NAVAL POSTGRADUATE SCHOOL

Monterey, California

THESIS

A Sociotechnical Design
for
Implementing the Defense Data Network

by

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March 1988

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REPORT DOCUMENTATION PAGE

1a Report Security Classification: Unclassified		1b Restrictive Markings	
2a Security Classification Authority		3 Distribution/Availability of Report: Approved for public release; distribution is unlimited.	
2b Declassification/Downgrading Schedule			
4 Performing Organization Report Number(s)		5 Monitoring Organization Report Number(s)	
6a Name of Performing Organization: Naval Postgraduate School	6b Office Symbol (if applicable): 54	7a Name of Monitoring Organization: Naval Postgraduate School	
6c Address (city, state, and ZIP code): Monterey, CA 93943-5000		7b Address (city, state, and ZIP code): Monterey, CA 93943-5000	
8a Name of Funding/Sponsoring Organization	8b Office Symbol (if applicable)	9 Procurement Instrument Identification Number	
8c Address (city, state, and ZIP code)		10 Source of Funding Numbers: Program Element No. / Project No. / Task No. / Work Unit Accession No.	

11 Title (include security classification): A SOCIOTECHNICAL DESIGN FOR IMPLEMENTING THE DEFENSE DATA NETWORK

12 Personal Author(s): David L. Woleslagle

13a Type of Report	13b Time Covered	14 Date of Report (year, month, day)	15 Page Count
Master's Thesis	From To	March 1988	72

16 Supplementary Notation: The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.

17 Cosati Codes			18 Subject Terms (continue on reverse if necessary and identify by block number)
Field	Group	Subgroup	Sociotechnical, DDN, computer communications, change.
			Management and Computer Communications

19 Abstract (continue on reverse if necessary and identify by block number)

This study examines the benefits of implementing the Defense Data Network at a military organization. The effects of computer-mediated communication, both intended and unintended, are examined. Sociotechnical design is discussed as one effective means to implement the DDN in order to maximize its benefits; this theory contends that the social as well as technical aspects of a system must be considered to generate improved performance. A technical analysis of applying this theory to DDN implementation is provided. A social analysis, the result of a questionnaire administered to three independent samples of DDN users, also is included. Conclusions and recommendations for the study are:

- DDN training is generally inadequate at the facilities sampled.
- DDN skills generally are not rewarded at the facilities sampled.
- Management structure and philosophy are critical for successful DDN implementation.
- Participative, team-building activities that encourage the formation of self-managed work teams are recommended for successful DDN implementation.

20 Distribution/Availability of Abstract	21 Abstract Security Classification	
☒ unclassified/unlimited ☐ same as report ☐ DTIC users	Unclassified	
22a Name of Responsible Individual: Judith H. Lind	22b Telephone (include Area code): (408) 646-2543	22c Office Symbol: 55Li

DD FORM 1473,84 MAR 83 APR edition may be used until exhausted
All other editions are obsolete

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A Sociotechnical Design
for
Implementing the Defense Data Network

by

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Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN TELECOMMUNICATIONS SYSTEMS MANAGEMENT

from the

NAVAL POSTGRADUATE SCHOOL
March 1988

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ABSTRACT

This study examines the benefits of implementing the Defense Data Network at a military organization. The effects of computer-mediated communication, both intended and unintended, are examined. Sociotechnical design is discussed as one effective means to implement the DDN in order to maximize its benefits; this theory contends that the social as well as technical aspects of a system must be considered to generate improved performance. A technical analysis of applying this theory to DDN implementation is provided. A social analysis, the result of a questionnaire administered to three independent samples of DDN users, also is included. Conclusions and recommendations for the study are:

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I. INTRODUCTION

A. BACKGROUND

The implementation of the Defense Data Network (DDN) on the scale envisioned by its developers brings the military abruptly into the arena of computer-mediated communications. The DDN offers many technical enhancements that can meet the increasing needs of the military for information processing and transfer. However, current research on the introduction of new technology into an existing organization reveals that many problems can arise. An organization's emphasis during the implementation process often is only on the technical aspects of the new system. The underlying social subsystem is ignored, along with the complex networks of relationships and interactions between the people who comprise an organization.

This thesis examines sociotechnical theory as a method of evaluating the full impact of new technology on all components of an organization. Sociotechnical theory contends that the full benefits of a system cannot be realized unless both the technical and the social subsystems are each considered equally. This theory should be of particular interest to the management of a military site that installs the DDN. For the local manager, the technology of the DDN is largely fixed. However, the attitude and skill of the DDN manager will determine whether the new system is implemented in a manner that will achieve the fullest possible benefits.

B. OBJECTIVES

The goal of this thesis is to provide detailed information needed for managerial decision making, with respect to introducing the DDN at military sites. Specific objectives of this study are:

- Identify how, and for what, the DDN is used in organizations.
- Identify the effects of computer-mediated communications on an organization.
- Examine strategies for overcoming barriers to innovation and performance improvement.
- Discuss effective training methods for electronic communications systems.
- Identify the key conditions for successful system introduction as proposed by sociotechnical theory, and determine the extent to which these conditions are present in organizations with access to the DDN.

- Identify measures of performance for DDN use, and determine what factors can affect them.
- Propose a sociotechnical plan for introducing the DDN to military organizations.

C. THESIS OVERVIEW

This study takes a general approach to implementation of access to the DDN at military sites. It does not address the installation of specific systems at specific locations. Emphasis is on acceptance of the new system by potential military and civilian users of the DDN.

The second chapter provides background information concerning the DDN, including its history, development, and benefits. The third chapter presents the key concepts of sociotechnical theory, tracing it from its origins to the development of a design for structuring organizations. The fourth chapter provides a technical analysis of organizations that have implemented computer-mediated communications systems, focusing on potential problems and solutions. The fifth chapter is an analysis, based on questionnaire data, of the social subsystems of several organizations that have the DDN installed. The sixth chapter provides conclusions and recommendations resulting from this study and proposes areas for further research.

II. THE DEFENSE DATA NETWORK

A. HISTORY

The Defense Data Network (DDN) is the sanctioned long-haul computer communications network for the United States Department of Defense (DOD).[1] It was selected after an indepth study of competing systems. The DDN has evolved as an outgrowth of the military's attempt to create an optimum, world-wide data communications network. The DDN is managed by the Defense Data Network Program Office of the Defense Communication Agency (DCA). It is intended for users engaged in official government business, research, or the support of the same.

Military computer communications began with the ARPANET, a purely experimental network originated by the Defense Advanced Research Projects Agency (DARPA) in late 1969 to advance the state of the art in computer networking. ARPANET was successfully designed to allow various computers to communicate with each other, in a convenient and economic fashion. In 1975, the DCA assumed control of ARPANET operations. The DDN was officially established in 1982 to provide an administrative umbrella over existing and planned DOD networks. ARPANET was then split into two entities, ARPANET and MILNET. ARPANET remains oriented primarily toward research and development, while MILNET serves as an operational military network. [Ref. 1:pp. 12-15]

The DDN also includes three Defense Secure Networks (DSNETS): GENSER, WINCS, and SCINET. Each DSNET is a physically distinct subnetwork that carries classified traffic at a single security level.

The DCA maintains an all-purpose repository for collecting and distributing information about both ARPANET and MILNET at the Network Information Center (NIC) in Menlo Park, California. The NIC disseminates information and provides services via online interaction, written publications, and over a toll free telephone hot line. This is the best initial source for obtaining answers to questions regarding the DDN.

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1 Long haul communications are communications intended for use over a large geographic area, usually involving distances greater than 20 miles.

B. SYSTEM ARCHITECTURE

1. Packet Switching

The DDN was designed to take advantage of off-the-shelf technology developed for ARPANET. The heart of this is a network technology known as packet switching, which enables a message to be broken up into pieces, or "packets". Each packet has the same destination address as the original message, as well as a sequence number that indicates which part of the original message it represents. The packets are forwarded along the network until they all ultimately reach their destination, where they are reassembled and delivered in total. The entire operation is transparent to the user.

A key concept of packet switching in the DDN is that of adaptive routing. Essentially, this means that no predetermined, dedicated path exists for delivery of the packets. Instead, each packet takes the best route it can find at that time. This means that all packets from a given message do not necessarily take the same path. [Ref. 2:pp. 8-11]

2. Network Components

The physical components of the DDN consist of four basic parts:

- Packet switching subnetwork
- Gateways
- Host computers
- Terminals.

These can be grouped into two areas: the part managed by the DCA, consisting of the packet switching subnetwork and gateways, and the user-managed hosts and terminals. [Ref. 3:pp. 1.3-1.4]

The packet switching subnetwork is often referred to as the backbone system. Its primary elements are shown in Figure 1 on page 5 and consist of:

- Packet Switching Nodes (PSNs)
- Terminal Access Controllers (TACs)
- Monitoring Center.

The packet switching device employed by the DDN is a Bolt, Beranek, & Newman (BBN) C/30 minicomputer. The BBN C/30 is a programmable communications processor that can be configured as either a PSN or a TAC. The PSN routes packets through the network with a shortest path algorithm. In this process each PSN continuously receives estimates of queuing and transmission delay times to adjacent nodes. Packets are then routed to the node that promises the least average time to get

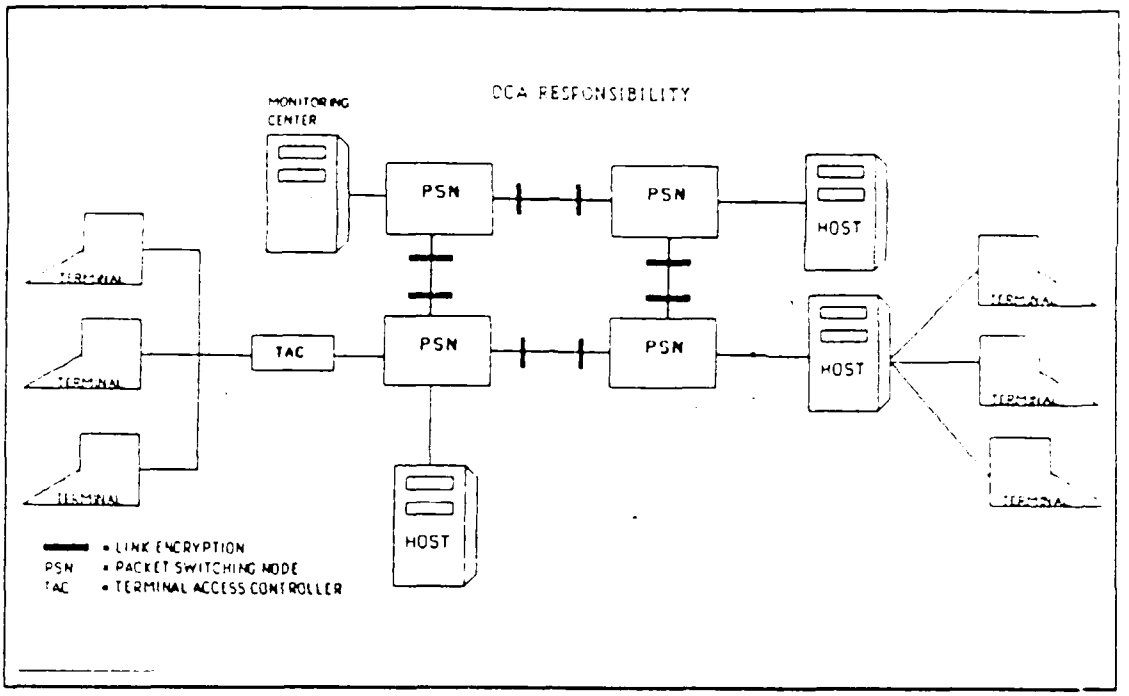

Figure 1. DDN Components: [Ref. 3:p. 1.3]

there and be processed. PSNs are interconnected by high-speed dedicated trunk lines. Multiple paths are provided to allow redundancy. The PSNs comprise the interface between network access devices (hosts and TACS) and the rest of the backbone network. They support two general host access protocols: X.25, and 1822 ARPANET Host Interface Protocol (AHIP). A protocol is the syntax of the language between two similar entities. That is, it is the set of rules that govern the way in which communication occurs.

