not applicable

9. If you had a personal computer with a word processing capability, would you consider this a benefit?
         YES          NO          MAYBE

10. Would the individual performing the typing duties use the time saved to fulfill some other task or objective which would contribute to your unit's mission performance?
         YES     NO     MAYBE

11. What percentage of your typed output is either of wholly standardized format or includes standard paragraphs?    _____%

15. If you were able to accomplish the above through the use of electronic messaging (electronic mail) via a personal computer, would you consider this a benefit?

    YES                 NO                 MAYBE

16. If yes, how much time each week do you think you would save?                    _____(Hrs/wk)

17. Is your administrative paper workload:
    a.  Increasing
    b.  Decreasing
    c.  Relatively unchanged over the past year


III.  Information Distribution

    1.  How is paper output internal to your office distributed?  (Please circle the letter(s) that apply)
        a.  Central mailbox   d.  Designated "runner"
        b.  Guard mail        e.  Telephonic notice
        c.  Personally        f.  Other (Please
            delivered             specify)
            _____

    2.  How many hours each week does the distribution of your office's paper output require?
                              _____(Hrs/wk) Don't know

    3.  How is paper output external to your office distributed?
        a.  Central mailbox   d.  Designated "runner"
        b.  Guard mail        e.  Telephonic notice
        c.  Personally        f.  Other (Please
            delivered             specify)
            _____

    4.  How many hours each week does the external distribution process require?
                              _____(Hrs/wk)   Don't know

    5.  Are you satisfied with the current methods used to distribute paper output both internal and external to your office?
        a.  Very              d.  Somewhat
            satisfied             dissatisfied
        b.  Somewhat          e.  Very
            satisfied             dissatisfied
        c.  Neutral or no opinion  f.  Don't know


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6.  What percentage of paperwork do you estimate misses
    deadlines primarily because of the method used to
    get it to its destination?

    _____%     Don't know

7.  What percentage of paperwork do you estimate is
    lost primarily due to the method used to get it to
    its destination? ____ _____%     Don't know

8.  How many trips does the "runner" make each day to
    pick up and deliver paperwork?

    _____ (Trips/day)

9.  What is the average time per trip for the "runner"?
    Minutes/trip:_____     Don't know

10. Would the "runner" use the saved time to
    accomplish: (Circle the letter(s) that apply)
    a.  Primary task directly related to MOS/Billet
    b.  Training related to primary task
    c.  Other_____
    d.  No other use of time


IV. Information Management

1.  How is your office's paperwork maintained?
    (Please circle the letter(s) that apply)
    a.  Personal filing cabinet/drawer
    b.  Personal electronic files
    c.  Office filing cabinet
    d.  Office electronic files
    e.  Don't know

2.  About how much time is spent each week maintaining
    the primary filing system used in your office?
    _____(Hrs/wk)     Don't know

3.  How much time is spent each week searching for
    missing or misplaced files?
    _____(Hrs/wk)     Don't know

4. What do you think the benefits of such a Management Information System (MIS) would be:
(Please circle the letter(s) that apply)
a. Reduction in paper-based files
b. Reduction in lost information
c. Reduction in retyping of lost information
d. Reduction in file searching time
e. Quicker access to documents and information
f. Greater amount of information to complete tasks
g. Ability to make quicker, better informed decisions
h. Other (Please specify)_____

## V. General

4. If a local area network was installed so that you had a personal computer and access to the application software listed above, would you consider this a benefit?

YES          NO          MAYBE

5. If such a system was implemented, would you use it?

YES          NO          MAYBE

APPENDIX C


DATA ANALYSIS METHODOLOGY


**DESCRIPTION**: A statistical analysis of the data obtained from the surveys was performed. Specific statistical analysis formulaes which were used are presented.

The survey asked for three different types of responses. One type of question required the individual to provide a numerical response. Another type of question asked the individual to select a single answer from a list of answers and the last type of question asked the individual to select all answers that were applicable.

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Formulas and variables used are defined as follow:    The
arithmetic mean is given as:

$$\overline{X} = \frac{1}{n} \sum_{i=1}^{n} (X_i)$$

where:  $\overline{x}$  =  (x bar) arithmetic mean (or simply mean);

   $x_i$  =  is the ith value of x;

   n  =  is the number of observations

The standard deviation was computed by:

$$S = \sqrt{\frac{\sum_{i=1}^{n} (X_i - \overline{x})^2}{n-1}}$$

and the formula for the variance is:

$$S^2 = \frac{\sum_{i=1}^{n} (X_i - \overline{X})^2}{n-1}$$

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For those questions where numerical responses were provided, the responses were summed and means, variances and standard deviations were computed. To ensure that the sample mean is representative of the population mean, confidence intervals were constructed. The confidence level was arbitrarily established as 0.95.