The TAC is one of several devices that can be used to access the backbone network from a network host computer. TACs differ from PSNs in their software and input output configurations. Basically, they provide a method for asynchronous terminals to access the backbone network.

A host which supports X.25 or AHIP protocols can access a PSN directly through one of the PSN's 62 ports. TACs are used when hosts and terminals do not support X.25 or AHIP protocols. The TAC functions as a traffic manager, accepting inputs from up to 62 asynchronous terminal network subscribers, and directing them

through one of a PSN's high-speed ports. TACs also provide a security function by requiring the user to identify himself through a valid access code and password.

The Monitoring Center is a BBN C 70 computer that uses a network utilities program to monitor and control the network. This program sets up routines to oversee the network, manipulate data bases, display status, process control commands, and generate reports. In essence, it acts as referee, umpire, and judge for the entire network. [Ref. 4:pp. 5.12-5.15]

Gateways are network components that allow data transmissions to be transferred between networks. For example, gateways allow messages to be transferred between MILNET and ARPANET. Each gateway is a computer that is capable of acting as a network host on its attached networks. The gateway uses a special protocol, the Internet Protocol (IP), to control data flow, routing, and error checking.

In the subscriber portion of the DDN system, users can be categorized as either hosts or terminal users. Hosts are computers that can support either the AHIP or X.25 protocol, and thus can access the DDN directly through a dedicated circuit to the nearest PSN. Subscribers using other kinds of computers or asynchronous terminals must access the DDN through a TAC. TAC access requires only that terminals be configured to support ASCII code. In an ideal situation, users would all have synchronous equipment that supported backbone protocols. However, the disparities in equipment utilized by the variety of activities supported by the network make this impossible. As a result, the DDN Program Manager is committed to providing network access support devices for non-X.25 and non-AHIP equipment. [Ref. 5:pp. 7.2-7.5]

C. LAYERED ARCHITECTURE

The concept of a layered computer architecture is that similar network functions are logically grouped together. In the DDN and other layered architectures, the communicating entities are known as layers. Layers are arranged in a vertical hierarchy so that network functions can be performed in a sequential order. Each layer provides services to the layer directly above it, and utilizes the services of the layer directly below it. An overview of the layers is shown in Figure 2 on page 7.

1. Open Systems Interconnection

The increase in communications systems and equipment has created the need for a framework that allows the development of standards. The purpose of communications networks is to communicate, and without some method of coordination this would be nearly impossible. The International Standards Organization (ISO) responded

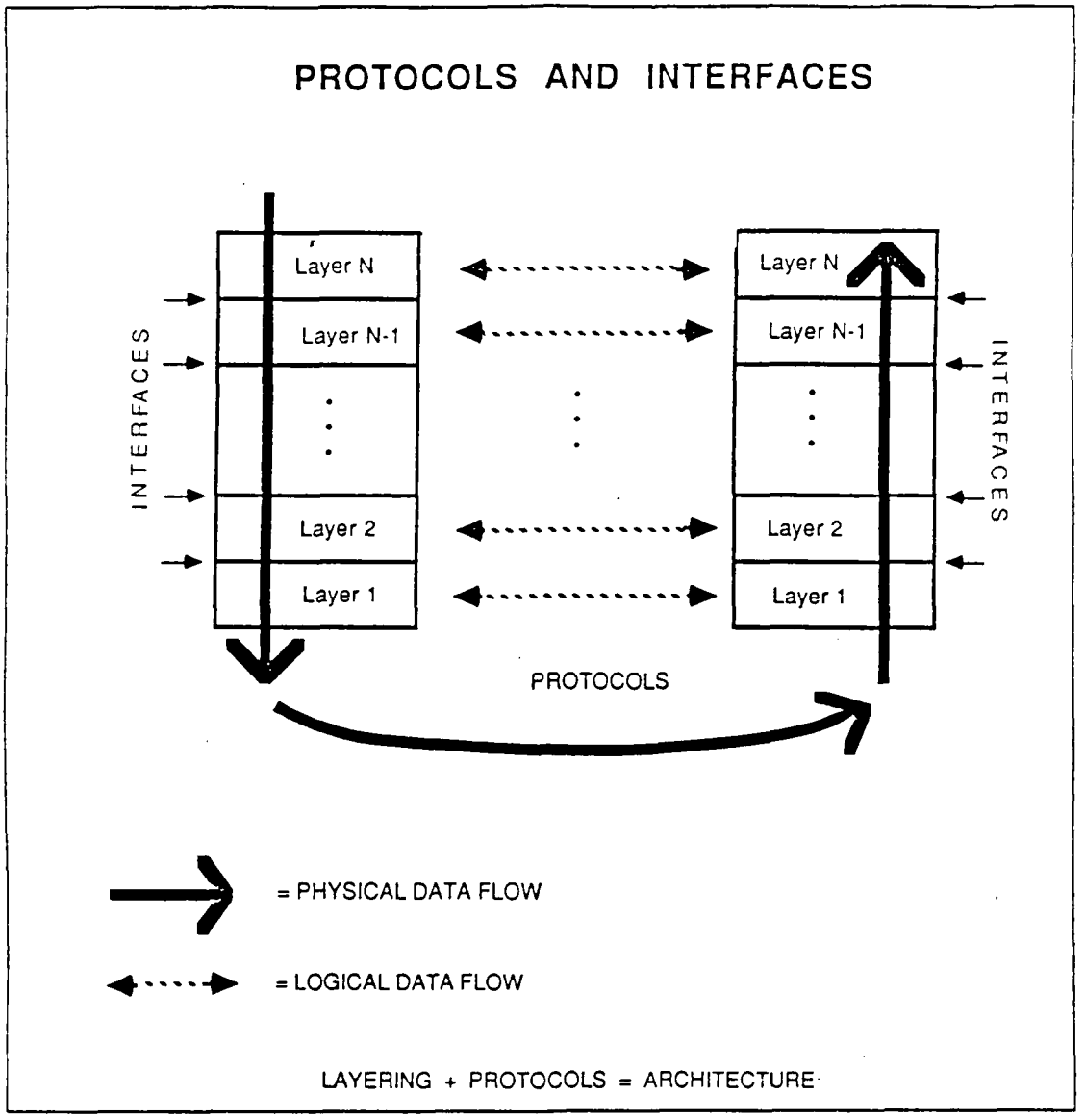

Figure 2. **Layered Protocols:** [Ref. 4:p. 6.7a]

to this need by devising a multilayered architecture that will facilitate the establishment of standards to achieve interoperability between computer systems. The model they devised is the Open Systems Interconnection (OSI) model. See Figure 3 on page 8 for an example of this model.

Interoperability is attained by adopting standardized protocols for each of the model's seven layers. Only the lowest layer has an actual physical connection; that is, only in this layer is there an actual exchange of raw bit streams. In all others, only a

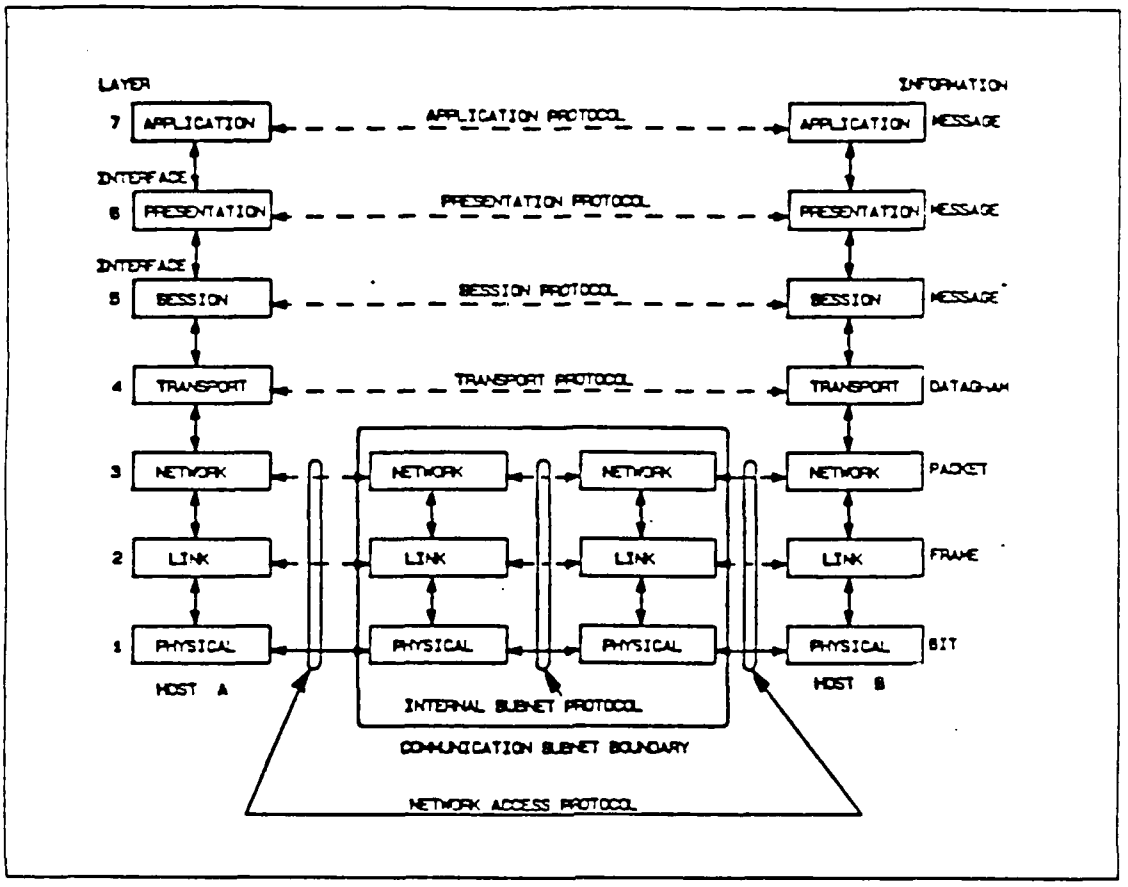

Figure 3. **The OSI Architecture:** [Ref. 5:p. 3.10]

logical connection is established. Each must send data down to the next layer in order to get it across to another system. The layers and data flow are like the floors and occupants of an office building. People, like data, can move between floors, but can only get to another building by exiting through the bottom floor. A brief description of each layer and how it is used in the DDN follows. [Ref. 5:pp. 3.8-3.12]

2. The OSI Layers

- *Physical Layer* This layer defines the physical interface between devices, along with the rules by which bits are passed from one to another. It is said to determine the interface between data terminal equipment (DTE) and data circuit terminating equipment (DCE).
- *Data Link Layer* This layer provides an assured, error-free link for data flow, and the means to activate, maintain, and deactivate the link.
- *Network Layer* This layer creates and exchanges packets between a host and a network, and between network components. Two DDN protocols are used here.

The internet protocol (IP) is responsible for routing and delivering data between networks. The network access protocol establishes the connection between the host and backbone network. The network access protocol can invoke protocols in the lower layers. The preferred network access protocol for the DDN is X.25 Standard, but AHIP 1822 and X.25 Basic will be supported until 1991.

- *Transport Layer* This layer provides a reliable mechanism for the exchange of data between different systems. It ensures that data are delivered error free, in sequence, and with no losses or duplication. The standard protocol for the DDN is the DOD standard transmission control protocol (TCP). The TCP results in reliable communications between hosts.
- *Session Layer* This layer provides an end-to-end procedure that establishes, maintains, and terminates logical relationships between processes in the higher layers. Standard DDN protocols include telecommunications network (TELNET) protocol, file transfer protocol (FTP), and simple mail transfer protocol (SMTP).
- *Presentation Layer* This layer provides a host-to-host procedure that prescribes data formatting and data transformation. In the DDN, the presentation layer is combined with the session layer.
- *Application Layer* This layer provides a means for application processes to access the OSI environment. It contains management functions and mechanisms to support distributed applications. There are no DDN standards for this layer.

D. FUNCTIONAL COMPONENTS

The DDN offers a number of services that are of special interest to subscribers. They are transparent to the user, but rely heavily on the previously mentioned protocols. Though details of use vary from host to host, depending on the software installed, three functions stand out as applicable across the network. They are TELNET, FTP, and SMTP.

1. TELNET Protocol

TELNET is the DDN function that allows a user to log in to a remote host from a local host, that is, one at his location. Once connected and logged in, the user can enter data, run programs, or perform any other operation just as if he were logged in directly at the remote computer on which he is working [Ref. 2:p. 34]. The TELNET protocol utilizes the idea of a network virtual terminal: characteristics of specific terminals are mapped into the network standard to allow terminals from a variety of vendors to be connected to a variety of hosts. TELNET also specifies the protocol between hosts that allows such things as differing line width and page size to be resolved. All TELNET data exchange is provided for through TCP.

2. File Transfer Protocol

FTP is used to transfer a file or portion of a file from one system to another. This can be done despite different computers and file storage formats. The user can

transfer a file from or to another system, or even between two remote systems. The FTP programs of the two systems communicate through TCP. FTP offers a number of options. Text files can be transferred using ASCII or EBCDIC character codes. Data can be compressed to reduce communication costs. FTP also provides mechanisms for controlling user access. In order to access files on a given system, a user must have an authorized password for that system.

3. Simple Mail Transfer Protocol

SMTP provides the basis for a network electronic mail facility. A file exists in which electronic mail is stored for each user who has access to the system, similar to a postal mailbox. When a user signs on to that host, he can send mail by placing a message in the host's outgoing mailbox, or in the mailbox of another user, and can receive mail by reading messages in his own mailbox. Typically, mailboxes are maintained through a computer's file management system. Each mailbox is a portion of computer memory that can contain text files. These files are messages that can be printed out, read, or deleted using the local software mail program. SMTP sets up a mechanism for transferring messages among separate host systems. Thus a user can send mail anywhere in the DDN, making use of TCP. The user usually sees the same mail program interface whether sending local or remote mail, so he only has to learn one format. [Ref. 6]

E. ATTRIBUTES

The DDN is primarily designed to be an operational DOD network. As such, it incorporates many qualities that contribute to overall effectiveness. The first of these, especially important to a military system, is survivability. This is enhanced by redundancy. As of early 1987, some 200 PSNs are channeling data along some 300 trunk lines [Ref. 7]. These nodes, backed up at critical locations, are dispersed over a wide geographic area. The dynamic DDN adaptive routing algorithm automatically routes traffic around damaged or congested circuits. Four levels of precedence ensure that essential, time sensitive data can get through in an emergency. In addition, the automatic monitoring of the multiple trunks, switches, and access lines helps ensure that the DDN

will gracefully degrade when transmission paths begin to go down.

Availability is a critical DDN attribute: the system operates 24 hours a day, seven days a week. The inherent redundancy of the system allows a predicted 99% availability rate for electronic communications. Dual homing, in which two access lines are connected to two different switching nodes, increases this availability up to 99.95%. [Ref. 4:p. 6.2]

Transmission quality and network delay are also important DDN attributes. Transmission quality is the probability that a message will reach the desired destination (measured by the probability of a misdirected packet) and the chances that it will contain no mistakes (measured by the bit error rate). A 16 bit cyclic redundancy check used on all access and trunk circuits, coupled with a 16 bit checksum utililized for TCP subscribers, gives an overall undetected bit error rate of less than 0.00000000000000000029, or about one occurance every 174,000 years. This same checking system also yields a probability that a packet will be misdelivered only about once out of every 184 billion packets.

Network delay is measured as the time it takes for a packet to be routed through the backbone network. This depends on several factors, including packet size, transmission rate, and precedence level. On the average, this delay is calculated to be 0.09 second for a high precedence message, falling off to 0.122 second for lower precedence traffic. [Ref. 4:pp. 6.3-6.5]

III. THE SOCIOTECHNICAL MODEL

A. HISTORY

The sociotechnical theory of job design, though initially sounding imposing, is essentially a simple proposition. It postulates that there are two inseparable components at any work site--the equipment used to perform work, or technical aspects, and the people who use the equipment, or social aspects. The goal of sociotechnical theory, at its most basic level, is to find the best match between the two. This simple premise, which appears to be common sense, all too often breaks down in practical application. In actual managerial usage, technical aspects are often emphasized to the exclusion of the social. Efforts are concentrated on expanding the technological base (not a bad thing in itself), but little thought is given to how people will use this technology. The purchase of new technological equipment does not automatically result in productive use of the same [Ref. 8]. The users must accept and comprehend the technology in order to realize potential benefits fully. Sociotechnical theory arose to attempt to bridge the gap between hardware and software systems and the people who use them.

Sociotechnical theory has its beginnings in the period shortly after World War II. In the late 1940s, a group of researchers from the Tavistock Institute made a startling observation in the coal industry. Though new production technologies had recently been employed, not all coal mines reaped the same benefits. The productivity of workers employed at production-line-style sites was consistently lower than that of workers at sites where they were organized in small groups. Thus, the researchers postulated that high performance, technology, and work organization need to support each other. [Ref. 9:pp. 33-36]

This conclusion ran counter to the then-prevailing view that productivity is strictly a function of industrial engineering. The ensuing years have produced voluminous research exploring the interactions between men and technology. The terminology varies, depending on the researcher, but the conclusions are similar. Technology is only one side of the coin. The characteristics of the users must be considered, to attain the desired benefits of advanced equipment.

B. DESIGN

The sociotechnical model used in this thesis draws heavily on the model design done by Pava [Ref. 9]. Sociotechnical design contains elements of both theory and procedure. The emphasis is on the work organization, and on how reorganization can provide a more satisfying and productive environment. The key idea underlying sociotechnical design is the view of the organization as an open system. A systems approach regards the organization as a set of interrelated parts, called subsystems, that transforms various inputs into desired outputs. This relationship is shown in Figure 4.

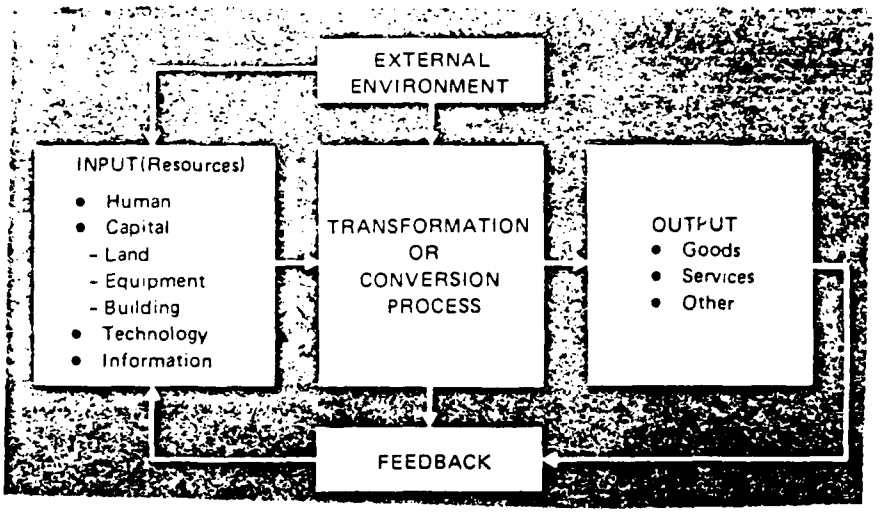

Figure 4. Conversion Model of an Operations System: [Ref. 10:p. 200]

The subsystems exhibit synergy in that the parts are more productive working together than independently. Control is exercised by the use of feedback, which is information that measures the difference between desired and actual output. The system is considered open because it extensively interacts with, and is influenced by, its environment [Ref. 10:p.44].

There are several premises in this approach. The first is that of the importance of self design. Ideas are better accepted if they originate from within the organization. This encourages collaboration and fosters a feeling of participation, as well as revealing what the workers feel needs to be improved.

The second premise is that details of a work system should not be overspecified in advance. At any point in the design process, only the minimum critical specifications should be defined. This allows for further adaptation once the minimum criteria have been met.

Finally, the design process is considered to be open-ended. This means the job is never really over. The entire process is continuously under review and subject to alteration as conditions change. Sociotechnical design encourages the development of organization members who are capable of adjusting to change. [Ref. 9:pp. 17-18]

C. TECHNICAL SUBSYSTEM

The sociotechnical approach regards the technical subsystem as the tools and techniques used to convert inputs into desired outputs. To a large extent, this is primarily the management of uncertainty. Galbraith defines uncertainty as " . . . the difference between the amount of information required to perform a task and the amount already possessed by the organization" [Ref. 11:p. 5]. The level of uncertainty is directly proportional to

- Instability of the environment
- Complexity of the tasks
- Level of task interdependence. [Ref. 12:pp. 126-27]

As the level of uncertainty increases, so does the need for processing information. In an organization where new technology has been introduced, four major elements are often affected.