Using the formula

$$\overline{X} \pm Z_{\alpha/2}\left(\frac{S}{\sqrt{n}}\right)$$

to construct the confidence interval, there is a 95% certainty that the population mean falls within that interval.

In the second case, the underlying assumption was that each possible answer in the list was equally likely to have been chosen.

In order to validate the statistical inferences drawn from this set of data, one-tailed hypothesis testing was performed. The hypothesis tested in each case, referred to as the null hypothesis ($H_0$) was that the observed probability $p$ was equal to the hypothesized probability $p_0$. The alternative hypothesis ($H_1$) which represents the negation of the null hypothesis was that $p > p_0$. The level of significance used was 0.05. The null hypothesis was accepted when the

observed p was less than $p^*$ and statistical significance was denied. The computational formula is given as:

$$P\left(Z > \frac{p^* - p_0}{\sqrt{\dfrac{p_0(1 - p_0)}{n}}}\right) = \alpha$$

(Smith and Williams 1976:327)

APPENDIX D


SURVEY RESULTS


**DESCRIPTION**:   This appendix presents the numerical results of
the survey data analysis.   The responses for which confidence
intervals were constructed, the upper and lower bounds of the
interval are given with the mean.   The responses which were
tested using the hypothesis testing, statistical significance
is affirmed or denied.   The results of the tally are
presented for the remaining responses.

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| Quest | N | # of Responses | Mean | Std Dev | Confidence Interval Lower | Upper | Hypothesis Test % |
|-------|---|------|------|------|------|------|------|
| **Part I** | | | | | | | |
| 1A | | 184 | 32.14 | 46.44 | 25.43 | 38.85 | |
| 1B | | 181 | 11.43 | 23.48 | 8.01 | 14.85 | |
| 1C | | 180 | 16.02 | 28.29 | 11.89 | 20.15 | |
| 1D | | 185 | 49.43 | 52.65 | 41.84 | 57.01 | |
| 2A | | 186 | 23.65 | 32.54 | 18.97 | 28.33 | |
| 2B | | 179 | 9.22 | 21.67 | 6.05 | 12.40 | |
| 2C | | 180 | 13.02 | 21.92 | 9.82 | 16.22 | |
| 2D | | 181 | 41.52 | 53.86 | 33.68 | 49.37 | |
| 3A | | 189 | 67.77 | 24.74 | 64.24 | 71.29 | |
| 3B | | 180 | 19.86 | 15.66 | 17.57 | 22.15 | |
| 3C | | 159 | 11.24 | 12.96 | 9.23 | 13.26 | |
| | | | | | | | |
| **Part II** | | | | | | | |
| 1A | | 72 | | Tally | | | |
| 1B | | 62 | | | | | |
| 1C | | 36 | | | | | |
| 1D | | 151 | | | | | |
| 1E | | 4 | | | | | |
| 2A | | 123 | | Tally | | | |
| 2B | | 47 | | | | | |
| 2C | | 23 | | | | | |
| 2D | | 22 | | | | | |
| 2E | | 8 | | | | | |
| 3A | | 67 | | Tally | | | |
| 3B | | 48 | | | | | |
| 3C | | 94 | | | | | |
| 3D | | 28 | | | | | |
| 4A | | 166 | 26.00 | 29.32 | 21.54 | 30.46 | |
| 4B | | 143 | 14.47 | 19.86 | 11.21 | 17.72 | |
| 5A | 186 | 164 | | | | | 88.17 |
| 5B | | 22 | | | | | 11.83 |
| 6 | | 165 | 23.59 | 28.78 | 19.20 | 27.98 | |