- *Operator skills.* New knowledge and skills are required to utilize the technology.
- *Procedural enhancements.* The work of nonoperators must change to accomodate limitations of a system, such as adapting new administrative procedures.
- *Structure.* Changes in the organizational structure, such as allocation of responsibility, information flow, role coordination, incentives, and compensation, are necessary.
- *Culture.* Profound changes may be required in the core beliefs that comprise an organization. These include things like status differentiation, definition of mission, and underlying management philosophy. [Ref. 9:pp. 3-5]

All of these elements can contribute to confusion in an enterprise. Two options are available to organizations operating under a mismatch between information processing needs and capabilities. One is to reduce uncertainty. This can be accomplished by increasing the amount of resource inputs, such as men, material, or time, to yield a desired

output (goods or services). This is known as introducing slack. The second option is to increase the capacity to process information. This can be done by changing the tasks or their interrelationships. The result is a decentralized decision-making process, meaning decisions are made at the lowest possible level.

A key concept in sociotechnical analysis is identifying where the areas of greatest uncertainty occur. The greatest chance for making mistakes lies in these areas. Benefits accrue from placing the information, authority, and skills needed to control errors at the points where they will do the most good: the lines of authority are more horizontal than vertical. From the sociotechnical viewpoint, this improves response, encourages participation, and improves performance.

D. MOTIVATION

The sociotechnical design process is centered around the principle of motivation. Motivation is that which instigates, focuses, and supports people's behaviour. The traditional view of motivational theory held that people naturally disliked work. Work was regarded as dull and repetitive. It was the job of the manager to create financial incentives in order to get workers to perform. However, the recent works of many researchers have provided an alterative position, that of a human resources model of motivation. This model proposes that people do not inherently find work distasteful. They want, even need, to contribute to meaningful goals when they have had an input in setting those goals. The concept embodied in this model is that most people can exercise far more creativity, self-direction, and self-control than their present jobs require [Ref. 10:pp. 419-420].

All people bring certain needs with them to a workplace. Their motivation is directly correlated with the degree to which these needs are fulfilled. It is the manager's function to meet the organizational goals better by tailoring the characteristics of the job to fit the needs of the workforce.

Fredrick Herzberg developed a two-factor theory to explain what these needs are and what determines them. He called the first group hygiene factors. These include salary, working conditions, and company policies. Hygiene factors deal with the worker's relationship to the organizational environment. When low, they can cause dissatisfaction. But, when high, the best they can cause is a not-dissatisfied, or neutral, condition. The second group of factors relates to job content, and includes things such as achievement, recognition, and responsibility. Herzberg called these motivating factors. Motivating factors, when high, result in job satisfaction. When low, the worst

effect they can have is a neutral state. Thus, job satisfaction and job dissatisfaction are influenced by different factors. [Ref. 13]

E. SOCIAL SUBSYSTEM

The social subsystem is concerned with two primary areas: (1) the division of work, and (2) the methods of coordination used to control uncertainty in the technical conversion process. The division of work in an organization defines the manner in which tasks are assigned. It implicitly specifies the roles people play, i.e., what their jobs are. Hackman and Oldham have identified five core job dimensions. They are:

- *Skill Variety*. The extent to which a variety of skills and talents are required to accomplish the assigned tasks.
- *Task Identity*. The extent to which the job involves completion of an identifiable unit, project, or other piece of work.
- *Task Significance*. The extent to which the task affects the work or lives of others, inside or outside the organization.
- *Autonomy*. The extent to which the individual has freedom on the job, and the discretion to schedule tasks and determine procedures for carrying them out.
- *Feedback*. The extent to which an individual has receives praise, blame, or criticism about the effectiveness with which tasks have been performed. [Ref. 14:pp. 159-170]

Meaningfulness, responsibility, and an understanding of the results of one's work are critical factors in generating motivation and job satisfaction. Researchers have shown that a high degree of skill variety, task identity, and task significance all contribute meaning to the job. Increased autonomy results in a greater sense of responsibility. Feedback instills in the workers a sense of understanding of their roles and functions in the organization. Thus, the design of the job is extremely important. The effects of these core characteristics are illustrated in Figure 5 on page 17.

The sociotechnical design of jobs is intended to make the job something worth doing well. This runs against the traditional industrial engineering approach to work. In this older approach the goal is to simplify work, often to a minimal number of mundane, repetitive steps. All too frequently this can be the end product of automation. Efficiency is improved, but at the cost of variety in the work, and of identity and autonomy in the workforce. The ultimate effect on productivity varies. Workers with high needs for personal growth may become dissatisfied and experience a decrease in performance, while those who fail to identify with their jobs want to keep things as simple as possible [Ref. 10:pp. 235-241]. Sociotechnical intervention seeks to determine what the needs of the workforce are, and encourages commitment and involvement.

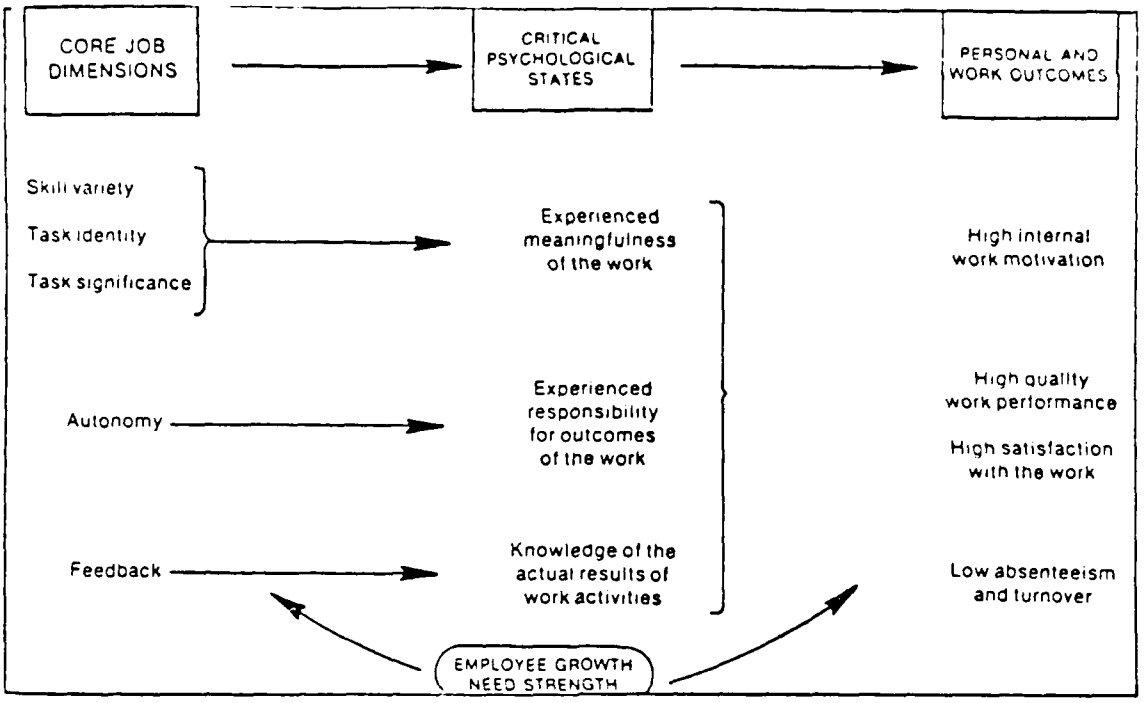

Figure 5. Effects of Core Job Characteristics: [Ref. 10:p. 239]

Once the work has been divided, the jobs must be coordinated to produce the desired outcomes. The amount of coordination needed depends on how much information flow is required to perform tasks, and on the level of interdependence between the groups performing them. Interdependence relates to the degree that one group relies on other groups to complete a finished product. Coordination needs increase as work becomes more dynamic, the environment changes, and interdependence is high. It is achieved through a variety of methods. The organization's chain of command can specify relationships between workers. Rules and procedures can be installed to handle routine events. In addition, the use of planning and goal setting attain coordination by directing efforts to the same targets.

When these relatively simple methods do not provide the necessary coordination, other, more complex means can be employed. Coordination can come from upper or from cross levels in the organization. Vertical coordination methods involve data transfer up and down the chain of command. For example, control can be effected through computerized management information systems. A potential problem is that

if a work force is already disenfranchised by automation, this is adding fuel to the fire. Horizontal coordination mechanisms cut across the management layers. This allows information exchange and decision making at the level where the needed information exists. Horizontal coordination can be facilitated by creating a liason role between departments with frequent contact, a process known as boundary spanning. Individual expertise can be pooled by forming teams, thereby channeling efforts to a common end. [Ref. 10:pp. 264-268]

It is on this concept of team building that sociotechnical design is focused. The formation of work groups is encouraged. Group members learn how to perform multiple jobs. Training is done within the group. The group determines task assignments and means of coordination, without involving higher level supervision. The group members are treated as valuable resources. They serve to enhance both the structure of the social subsystem at work and the social relations among the people on the job. [Ref. 9:p. 23]

Bertrand Russell said:

> Work is of two kinds: first, altering the position of matter at or near the earth's surface relatively to other such matters; second, telling other people to do so. The first is unpleasant and ill paid; the second is pleasant and highly paid. [Ref. 15]

Management, which falls into Russell's second category, is an information-intensive activity. Computer-mediated communications systems such as the DDN provide the promise of significant benefits for the manager who can optimize the use of this technology. Part of the benefits accrue through increased efficiency, that is, the ability to produce more with less. However, the greatest benefits can be realized through increasing effectiveness. In the simplest terms, the essential function of an organization is one of adding value. This value is what is imparted during the conversion process of inputs to outputs by the organization's activities. The technology is a tool, not an end in this process. The key ingredient in attaining greater effectiveness is the human factor. Management gets the greatest payoff from a new technology by increasing the value added by the workers. It follows then, that it is incumbent upon management to create and sustain the conditions that lead to the greatest value added by the workforce. [Ref. 16]

Sociotechnical design proposes to create the best possible scenario for maximizing the human value-added potential. In practice there is no set formula for optimum performance. No one can devise a scheme to encompass all the variables that go into this

optimum, and sociotechnical theory says that no one should. The goal, instead, is to set the stage to allow the greatest possible flow of ideas to occur, and from this flow the best feasible solutions will arise.

The method recommended by sociotechnical theory is the formation of natural work groups as the basic organizational building block. Some analysts have said that any work process should be organized around the self-managed team concept [Ref. 17:p. 297]. Using one approach to team formation, a company specified that every person in the organization should become part of a group consisting of eight to fifteen people. Each group was highly autonomous: responsible for its own scheduling, training, problem-solving, and many other activities. The teams developed their own quantitative performance indicators. Meetings occured at least once a week. Members were rewarded as a group by top management; individual performance ratings emphasized support for the team. Job specialization was virtually eliminated due to the emphasis on cross training members in all areas of the group's responsibilities. The results for the organization as a whole were improved productivity and quality. [Ref. 17:pp. 298-300]

The organization of work groups revolves around four major principles:

- The group is responsible for a specific product.
- The group is expected and helped to become self-regulating.
- Groups have multi-skilled responsibilities.
- Skill-based rewards are given to group members. [Ref. 9:p. 30]

Self-managed teams might be perceived as a threat to the rank structure in a military organization. This need not be the case. Top management, as personified by the upper rank echelons, sets the policies and objectives for the organization. The teams carry them out. The important distinction here is that there is no over-specification or "micro-managing" of how these objectives are met. The decision-making process, which is contingent on information (the primary output of the DDN), is devolved to the teams. This is where the greatest expertise and experience resides. In cases where the teams fail to reach a consensus, the decision can be passed up to the next level in the chain of command. The incentive is created for the teams to resolve their own problems to avoid the costs of high level intervention.