| Quest | N | # of Responses | Mean | Std Dev | Confidence Interval Lower | Confidence Interval Upper | Hypothesis Test |
|-------|-----|------|-------|-------|-------|-------|-------|
| **Part II** | | | | | | | |
| 7 | | 129 | 13.64 | 12.39 | 11.50 | 15.78 | |
| 8A | | 113 | 17.46 | 22.77 | 13.26 | 21.66 | |
| 9A | 182 | 146 | | | | | 80.22 |
| 9B | | 6 | | | | | 3.30 |
| 9C | | 30 | | | | | 16.48 |
| 10A | 179 | 150 | | | | | 83.80 |
| 10B | | 4 | | | | | 2.23 |
| 10C | | 25 | | | | | 13.97 |
| 11 | | 177 | 53.77 | 34.26 | 48.73 | 58.73 | |
| 14A | | 182 | 32.71 | 26.18 | 28.91 | 36.51 | |
| 14B | | 158 | 10.61 | 12.80 | 8.62 | 12.61 | |
| 14C | | 141 | 8.54 | 12.48 | 6.48 | 10.60 | |
| 14D | | 128 | 9.84 | 16.20 | 7.03 | 12.64 | |
| 14E | | 147 | 12.63 | 13.00 | 10.53 | 14.73 | |
| 14F | | 123 | 8.93 | 15.35 | 6.21 | 11.64 | |
| 15A | 188 | 115 | | | | | 61.17 |
| 15B | | 16 | | | | | 8.51 |
| 15C | | 57 | | | | | 30.32 |
| 16 | | 118 | 9.69 | 7.26 | 8.38 | 11.00 | |
| 17A | 182 | 131 | | | | | 71.98 |
| 17B | | 4 | | | | | 2.20 |
| 17C | | 47 | | | | | 25.82 |
| | | | | | | | |
| **Part III** | | | | | | | |
| 1A | | 64 | | Tally | | | |
| 1B | | 99 | | | | | |
| 1C | | 157 | | | | | |
| 1D | | 64 | | | | | |
| 1E | | 44 | | | | | |
| 1F | | 6 | | | | | |
| 2 | | 111 | 6.37 | 7.62 | 4.96 | 7.79 | |
| 3A | | 79 | | Tally | | | |

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| Quest | N | # of Responses | Mean | Std Dev | Confidence Interval Lower | Upper | Hypothesis Test % |
|---|---|---|---|---|---|---|---|
| **Part III (Cont)** | | | | | | | |
| 3B | | 166 | | | | | |
| 3C | | 128 | | | | | |
| 3D | | 85 | | | | | |
| 3E | | 53 | | | | | |
| 3F | | 11 | | | | | |
| 4 | | 110 | 7.45 | 6.45 | 6.25 | 8.66 | |
| 5A | 188 | 19 | | | | | 10.11 |
| 5B | | 74 | | | | | 39.36 |
| 5C | | 31 | | | | | 16.49 |
| 5D | | 50 | | | | | 26.60 |
| 5E | | 13 | | | | | 6.91 |
| 5F | | 1 | | | | | 0.53 |
| 6 | | 129 | 12.01 | 14.36 | 9.53 | 14.49 | |
| 7 | | 129 | 7.81 | 10.78 | 5.95 | 9.67 | |
| 8 | | 155 | 3.29 | 2.91 | 2.83 | 3.75 | |
| 9 | | 130 | 30.48 | 23.48 | 26.45 | 34.52 | |
| 10A | 183 | 130 | | | | | 71.04 |
| 10B | | 37 | | | | | 20.22 |
| 10C | | 9 | | | | | 4.92 |
| 10D | | 7 | | | | | 3.83 |
| | | | | | | | |
| **Part IV** | | | | | | | |
| 1A | | 120 | | Tally | | | |
| 1B | | 23 | | | | | |
| 1C | | 161 | | | | | |
| 1D | | 43 | | | | | |
| 2 | | 146 | 7.76 | 8.88 | 6.32 | 9.20 | |
| 3 | | 126 | 2.76 | 5.69 | 1.77 | 3.75 | |
| 4A | | 132 | | Tally | | | |
| 4B | | 108 | | | | | |
| 4C | | 96 | | | | | |

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| Quest | N | # of Responses | Mean | Std Dev | Confidence Interval | | Hypothesis Test % |
|---|---|---|---|---|---|---|---|
| | | | | | Lower | Upper | |
| Part IV (Cont) | | | | | | | |
| 4D | | 124 | | | | | |
| 4E | | 143 | | | | | |
| 4F | | 93 | | | | | |
| 4G | | 95 | | | | | |
| 4H | | 11 | | | | | |
| | | | | | | | |
| Part V | | | | | | | |
| 4A | 177 | 141 | | | | | 79.66 |
| 4B | | 3 | | | | | 1.69 |
| 4C | | 33 | | | | | 18.64 |
| 5A | 180 | 144 | | | | | 80.00 |
| 5B | | 5 | | | | | 2.78 |
| 5C | | 31 | | | | | 17.22 |

## APPENDIX E


## HARDWARE AND SOFTWARE REQUIREMENTS


**DESCRIPTION**: This appendix presents the hardware and software requirements and its estimated costs for the eight departmental subnetworks which were identified during the study.