IBM uses this technique in its budgeting procedure. Certain budgets are constructed by negotiation among all concerned parties. Each member has the option of concurring or not concurring with proposals. Non-concurrences that cannot be resolved escalate through the corporate ranks, until, if still not resolved, a central management committee

renders a decision. Thus, top management stimulates a variety of participation and constructive negotiations among the people in the company who are closest to the problem, while simultaneously reinforcing key corporate objectives and policies.

IV. TECHNICAL ANALYSIS OF DDN IMPLEMENTATION

A. SOURCES OF UNCERTAINTY

The DDN is, in its essence, a computer-aided communications medium. The introduction of it into a military organization is similar to the expansion in recent years of automation in the offices of the private sector. There is a large body of literature and research about this automation process that is of interest to the management of a site utilizing the DDN. Electronic communications are changing the way business is conducted, and have the potential to change how work is done. Electronic mail, in particular, opens up a Pandora's box of change in communications. The sociotechnical approach is to implement these changes in a manner that does not disrupt the social system of the work setting.

As discussed in the previous chapter, the primary purpose of the technical system is to reduce uncertainty. The very act of implementing a new system creates an uncertain environment. This uncertainty is heightened to the degree that tasks are complex and interrelated. In the communications milieu, management must answer the questions of who can use the system, what they can use it for, and how much it will cost. The answers to these questions can be partially derived through the experiences of other organizations in implementing electronic communications systems.

1. Rules Concerning Usage

Tushman and Nadler contend that uncertainty can be reduced through the use of rules and procedures [Ref. 18]. These rules and procedures would ideally be derived through participative negotiation. Those involved in the work process have a good conception of who needs to do what.

A good example is provided by Digital Electronics, a large corporation which recently installed an electronic communications system with over 6000 users. The company developed a set of guidelines for determining access. Electronic mail accounts were authorized on the basis of:

- The need to send a specified number of messages daily
- The need to communicate over a large geographic area
- The need to communicate with hard-to-reach personnel
- The need to coordinate and keep current on project information. [Ref. 19:p. 8]

Although obviously not comprehensive, these criteria provide a groundwork for negotiating the allocation of subscriber access.

2. Usage Purpose

The question of what computer-aided communications should be used for raises an interesting dilemma. Should usage be limited to task-related functions? And, if so, what exactly determines the relationship to task? One study of 96 organizations identified over 30 different purposes for electronic interaction [Ref. 20:p. 125]. Many of these could be classified as social, rather than strictly production-related functions. For example, social dialogue is often found among ARPANET users, although such interaction is officially discouraged. This social usage may not be dysfunctional. The use of electronic communication can help to integrate individuals into the organization. This networking effect can be used to support task-related information flow. Cohesiveness among employees may increase. Social use can encourage workers to improve their knowledge of the system, much the same way computer games increase the player's interaction and familiarity with computers. In effect, social use may be a means of establishing the lateral relations deemed necessary for processing work-related uncertainty. [Ref. 20:pp. 125-134]

3. Usage Costs

The subject of cost must receive serious consideration, especially in an era of declining budgets. The allocation of scarce resources (and no resource is perceived to be scarcer than money in a budget crunch) is a critical issue for management in any organization. Funding in the DOD is not static; money flows to those areas that, in the Congressional eye, demonstrate the most "bang for the buck." Thus, the manager is uncertain as to what amount will be included in next year's budget. This uncertainty can snowball through an organization, as each department tries to protect its budget base. New systems, with unproven effectiveness, tend to be highly suspect when budget cuts must be made.

Costs of the DDN can be broken down into two types: initial costs, which include those of installation, equipment, and routine maintenance, and transaction costs, which are the charges levied for using the network. In its early stages, transaction costs on the DDN have been financed solely by the DCA. However, as the program matures, these costs will be shifted to the subscribers. Uncertainty arises from the lack of knowledge about how these costs will be applied. BBN has proposed a usage-based cost recovery system that reflects the current commercial tariffs [Ref. 21]. Costs would be

roughly analogous to phone bills: price is determined by when and for how long the user is on the line. Although an indepth analysis of potential costing techniques is beyond the scope of this thesis, it seems clear that costs will be based at least partly on peak traffic usage and packet size [Ref. 22].

A pertinent topic in the area of costs is that of relevancy. The DDN, by directive, will be installed. This makes transaction costs the focal issue. Communications will occur; it is only the medium through which they do so that must be decided. In the Digital Electronics example used previously, the company performed a cost benefit analysis on communication through different media, considering such factors as equipment, labor, tariffs, and frequency of use. They found that the cost of sending one message via a computer-mediated path was the most expensive, but the cost of each additional message sent dropped dramatically when compared with other media. Ultimately, they realized a substantial marginal cost savings by using electronic mail [Ref. 19:p. 11].

The DOD currently spends approximately $204 million annually on the Automatic Voice Network (AUTOVON), and $90 million for the Automatic Distribution Network (AUTODIN) [Ref. 23]. These figures do not reflect the hidden costs of labor and frustration that can ensue from a long round of "telephone tag" with an elusive target. The extent to which DDN usage reduces these costs is a de facto savings that can be attributed to the system.

B. PROBLEMS IN IMPLEMENTING NEW TECHNOLOGY

1. Organizational Bureaucracy

When a military site comes online within the DDN, it is implementing an innovative change within the organization. This organization is of a type known (perhaps infamously) as a bureaucracy. A bureaucracy is denoted by:

- Large size
- Dependance on it by the majority of the members for most of their income
- Hiring, promotion, and retention that are based on some assessment of organizational role performance
- A major portion of output that is not evaluated in the economic market.

Additional characteristics include hierarchical structure, impersonality of operations, and the extensive use of rules. [Ref. 24:pp. 24-26]

In a bureaucracy, two traits stand out that have an effect on a sociotechnical approach for introducing the DDN: (a) the need for communications networks, and (b) multiple internal conditions that provide resistance to change.

The sheer size and complexity of bureaucracies necessitate a large volume of communications. These fall into two basic categories. The first is formal communications. These are regarded as official by the bureau. A plan of the day would be an official communication. The second type is known as informal. These incorporate the unwritten organizational rules and procedures, and reflect the personalities of the organizational members. For example, short interoffice correspondence falls in the informal category. Formal communications tend to flow along vertical channels, whereas informal communications flow horizontally. The majority of communications in an organization are informal [Ref. 24:p. 113]. Both types can be facilitated by the DDN. The electronic network provides the linkages between the formal and informal, but important, social networks.

2. Information Distortion

An inherent problem in flow of information is that of possible distortion. Distortion is the result of tampering with information due to bias on the part of the sender. Bias is an unavoidable product of such things as prejudice, intentional or unintentional selective editing of facts, or just simple human error. Decision making in an organization is contingent on information. When this information is faulty, it impinges on the quality of the decisions made. One of the primary methods of reducing distortion is through redundancy, that is, the duplication of information through alternative sources for the purpose of verification. [Ref. 24:pp. 112-120]

Electronic communications are ideal for redundant communications. Data files are readily transferable. Inputs and opinions can be obtained from a variety of sources through electronic mail. In addition, information sources external to an organization can be tapped through the DDN if necessary. The ability to transfer information literally at the touch of a key will greatly assist the collection process.

While electronic communications will enhance the ability to gather information, there is a downside risk that the volume of information will adversely affect the decision making process. One study found that decision makers have a nearly insatiable appetite for information. They will assimilate information beyond the amount that would be reasonably assumed to be needed to make a decision, and force themselves into a condition of information overload, adversely affecting their decisions. Curiously, though the

study concluded that information overload may result in poorer performance, these decision makers experienced greater satisfaction and confidence in their decisions. [Ref. 25]

The conclusion for managers of a DDN site is clear. Electronic communications should facilitate effective communication and reduce distortion. The means of achieving this, however, are less clear. The emphasis of innovation in computer-mediated communications has been on efficiency, that is, on increasing the throughput of information. This emphasis can result in the garbage-in, garbage-out syndrome familiar to programmers. In sociotechnical parlance, this phenomenon is known as micromyopia. Micromyopia is the assumption that increasing the efficiency of the parts of an organization will result in greater efficiency for the whole set of work activities [Ref. 9:p. 53]. This does not automatically happen. Greater attention must be given to improving the effectiveness (rather than the volume) of the information communicated. One key might be that the findings concerning the negative effects of information overload were based on individual decision makers, not on groups. When the goal is determining a means of improving the effectiveness of group communications, the participation of the work groups involved is critical.

3. Resistance to Change

Change is the fly in the bureaucratic ointment. The bureaucratic profusion of hierarchical layers and formal procedures is exactly the opposite of the organic structure proposed by many researchers as the most conducive to making successful changes and innovations [Ref. 10:p. 400]. The bureaucratic organization is structured to ensure predictability and reduce uncertainty. This results in inertia and resistance to anything that may upset the order of things. Individuals in the organization may resist change out of a fear of the unknown. They fear what their roles in the new system might entail, or are anxious because they lack the skills required to perform their tasks in it. The role of management, particularly middle management, is critical in overcoming this resistance. Management techniques that are the most effective in the long run are those that include the involvement and participation of group members. [Refs. 10:pp. 358-59, 12:pp. 343-45]

Information concerning the DDN should be disseminated early to facilitate the systematic participation by key management and non-management personnel during system implementation. Several factors are known to have a positive effect on the implementation of new technology: (1) concrete and on-going training, (2) availability of

"on-call" practical advice, (3) observation of the implementation in other organizations, and (4) regular meetings of all players to discuss problems [Ref. 26]. These factors can be used to excellent advantage to assure system acceptance by the elements of the organization that are most affected by the new technology.

C. ELEMENTS AFFECTED BY NEW TECHNOLOGY

1. Development of Skills

When a new system is installed, the first area to be impacted is that of the skill level and expertise of the workforce. New technology implies new things to learn. This underscores the need for a comprehensive, systematic training program. At the most basic level, the Naval Telecommunications Office provides publications relating to the DDN. A structured course, available on videotape, is offered through the Program Management Office of the DCA. [Ref. 27]

Providing training at a DDN site is complicated by the varying levels of computer expertise among potential users. These levels can run the gamut from novice to expert. For the novice, training must be conducted in a manner that will alleviate the very real problem of computer anxiety, brought on by a lack of understanding of how the system works, and what must be done to use it. Training geared to the experienced user often takes for granted a certain level of skill, intuition, and information that is lacking in the novice. The thrust of the training is to transform technical illiteracy to a working technical proficiency. [Ref. 28:p. 475]

Some points developed in recent research on learning are relevant to DDN training. Technical learning increases when the learner has a meaningful mental model of what is to be learned, and when the new material is actively processed during the learning phase. An important distinction is made between rote and meaningful learning. Material learned by rote simply exists in memory as isolated units of information, with little or no connection to existing knowledge patterns stored in long term memory. Meaningful learning implies understanding, which allows the transfer of learned knowledge to new situations. The learner must have some type of conceptual framework available during the process in order to assimilate the new material. This framework acts as an organizer for incorporating the material into the learner's existing knowledge. This concept was shown to be most effective in applications where the learner possessed little a priori expertise, and when previous knowledge was transferred to new situations, as would be the case at a new DDN site. [Ref. 29]

2. Organizational Rules and Procedures

A procedure is "a detailed set of instructions for performing a sequence of actions that occurs often or regularly" [Ref. 10:p. 91]. Procedures are formal controls imposed to coordinate action and reduce uncertainty. In a military environment, these are called standard operating procedures. A problem arises, when dealing with a new technology, that what worked before may not be applicable to the future.

Reliance on rules and procedures is the simplest and cheapest means to effect coordination [Ref. 10:p. 269]. However, rules and procedures are inflexible, as they relate to the processing of information. Sociotechnical intervention stresses minimization of detailed specifications, in order to maximize individual user contributions [Ref. 9:p. 17]. To an extent, rules and procedures are necessary in an organization. The most effective procedures are usually determined by including the inputs from users.

A reliance on standardized procedures may not be the best tactic at the work site utilizing the DDN. The more complex the technology employed in an organization, the greater the level of task interdependencies. Each area of the organization depends on the production of other areas in turn to produce its outputs. This necessitates a decentralized communication structure to handle the amount of communication that must occur horizontally through the organization simply to get the job done. The creation of lateral relations, as previously stated, is an effective way to process this information. In traditional studies, this method is considered costly. However, the extended electronic communications capabilities of the DDN result in the establishment of direct cross boundary communication. This linkage between users provides an opportunity to communicate about the best means of implementing the technology. [Ref. 20:pp. 24-31]

An appropriate area for procedural standardization at a DDN site is the format of electronic communications. The emphasis is not on what is said, but rather on how it is said. Communication is often an unstructured activity, and the formatting of an unstructured activity into an electronic medium can be difficult. When communication is carried out without visual and aural cues, it is difficult to resolve ambiguities and clarify nuances in meaning. A message must be sent correctly the first time to maximize the benefits of automation. Rules of good writing apply in any environment, but their importance is magnified in an automated one. Appropriate rules for DDN communications include:

1. Think before you write and know exactly what you want to say.
2. Consider who your readers are and what they want and need to know.

3. Write only what needs to be said, nothing more.

4. Write everything that needs to be said, nothing less.

5. Keep sentences under control: short, simple, direct.

6. Use words common to all readers; avoid jargon and alphabet soup acronyms.

7. Carefully weigh the advisability of using emotionally loaded phrases.

8. If a message is important or complicated, get a proofreader. Ask that person for comments, and if the message has come across as intended.

9. Reread what you have written with an eye not only for errors, but with thought for the impression it will make and the reaction it will elicit.

10. When these steps are accomplished, send it out. [Ref. 30]

3. Organizational Structure

The introduction of computer-mediated communication on a scale as large as that contemplated for the DDN can drastically affect an organization's structure, often in ways unforeseen by strategic planners. Change and uncertainty result in the emergence of networks within an organization, as people try to deal with change. Communication within and between these networks leads to a change in organizational structure from a vertical hierarchy to a broader, more horizontal arrangement. [Ref. 31]

The full impact of introducing the destabilizing effects of a computer communications system such as the DDN on the traditional, vertical hierarchy of military bureaucracies is still to be determined. Researchers have noted the following structural changes occuring in organizations that implement an electronic communications system:

- De-emphasis on the geographic spread of people
- Lack of traditional authority power lines as information becomes accessible to more personnel
- Flattening of organizational structure as communication with subordinates is streamlined electronically
- Promotion of teamwork as physical isolation is diminished
- Increased pressure on management to act quickly
- Increased quantity and timeliness of information accessible from within or from outside the organization. [Ref. 32]

Contemporary research is just beginning to explore the effects of computer networks on organizations. Kiesler states that:

> New technology has three orders of effects. The first is the intended technical effects--the planned improvements in efficiency that justify investments in new technology. The second is the transient effects--the very important organizational adjustments made when a technology is introduced but that eventually disappear. The third is the unintended social effects--the permanent changes in the way social and work activities are organized. [Ref. 33:p. 46]

The planned enhancements in information processing through use of the DDN can readily be identified. Computer-mediated communication is unparalleled in terms of speed, time, and the ability to reach a broad audience, particularly when the interoperability aspects of the DDN are considered. Even the transitory effects can be largely anticipated. Such things as the learning curve for people working with new systems, resistance to change, and worker anxiety invariably result when new technology is introduced, and can be anticipated. It is the unintended effects of change that can have the greatest impact on the structure of the organization. Little is known about such side effects, and how to deal with them.

Electronic communication allows people in groups, whether formal or informal, to interact about common interests or problems. The scope of the DDN removes the constraints of geography; users can communicate virtually worldwide. This union of people sharing the same interests and exchanging ideas about shared problems creates, in effect, an electronic quality circle for problem solving. A quality circle is a characteristic of an open, organic organization [Ref. 10:p. 280]. Thus, conflict can arise if the previous structure was tightly controlled and mechanistic, due to the gap between the way management perceives work being done and the way it is actually performed.

Several features of electronic communications are organizationally important. First, the ease and availability of communications encourages teamwork, a foundation for the formation of work groups in a sociotechnical design. Second, message senders and receivers usually process their own communications, without going through an intermediary such as a secretary. This is a large step in breaking down organizational barriers. Third, subordinates can communicate directly with their superiors, essentially democratizing the workplace. In a military context, this implies a potential for circumventing the chain of command. Finally, electronic communications reduce the volume of paper, if not paperwork. Messages and files exist electronically, with no need to make hard copies unless it is desired. This can result in a significant savings in storage space, once personnel adapt to the idea. [Ref. 33:p. 48]

Decision-making policy in a computer-mediated communications environment can encourage more participation from the workforce. Wide information searches are

possible, reaching to all areas of the organization and beyond. This allows minority views from geographically distant or structurally separate groups to be obtained. It is possible for all points of view on an issue in the organization to be considered, thereby giving all workers a voice in their own determination. [Ref. 33:p. 58]

The final area of organizational structure to be considered is where the work is performed. It has been demonstrated that computer-mediated communication removes the restriction of geography. Physically distant locations are electronically joined. A logical extension of this is "telecommuting", or the performance of work from the home rather than the office. DDN users can connect to the network from a personal computer (PC) through a TAC. At present, the DDN treats the PC as a terminal, that is, it ignores the computing power of the PC. This is changing. Development is underway on a new DDN access paradigm that will allow PCs to connect directly into the DDN. The user could do almost anything from the PC that could be done from a mainframe. [Ref. 34]

Private industry now is considering the use of computer-mediated communications to create electronic "cottage industries". Studies indicate that the acceptability of the decision to work at home is primarily related to work position and job characteristics. Working at home is favored by those whose jobs require independence and freedom from interruption, such as programmers, and by those who have low social needs from the job. On the other hand, supervisors are more resistant to the idea. In all cases studied, the interest of workers, support by management, and the expectations of both are critical in implementing telecommuting. [Ref. 35]

The implications for management of home-based DDN use are mixed. Advantages include the great potential of reducing transaction costs by allowing transmission during off-peak hours. Telecommuting may find favor at sites such as the Navy Regional Data Centers (NARDAC), where there are a large number of programmers. At such sites, the privelige of being able to telecommute could become part of the reward system, something given to the more trusted workers as a means to increase productivity and worker morale.

A disadvantage of telecommuting is that for many workers the important social interaction at the worksite is lost, as a result of the physical isolation of telecommuting. Management must be willing to give up direct-contact supervision, actually trusting people to do their work on their own. Psychological problems may result from breaking

down the distinction between home and work. Nevertheless, telecommuting is a useful alternative to the existing system, under the right working conditions.

4. Organizational Culture

One of the subtlest areas of an organization to be affected by a new technology is the culture. A group's collective beliefs, status differentiations, and power distributions can all be impacted by electronic communications. Nonverbal behaviors such as gestures, tone of voice, and eye contact strongly affect the roles played in face-to-face communication. These are absent in electronic communication. Software is blind with respect to vertical hierarchy. While in verbal communication one individual often dominates due to position, status, or personal charisma, this has not been the case with computer-mediated communications.

Another culture-related factor is that depersonalized messages invite more assertive, less inhibited communications. There is a long history in computer networks of "flaming", that is, expressing oneself more strongly on a computer than would be done in other communications settings. ARPANET has had to screen network bulletin boards for messages of questionable taste [Ref. 36:pp. 1124-28]. This no-holds-barred style of communication provides a wealth of opportunity for the manager at a DDN site. Sampling the attitudes of workers is easier, and there exists the capability to have an honest exchange of ideas, stripped of many of the artifices of convention and status. Anonymous electronic communications can serve as a source for new ideas to improve production, and as an outlet for improving morale.

An organization's communications system serves to implement goals and coordinate and control activities. It can also be a source of power. Personal influence in organizations is a matter of both positional authority and individual skills in comprehending and manipulating organizational processess. Simply put, it is the ability to get things done. One study established that an individual's power is positively related to his ability to access organizational resources such as people and information. [Ref. 37:pp. 3-7]

If information can be regarded as a power resource, then the speed and ease of access to information offered by the DDN could shift the balances of power previously in place at the organization. More people could become privy to the information necessary for decision making, changing status relationships while increasing participation. One of the determinants of power is irreplaceability [Ref. 37:p. 5]. People who can make themselves indispensible in some way gain a certain amount of power. Those who

master the use of the DDN could create powerful niches for themselves. Equally important, those who don't use this medium could lose influence, regardless of their hierarchical position. Management must be aware of and monitor any such fluctuations in the organizational power bases.

V. SOCIAL ANALYSIS OF DDN IMPLEMENTATION

The DDN is a computer-mediated communication system that is implemented in a pre-existing military organization. It is important to remember that it is not an end unto itself. That is, the primary function of most users is not just to become experts on the DDN. Rather, the DDN is implemented to enhance the operations of a variaty of organizations. These operations range from the transmission of financial records at Personnel Support Detachments to the sharing of information between scientists at military research centers.

This variety of uses also implies a diversified population of users. It would be difficult, if not impossible, to determine a single set of specific characteristics to apply to the users that would prescribe an optimal means of implementing and utilizing the DDN. Instead, the process of implementing the new technology must be adapted to the unique attributes of each workforce to obtain the best results. This is the goal of sociotechnical design.