It also includes a description of the backbone network and an estimate of its cost based on current industry averages.


## **Note**:

1. The prices for the workstations, dot matrix printers and modems are from the Zenith GSA contract.

2. Higgins E-mail software is quoted from commercial sources.

3. The remaining prices are found in GSA Contract Number GS00K87AGS5354.

## Civilian Personnel Office

| Hardware Requirements | Qty | Unit Price | Total Price |
|---|---|---|---|
| Workstation | | | |
| Z-248 Computer<br>-80286 CPU<br>-512KB RAM<br>-2 360KB Floppy<br>  Disk<br>-MS DOS 3.1 | 4 | $1,103.00 | $4,412.00 |
| -Monochrome monitor | 4 | $116.00 | $464.00 |
| Network Interface<br>Card | 4 | $450.61 | $1,802.44 |
| Network Server<br>-70MB Hard Disk<br>-Tape Backup<br>-Port Expansion Unit<br>-Memory Cache Card | 1 | $7,580.79 | $7,580.79 |
| Dot Matrix Printer | 2 | $528.00 | $1,056.00 |
| NLQ Printer | 1 | $716.40 | $716.40 |
| Laser Printer | 1 | $1,953.57 | $1,953.57 |
| Dial-up 2400 baud modem | 1 | $158.00 | $158.00 |
| Coax cable w/conn | 200m | $325.66 | $325.66 |
| Software Requirements | | | |
| Network Operating<br>System | 1 | $1,951.07 | $1,951.07 |
| Word Processing<br>-Per server<br>-Per node | 1<br>4 | $295.00<br>$78.00 | $295.00<br>$312.00 |
| Database Management<br>-dBase III +<br>-LAN Pack | 1<br>1 | $427.25<br>$597.00 | $427.25<br>$597.00 |
| Spreadsheet<br>-Planperfect Network<br>-Per node | 1<br>4 | $193.05<br>$78.00 | $193.05<br>$312.00 |
| E-Mail, Communication<br>Scheduling - Higgins | 1 | $695.00 | $695.00 |

TOTAL HARDWARE AND SOFTWARE COSTS = $23,251.23

**Disbursing**

Hardware Requirements  Qty  Unit Price Total Price

Workstation **

  Zenith Z-248
   -80286 CPU
   -512KB RAM
   -2 360KB Floppy
      Disk Drives
   -MS DOS 3.1
   -Monochrome monitor
   -RBG Color Monitor

| Hardware Requirements | Qty | Unit Price | Total Price |
|---|---|---|---|
| Network Interface Card | 4 | $450.61 | $1,802.44 |
| Network Server<br>-70 MB Hard Disk<br>-Tape Backup<br>-Port Expansion Unit<br>-Memory Cache Card | 1 | $7,580.79 | $7,580.79 |
| Laser Printer | 1 | $1,953.57 | $1,953.57 |
| Dial-up 2400 baud modem | 1 | $158.00 | $158.00 |
| Coax Cable w/connectors | 200m | $302.94 | $302.94 |

Software Requirements

| Software Requirements | Qty | Unit Price | Total Price |
|---|---|---|---|
| Network Operating System | 1 | $1,951.07 | $1,951.07 |
| Word Processing<br>-Per Server<br>-Per node | <br>1<br>4 | <br>$295.00<br>$78.00 | <br>$295.00<br>$312.00 |
| Database Management<br>-dBase III+, 1 user<br>-LAN Pack | <br>1<br>1 | <br>$427.25<br>$597.00 | <br>$427.25<br>$597.00 |
| Spreadsheet<br>-PlanPerfect Network<br>-Per node | <br>1<br>4 | <br>$193.05<br>$78.00 | <br>$193.05<br>$312.00 |
| E-Mail, Communications<br>Scheduling - Higgins LAN | 1 | $695.00 | $695.00 |

   TOTAL HARDWARE AND SOFTWARE COSTS =      $16,580.11

** Z-248s were procured by HQMC

**Facilities Management**

| Hardware Requirements | Qty | Unit Price | Total Price |
|---|---|---|---|
| Workstation | | | |
| Zenith Z-248 | 16 | $1,103.00 | $17,648.00 |
| -80286 CPU | | | |
| -512KB RAM | | | |
| -2 360KB Floppy | | | |
| Disk Drives | | | |
| -MS DOS 3.1 | | | |
| -Monochrome monitor | 12 | $116.00 | $1,392.00 |
| -RBG Color Monitor | 4 | $302.00 | $1,208.00 |
| Network Interface Card | 16 | $450.61 | $7,209.76 |
| Network Server | 1 | $12,495.81 | $12,495.81 |
| -140 MB Hard Disk | | | |
| -Tape Backup | | | |
| -Port Expansion Unit | | | |
| -Memory Cache Card | | | |
| -Expansion Disk Unit | | | |
| -Expansion Disk Option | | | |
| Dot Matrix Printer | 12 | $528.00 | $6,336.00 |
| NLQ Printer | 4 | $716.40 | $2,865.60 |
| Laser Printer | 1 | $1,953.57 | $1,953.57 |
| Graphics Plotter | 1 | $1,063.84 | $1,063.84 |
| Dial-up 2400 baud modem | 1 | $158.00 | $158.00 |
| Coax Cable w/connectors | 500m | $602.26 | $602.26 |
| Software Requirements | | | |
| Network Operating System | 1 | $1,951.07 | $1,951.07 |
| Word Processing | | | |
| -Per Server | 1 | $295.00 | $295.00 |
| -Per node | 16 | $78.00 | $1,248.00 |
| Database Management | | | |
| -dBase III+, 1 user | 1 | $427.25 | $427.25 |
| -LAN Pack | 3 | $597.00 | $1,791.00 |
| Spreadsheet | | | |
| -PlanPerfect Network | 1 | $193.05 | $193.05 |
| -Per node | 16 | $78.00 | $1,248.00 |
| E-Mail, Communications, Scheduling - Higgins LAN | 1 | $695.00 | $695.00 |
| TOTAL HARDWARE AND SOFTWARE COSTS = | | | $60,781.21 |

**Headquarters**

| Hardware Requirements | Qty | Unit Price | Total Price |
|---|---|---|---|
| Workstation ** | | | |
| Zenith Z-248<br>-80286 CPU<br>-512KB RAM<br>-2 360KB Floppy<br>  Disk Drives<br>-MS DOS 3.1<br>-Monochrome monitor<br>-RBG Color Monitor | 5 | $1,103.00 | $5,515.00 |
| Network Interface Card | 20 | $450.61 | $9,012.20 |
| Network Server<br>-70 MB Hard Disk<br>-Tape Backup<br>-Port Expansion Unit<br>-Memory Cache Card | 1 | $7,580.79 | $7,580.79 |
| Laser Printer | 1 | $1,953.57 | $1,953.57 |
| Dial-up 2400 baud modem | 1 | $158.00 | $158.00 |
| Coax Cable w/connectors | 450m | $462.60 | $462.60 |
| Software Requirements | | | |
| Network Operating System | 1 | $1,951.07 | $1,951.07 |
| Word Processing<br>-Per Server<br>-Per node | 1<br>5 | $295.00<br>$78.00 | $295.00<br>$390.00 |
| Database Management<br>-dBase III+, 1 user<br>-LAN Pack | 1<br>4 | $427.25<br>$597.00 | $427.25<br>$2,388.00 |
| Spreadsheet<br>-PlanPerfect Network<br>-Per node | 1<br>20 | $193.05<br>$78.00 | $193.05<br>$1,560.00 |
| E-Mail, Communications,<br>Scheduling - Higgins LAN | 1 | $695.00 | $695.00 |

TOTAL HARDWARE AND SOFTWARE COSTS =    $39,340.08

** Headquarters is well established
in the use of microcomputers.
Primary emphasis is on network
components and software.