In sociotechnical design, the underlying social subsystem of the organization is linked to technology to optimize performance. Sociotechnical theorists have prescribed conditions necessary for this linkage. These conditions evoke and sustain commitment and involvement. They are:

- Autonomy
- Opportunity to learn and continue learning
- Variety
- Opportunity to exchange help and respect
- Sense of meaningful contribution
- Prospect of a meaningful future. [Ref. 9:p. 21]

Thus, the optimal sociotechnical system is a work system in which the jobs provide the opportunity to use a variety of skills, to make decisions, to complete meaningful, whole pieces of work, to know how well one is performing, to interact with others, and to learn [Ref. 38 :p. 28].

A. DATA COLLECTION

1. Procedure

This study attempted to measure the degree to which the conditions for sociotechnical design are present in organizations using the DDN. The primary method for collecting data was a self-administered, closed-end questionnaire using a seven point Likert scale. The respondents answered a question by selecting an ordered number between one and seven that best reflects their estimation of the answer. A response of one represents the strongest disagreement and seven the strongest agreement. In addition, the questionnaire included several open-ended questions to elicit respondent's greatest likes and dislikes concerning the DDN. The study also sought to determine the level of awareness of the respondents about the DDN, and the level of their use of it. Appendix B contains a sample questionnaire.

The questions were designed to reflect, from a user's perspective, the presence of the sociotechnical conditions in the organization. The questions were divided into those relating specifically to the DDN, and those focusing on the respondent's overall functions in the organization. This was done in order to give due consideration to the dependent role of the DDN within the larger context of the organization's concept of operations.

The questionnaire can be broken down into several areas of concentration. These reflect the six previously-listed sociotechnical conditions that are theorized necessary for optimal performance, as well as other information. The additional areas are:

- Experience with computers and or the DDN
- Comfort with using the DDN
- Likes and dislikes about the DDN.

2. Data Analysis

The data collected from the questionnaires were analyzed in three ways. First, the responses from all three groups were reported according to the percentages that fell under each of five Likert scale categories (original response values of 2 and 3 were combined, as were response values of 5 and 6, to facilitate the reporting of results.) This was done in order to show the full spread of the responses, and to avoid any misrepresentation of the data that might occur from depicting only some aggregated presentation of the data. Second, the means and standard deviations of the responses were calculated. This was done to show an average response to each question from each of the three

groups, and to present the associated variability with respect to each mean. Third, correlation analysis was performed with respect to each question and all the other questions. This was done to show the relationships between the responses to different questions, and as a preliminary step for performing regression analysis.

Correlation produces a number between -1 and 1, called the correlation coefficient, that gives an indication of the amount and direction of association between the responses to any two selected questions. For example, a correlation coefficient of near 1 indicates a high level of correlation between the two responses. A value near -1 indicates a negative correlation. Values near 0 indicate little or no correlation. Such correlations can be used to derive an estimate of the extent to which the response to one question can be used to predict the response to another. The procedure for deriving such predictive values is regression analysis. When regression analysis is used to compare the response to question A with the responses to one or more other questions, the procedure yields a coefficient of determination, which is the square of the correlation coefficient (R^2) between A and the other questions. The value of R^2 indicates the percentage of the variation of A that can be explained by the other questions. Table 1 gives guidelines for interpreting the size of R^2.

An accepted convention is to present all statistics in terms of how much confidence the observer can place in the number calculated. This study used the student's t-test to determine a confidence level for each calculation. For example, a 95% confidence level means that the observer can be 95% certain that the calculation is statistically significant. [Ref. 39]

Table 1. CORRELATION COEFFICIENT VALUES

R^2	*Interpretation*
0	No Correlation
0-.25	Weak Correlation
.25-.64	Medium Correlation
.64-1.0	Strong Correlation
1.0	Perfect Correlation

3. Development and Use of Performance Measures

Management personnel in an organization presumably invest in a new technology because the new technology is superior to an existing system. Some form of measurement should be established to evaluate this superiority; that is, measures of performance are needed. This study makes use of two DDN-related measures of performance.

(a) A measure of DDN superiority over other means of communication was obtained by determining the extent to which the use of the DDN reduces the use of other media.

(b) A measure of DDN effectiveness was obtained by determining the extent to which the DDN has improved work performance.

Regression analysis was used to examine what conditions, represented by questionnaire items, could be used to predict high performance measures.

4. Study Participants

The DDN consists of thousands of subscribers, and tens of thousands of potential users. Three groups were selected as approximately representative of the potential user population, within workable limits. All respondents worked at a military site that has access to the DDN.

The first group consisted of scientists and engineers at the Naval Weapons Center at China Lake, CA. This group was chosen to represent research-oriented DDN users. The second group was a sample of students at the Naval Postgraduate School in Monterey, CA. The students were chosen to represent the general military population that is newly exposed to the DDN. The third group was made up of operational users, selected from the United States Army Information Systems Center at the Presidio of San Francisco, CA, and the DCA at Wheeler Air Force Base, Oahu, HI. This sample was chosen to represent DDN users in an operational military environment. The 90 participants were randomly selected from these three sites. The sample sizes were 47 in group one (research), 21 in group two (student), and 22 in group three (operational).

5. Study Limitations

To keep this study within reasonable limits, several restrictions were necessary. These resulted in certain weaknesses in the study, including:

- The number of participants in the study is small relative to the total number of DDN users and potential users.
- The degree to which the three groups selected are representative of all organizations using the DDN is unknown.

- The use of a prestructured questionnaire limits the areas in which a respondent can reply. Significant data could be missed because there is no place on the questionnaire to include it.
- The questionnaire is geared to those who use the DDN. No allowance is made for determining the reasons that non-users fail to utilize the DDN.
- The data collected are of an ordinal, rather than interval, type. Statistical analysis was performed in accordance with general accepted practice, as described in Ref. 40.

In spite of these methodological weaknesses, the lack of previous empirical research in this area justifies the exploratory approach taken in this study.

B. RESULTS

1. User Experience

Variables related to the participants' previous experience include (1) experience with DDN, (2) experience with computers in general, and (3) the amount of the job accomplished using the DDN. The results are shown in Table 2 below. In the research group, 77% of the respondents did not use the DDN. The other two groups were composed entirely of personnel who use, or had been exposed to, the DDN. The research group had a mean of 6.5 years of computer experience, and 3.1 years of DDN experience. The student group had a mean of 3.1 years computer experience, and 0.6 years DDN experience. The operational group had a mean of 12.6 years computer experience, and 3.1 years of DDN experience. The percentage of the job accomplished for each sample is displayed in Figure 6 on page 38. The overwhelming majority of respondents in all samples use the DDN for less than 10% of their jobs.

Table 2. PARTICIPANT EXPERIENCE LEVELS

Variable	*Group*		
	Research	*Student*	*Operational*
Use DDN, %	23%	100%	100%
Computer experience, years	6.5	3.1	12.6
DDN experience, years	3.1	0.6	3.1

2. User Learning

Two multiple-response questions dealt with learning to use the DDN. The results are given in Table 3 on page 39. In question 6 (see Appendix B), respondents were asked if instructional materials for the DDN are easy to read and understand. The

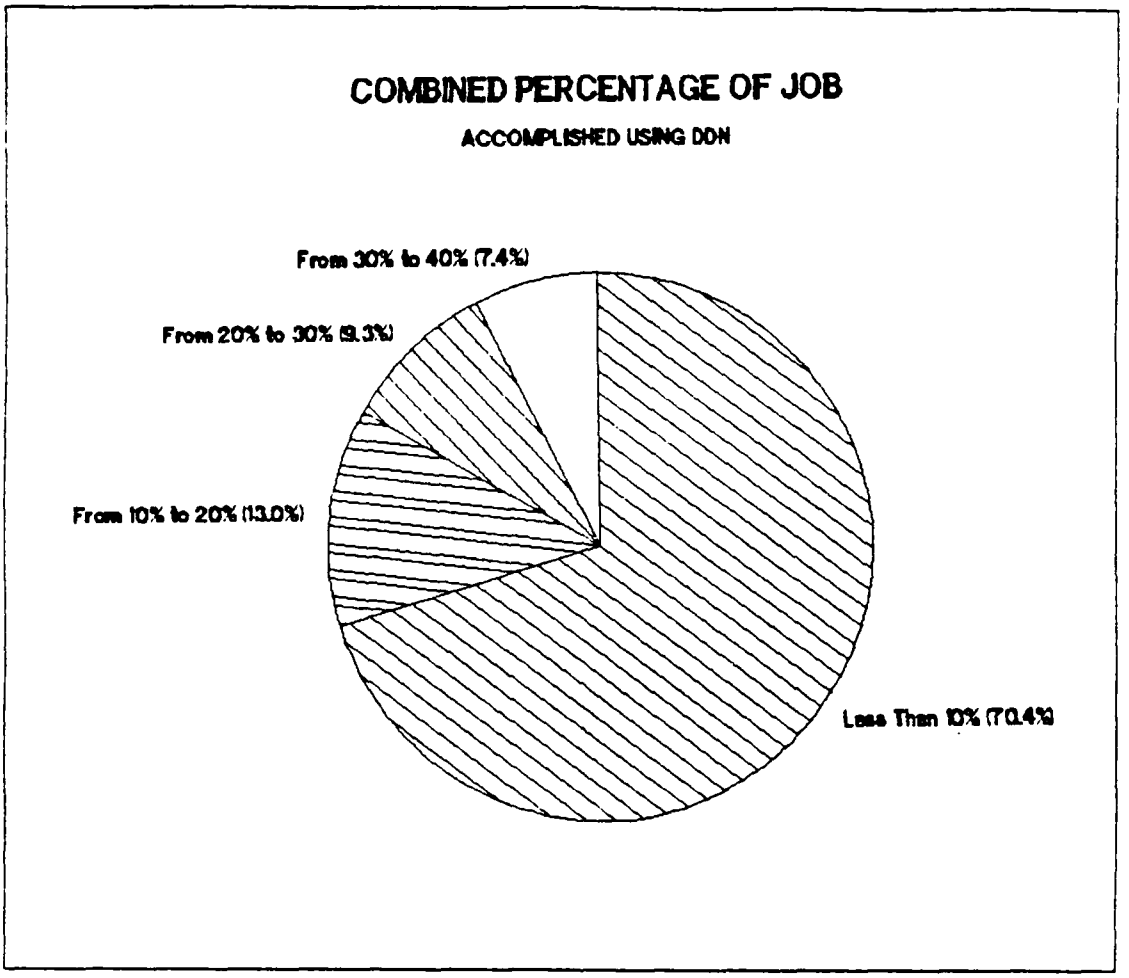

Figure 6. Percentage of Job Involving DDN Use

largest response for the research group, 55%, was in the undecided category. The student group had the largest percentage, 53%, of all three groups to report positively. The operational group had 37% undecided, as well as 45% who thought instructional materials were not understandable.

In question 4, participants were asked if they had received enough training to use the DDN well. Of the research group, 46% reported they had not, 27% were undecided, and 27% reported that they had. Of the student group, 62% reported that they had adequate training; only 19% said training was inadequate. The operational group tallied 64% with enough training, and 18% each undecided and reporting not enough training.