## Information Resource Center

| Hardware Requirements | Qty | Unit Price | Total Price |
|---|---|---|---|
| Workstation | | | |
| Zenith Z-248 | 10 | $1,103.00 | $11,030.00 |
| -80286 CPU | | | |
| -512KB RAM | | | |
| -2 360KB Floppy | | | |
|   Disk Drives | | | |
| -MS DOS 3.1 | | | |
| -Monochrome monitor | 9 | $116.00 | $1,044.00 |
| -RBG Color Monitor | 1 | $302.00 | $302.00 |
| Network Interface Card | 10 | $450.61 | $4,506.10 |
| Network Server | 1 | $7,580.79 | $7,580.79 |
| -70 MB Hard Disk | | | |
| -Tape Backup | | | |
| -Port Expansion Unit | | | |
| -Memory Cache Card | | | |
| Dot Matrix Printer | 2 | $528.00 | $1,056.00 |
| NLQ Printer | 1 | $716.40 | $716.40 |
| Dial-up 2400 baud modem | 1 | $158.00 | $158.00 |
| Coax Cable w/connectors | 200m | $392.26 | $392.26 |
| Software Requirements | | | |
| Network Operating System | 1 | $1,951.07 | $1,951.07 |
| Word Processing | | | |
| -Per Server | 1 | $295.00 | $295.00 |
| -Per node | 10 | $78.00 | $780.00 |
| Database Management | | | |
| -dBase III+, 1 user | 1 | $427.25 | $427.25 |
| -LAN Pack | 2 | $597.00 | $1,194.00 |
| Spreadsheet | | | |
| -PlanPerfect Network | 1 | $193.05 | $193.05 |
| -Per node | 10 | $78.00 | $780.00 |
| E-Mail, Communications, Scheduling - Higgins LAN | 1 | $695.00 | $695.00 |

TOTAL HARDWARE AND SOFTWARE COSTS = $33,100.92

**Provost Marshall's Office**

| Hardware Requirements | Qty | Unit Price | Total Price |
|---|---|---|---|
| Workstation | | | |
| Zenith Z-248 | 11 | $1,103.00 | $12,133.00 |
| -80286 CPU | | | |
| -512KB RAM | | | |
| -2 360KB Floppy | | | |
| Disk Drives | | | |
| -MS DOS 3.1 | | | |
| -Monochrome monitor | 8 | $116.00 | $928.00 |
| -RBG Color Monitor | 3 | $302.00 | $906.00 |
| Network Interface Card | 15 | $450.61 | $6,759.15 |
| Network Server | 1 | $12,495.81 | $12,495.81 |
| -140 MB Hard Disk | | | |
| -Tape Backup | | | |
| -Port Expansion Unit | | | |
| -Memory Cache Card | | | |
| -Expansion Disk Unit | | | |
| -Expansion Disk Option | | | |
| Dot Matrix Printer | 8 | $528.00 | $4,224.00 |
| NLQ Printer | 4 | $716.40 | $2,865.60 |
| Laser Printer | 1 | $1,953.57 | $1,953.57 |
| Dial-up 2400 baud modem | 2 | $158.00 | $316.00 |
| Coax Cable w/connectors | 300m | $462.60 | $462.60 |
| Software Requirements | | | |
| Network Operating System | 1 | $1,951.07 | $1,951.07 |
| Word Processing | | | |
| -Per Server | 1 | $295.00 | $295.00 |
| -Per node | 15 | $78.00 | $1,170.00 |
| Database Management | | | |
| -dBase III+, 1 user | 1 | $427.25 | $427.25 |
| -LAN Pack | 3 | $597.00 | $1,791.00 |
| Spreadsheet | | | |
| -PlanPerfect Network | 1 | $193.05 | $193.05 |
| -Per node | 15 | $78.00 | $1,170.00 |
| E-Mail, Communications, Scheduling - Higgins LAN | 1 | $695.00 | $695.00 |

TOTAL HARDWARE AND SOFTWARE COSTS = $50,736.10

**Staff Judge Advocate**

| Hardware Requirements | Qty | Unit Price | Total Price |
|---|---|---|---|
| Workstation | | | |
| Zenith Z-248<br>-80286 CPU<br>-512KB RAM<br>-2 360KB Floppy<br>    Disk Drives<br>-MS DOS 3.1 | 8 | $1,103.00 | $8,824.00 |
| -Monochrome monitor | 6 | $116.00 | $696.00 |
| -RBG Color Monitor | 2 | $302.00 | $604.00 |
| Network Interface Card | 8 | $450.61 | $3,604.88 |
| Network Server<br>-70 MB Hard Disk<br>-Tape Backup<br>-Port Expansion Unit<br>-Memory Cache Card | 1 | $7,580.79 | $7,580.79 |
| Dot Matrix Printer | 4 | $528.00 | $2,112.00 |
| NLQ Printer | 2 | $716.40 | $1,432.80 |
| Laser Printer | 1 | $1,953.57 | $1,953.57 |
| Dial-up 2400 baud modem | 1 | $158.00 | $158.00 |
| Coax Cable w/connectors | 300m | $327.65 | $327.65 |
| Software Requirements | | | |
| Network Operating System | 1 | $1,951.07 | $1,951.07 |
| Word Processing<br>-Per Server | 1 | $295.00 | $295.00 |
| -Per node | 8 | $78.00 | $624.00 |
| Database Management<br>-dBase III+, 1 user | 1 | $427.25 | $427.25 |
| -LAN Pack | 2 | $597.00 | $1,194.00 |
| Spreadsheet<br>-PlanPerfect Network | 1 | $193.05 | $193.05 |
| -Per node | 8 | $78.00 | $624.00 |
| E-Mail, Communications,<br>  Scheduling - Higgins LAN | 1 | $695.00 | $695.00 |

TOTAL HARDWARE AND SOFTWARE COSTS =     $33,297.06

**Supply**

| Hardware Requirements | Qty | Unit Price | Total Price |
|---|---|---|---|
| Workstation | | | |
| Zenith Z-248<br>-80286 CPU<br>-512KB RAM<br>-2 360KB Floppy<br>   Disk Drives<br>-MS DOS 3.1 | 40 | $1,103.00 | $44,120.00 |
| -Monochrome monitor | 35 | $116.00 | $4,060.00 |
| -RBG Color Monitor | 5 | $302.00 | $1,510.00 |
| Network Interface Card | 40 | $450.61 | $18,024.40 |
| Network Server (Small)<br>-70 MB Hard Disk<br>-Tape Backup<br>-Port Expansion Unit<br>-Memory Cache Card | 3 | $7,580.79 | $22,742.37 |
| Network Server (Medium)<br>-140 MB Hard Disk<br>-Tape Backup<br>-Port Expansion Unit<br>-Memory Cache Card<br>-Expansion Disk Unit<br>-Expansion Disk Option | 2 | $12,495.81 | $24,991.62 |
| Dot Matrix Printer | 30 | $528.00 | $15,840.00 |
| NLQ Printer | 10 | $716.40 | $7,164.00 |
| Laser Printer | 5 | $1,953.57 | $9,767.85 |
| Dial-up 2400 baud modems | 7 | $158.00 | $1,106.00 |
| Coax Cable w/connectors | 1000m | $1,486.55 | $1,486.55 |
| Software Requirements | | | |
| Network Operating System | 5 | $1,951.07 | $9,755.35 |
| Word Processing | | | |
| -Per Server | 5 | $295.00 | $1,475.00 |
| -Per node | 40 | $78.00 | $3,120.00 |
| Database Management | | | |
| -dBase III+, 1 user | 5 | $427.25 | $2,136.25 |
| -LAN Pack | 8 | $597.00 | $4,776.00 |
| Spreadsheet | | | |
| -PlanPerfect Network | 5 | $193.05 | $965.25 |
| -Per node | 40 | $78.00 | $3,120.00 |
| E-Mail, Communications,<br>Scheduling - Higgins LAN | 5 | $695.00 | $3,475.00 |

TOTAL HARDWARE AND SOFTWARE COSTS =   $179,635.64

The cost of the backbone network is a general estimate of the cost of analysis, design, installation and testing. Using the current CATV cable plant as the basis of the backbone design and ensuring that the backbone provides potential connectivity and future expansion, it was determined that the backbone network would extend approximately 24,000 feet or roughly 7.5 kilometers. The cost per foot includes the analysis, design, installation and testing.

24,000 ft @ $20.00/ft = $480,000.00

Total network cost is:

| | |
|---|---|
| Subnetworks | $436,722.35 |
| Backbone network | $480,000.00 |
| **Total** | $916,722.35 |
| Approximate Total | 917,000.00 |
| 10% overhead | 91,700.00 |
| **GRAND TOTAL** | $1,008,700.00 |

APPENDIX F


LAN BENEFITS CALCULATIONS


**DESCRIPTION**: The calculations presented below are based on six of the eight departmental subnetworks identified in Table VII of Chapter IV. The six departments are: (1) Civilian Personnel Office; (2) Disbursing; (3) Headquarters; (4) Provost Marshall's Office; (5) Staff Judge Advocate; and (6) Supply.


Benefits for these six departments are based upon improved productivity through automation and more efficient utilization of human resources by reducing the amount of non-productive, redundant work (such as retyping and "guard mail" duties).

Specific economic analysis was obtained from the Facilities Management department. This is summarized and included in the total benefits.

The Information Resource Center will provide a return of investment by providing requirements analysis, design, implementation and in-house network training programs as the corporate knowledge and experience of the Center grows.

Pay grades used in the calculations are E-3, E-5, GS-3/5 and GS-5/5. The underlying assumption in each of the calculations is that one individual in each pay grade for each department identified performs the specific task being


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considered. The pay grades were selected as being representative of the personnel "normally" performing those duties.

The actual number of personnel involved in those duties varies by department. One individual per pay grade per department was selected to demonstrate savings and yet provide a conservative estimate. Computations can be refined by department as well as estimating the benefits derived by the principles involved as opposed to the clerical staff.

Inferences refer to the question number in the local area network survey. The specific benefit areas also correspond to those used in the survey. The survey results provided the average hours per week used in the calculations.

**Notes**:

1. The first figure represents estimated savings. It is obtained from inferences drawn from the survey.

2. The first figure is 50% of the midpoint of the confidence interval to provide a conservative estimate.

3. The hourly wages for the military personnel are composite rates obtained from NavComptNote 7041 dated 9 December 1986. Civilian wages were obtained from Executive Order 12578 dated 31 December 1986. Commandant of the Marine Corps letter LLF-5/KM/shw 4860 dated 24 February 1987 contains guidance for standardizing civilian pay in order to effectively compare wage results.

## Information Production

**Application:** Document preparation/editing capability
(Word processing)

Inferences: 1, 3, 4, 6, 7, 9, 10

Calculations:

6.82 hrs/wk * 52 wks/yr * $9.69/hr  * 6 E-3s  = $20,618.76

6.82 hrs/wk * 52 wks/yr * $15.92/hr * 6 E-5s  = $33,875.20

6.82 hrs/wk * 52 wks/yr * $8.33/hr  * 6 GS-3s = $17,724.90

6.82 hrs/wk * 52 wks/yr * $10.47/hr * 6 GS-5s = $22,278.48

                                        **Subtotal**    $94,497.34


**Application:** Electronic messaging (Document review,
electronic chop -- word processing)

Inferences: 11, 15, 16

Calculations:

4.85 hrs/wk * 52 wks/yr * $9.69/hr  * 6 E-3s  = $14,662.90

4.85 hrs/wk * 52 wks/yr * $15.92/hr * 6 E-5s  = $24,090.14

4.85 hrs/wk * 52 wks/yr * $8.33/hr  * 6 GS-3s = $12,604.95

4.85 hrs/wk * 52 wks/yr * $10.47/hr * 6 GS-5s = $15,843.20

                                        **Subtotal**    $67,201.19

                                                94,497.34

                                        **Total**       $161,698.53

## Information Distribution

**Application**: Electronic mail (intra and interdepartmental communications)

Inferences: 1, 2, 3, 4, 8, 9, 10

Calculations:
 Internal --

3.19 hrs/wk * 52 wks/yr * $9.69/hr  * 6 E-3s  = $9,644.26

3.19 hrs/wk * 52 wks/yr * $15.92/hr * 6 E-5s  = $15,844.85

3.19 hrs/wk * 52 wks/yr * $8.33/hr  * 6 GS-3s = $8,290.68

3.19 hrs/wk * 52 wks/yr * $10.47/hr * 6 GS-5s = $10,420.58

 External ("Guard mail") --

4.18 hrs/wk * 52 wks/yr * $9.69/hr  * 6 E-3s  = $12,637.31

                                        **Total**    $56,837.68


## Information Management

**Application**: Electronic storage and retrieval (Filing)

Inferences: 2, 3

Calculations:

5.26 hrs/wk * 52 wks/yr * $9.69/hr  * 6 E-3s  = $15,902.45

5.26 hrs/wk * 52 wks/yr * $15.92/hr * 6 E-5s  = $26,126.63

5.26 hrs/wk * 52 wks/yr * $8.33/hr  * 6 GS-3s = $13,670.52

5.26 hrs/wk * 52 wks/yr * $10.47/hr * 6 GS-5s = $17,182.52

                                        **Total**    $72,882.12

Reduce the redundant typing and entering of data that
is common within the Facilities Management department
and improve the audit trail of document flow to other
departments such as Supply or the Comptroller;

Improved utilization of human resources thus negating
the requirement to hire additional personnel.


Estimated hours saved annually  --          1200

Estimated cost savings per year --  $24,000.00


Total annual dollar savings are estimated at $31,100.00.
This estimate is based upon an analysis of historical data
and a projection of benefits that can be obtained with a
local area network information support system.

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