Table 3. EVALUATION OF DDN TRAINING (IN PERCENTAGES)

Question	*Group*	*Strong Disagree*	*Disagree*	*Undecided*	*Agree*	*Strong Agree*
Instructional materials are clear	Research	0	27	55	18	0
	Student	0	24	24	47	5
	Operational	27	18	37	18	0
Training is adequate to use DDN well	Research	19	27	27	27	0
	Student	0	19	19	52	10
	Operational	9	9	18	27	37

In questions 15 and 16, the respondents were asked to rank the training methods that had the greatest impact on their learning how to use the DDN. In question 16, they were asked to rank what would be the most useful methods for improving their DDN skills, if they had the choice. Six options were presented. They are:

- On the job training (OJT)
- Formal classroom training
- Supervisorial instruction
- Standard operating procedures (SOP)
- Self taught
- Coworker instruction

Results for the three groups are tabulated and presented in Figure 7 on page 40. The research group reported OJT, self teaching, and coworkers both as the methods with which they learned to use the DDN and as the methods favored for improving skills. The students, all of whom had a formal class on the DDN, ranked self teaching and formal classroom as most important in learning to use the DDN; OJT, formal classes, and SOPs were listed as the most desirable means of improving their skills. The operational group reported that OJT, self-teaching, SOPs, and coworkers had the greatest impact on learning, and favored OJT, formal classes, and SOPs for improving their expertise.

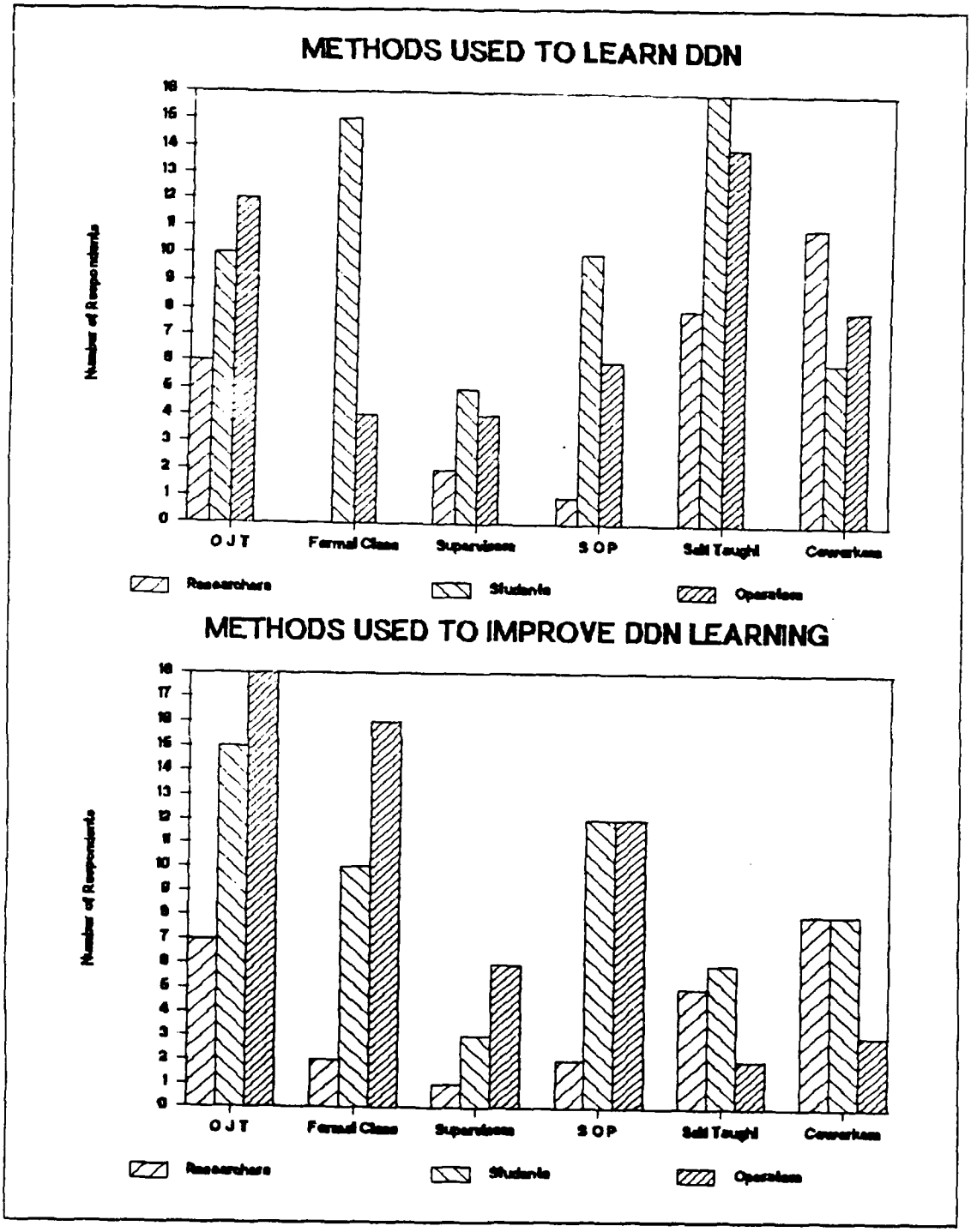

Figure 7. Training Used and Training Desired for the DDN

3. Meaningful Contribution of the DDN

Two questions were included to assess the extent to which DDN use makes a meaningful contribution to the respondent's job. Results are provided in Table 4 on page 41.

Question 2 asked if using the DDN reduced the usage of other communications media. In both the research and operator groups, 64% said that it did, while 36% and 27%, respectively, said that it did not. One of the operators who strongly disagreed said that management severely restricted electronic communication because they considered anything in writing to be official correspondence. Of the students, 38% said that using the DDN reduced usage of other media. Another 38% were undecided, possibly because this group has had little need to use the DDN outside a classroom.

Question 3 asked if using the DDN had improved work performance, a direct inquiry into the intended technical benefits of implementing the DDN. Positive responses were given by 46% of the research group, 55% of the operational group, and 28% of the student group. Large percentages (36%, 27%, and 48%, respectively) were undecided. Over 70% of all respondents with more than two years of DDN experience felt that it improved their performance. The majority of the undecided and negative responses came from respondents with less than two years of experience with the DDN.

Table 4. MEANINGFUL CONTRIBUTION OF THE DDN (IN PERCENTAGES)

Question	*Group*	*Strong Disagree*	*Disagree*	*Undecided*	*Agree*	*Strong Agree*
Reduces use of other media	Research	27	9	0	28	36
	Student	5	19	38	38	0
	Operational	9	18	9	37	25
DDN use improves work performance	Research	18	0	36	37	9
	Student	10	14	48	28	0
	Operational	9	9	27	46	9

4. Comfort With DDN

Question 5 dealt with the overall comfort respondents felt with using the DDN. The responses are provided in Table 5 on page 42. Comfort was selected as a general term that covers conditions such as system-induced stress and computer anxiety. The

research group gave mixed responses: 36% were uncomfortable with the DDN, 37% were undecided, and 27% felt at ease with the system. Among the students, many of whom are novice users, 85% were comfortable with the system. The operational group exhibited a large "comfort factor", with 27% comfortable and 64% strongly comfortable with using the DDN.

Table 5. COMFORTABLE WITH USING DDN (IN PERCENTAGES)

Question	*Sample*	*Strong Disagree*	*Disagree*	*Undecided*	*Agree*	*Strong Agree*
Comfort With Use	Research	9	27	37	27	0
	Student	0	5	10	71	14
	Operational	0	0	9	27	64

5. Meaningful Job Future

Two questionnaire items were employed to gauge the respondents' perceptions of the relationship between their current positions and the prospects of a meaningful future. These are presented in Table 6.

Table 6. MEANINGFUL JOB FUTURE FOR USERS (IN PERCENTAGES)

Question	*Group*	*Strong Disagree*	*Disagree*	*Undecided*	*Agree*	*Strong Agree*
Rewarded for DDN skills	Research	27	46	27	0	0
	Student	10	14	52	19	5
	Operational	18	27	18	27	10
Job aligned with career goals	Research	0	0	0	55	45
	Student	0	0	5	38	57
	Operational	9	18	0	46	27

Question 7 asked respondents to evaluate the extent to which they were rewarded for acquiring skills for use on the DDN. Researchers from Pavlov to Skinner have documented the importance of rewards to elicit desired behaviour. Of the research group, 73% said they were not rewarded for their DDN skills. The students reported 24% not rewarded, 52% undecided, and 24% rewarded. Results from the operational group were

divided: 45% felt they were not rewarded, 18% were undecided, and 37% felt they were rewarded. Several of the operators commented that the rewards they received were of personal satisfaction, explicitly stating that they received nothing from management.

Question 14 was geared to the respondent's overall job in the organization. It asked respondents to assess whether or not their current position was in line with their career aspirations. The research group unanimously said it was; 95% of the student group and 74% of the operational group reported that their positions were on track with their career goals.

6. Job Autonomy

Three questions asked respondents to evaluate the level of autonomy they felt they had in performing their roles in the organization. The responses for these questions are tabulated in Table 7. Question 10 asked respondents to specify the degree to which to which they were self-regulated in accomplishing tasks. Of the research and operational groups, 100% said they were self-regulated, 55% strongly so. Among the students, 90% said they were self-regulated.

Table 7. JOB AUTONOMY FOR USERS (IN PERCENTAGES)

Question	*Group*	*Strong Disagree*	*Disagree*	*Undecided*	*Agree*	*Strong Agree*
Self regulated	Research	0	0	0	45	55
	Student	0	0	10	61	29
	Operational	9	0	0	36	55
Prefer to exercise more judgement	Research	0	18	46	27	9
	Student	5	0	14	62	29
	Operational	0	0	27	27	46
Know responsibilities	Research	0	0	0	55	45
	Student	0	5	14	43	38
	Operational	0	0	27	27	46

Question 11 asked the respondents if exercising more of their own judgment would improve the quality of their work. Of the research group, 36% said it would, while 46% were undecided. Among the student group, 91% said more personal judgment would improve the quality of their work, and 73% of the operators said it would.

There was some ambiguity in the interpretation of the question. Comments from respondents answering positively included: "It does", indicating that the respondent did exercise a great deal of personal judgment, and "I wish I could", indicating an inability to do so. The numerical values of the responses for this question are probably only valid as a measure of a condition that the respondents like, not as an indicator of whether or not the condition exists at the work place.

Question 8 provides a measure of the degree to which respondents are aware of what they are responsible for with respect to their jobs. Of the research group 100% said they knew all their responsibilities; 82% of the students and 91% of the operators indicated an awareness of their responsibilities.

7. **Task Variety**

The existence of task variety was explored through two questions, as shown in Table 8. Question 12 asked respondents if they considered their jobs to be routine. The majority of all responses were negative. In the research group, 91% said that their jobs were not routine, 27% strongly so. For the students, 62% responded negatively. The operators had an 82% negative response, with 36% strongly asserting that their jobs were not routine.

Table 8. TASK VARIETY (IN PERCENTAGES)

Question	*Group*	*Strong Disagree*	*Disagree*	*Undecided*	*Agree*	*Strong Agree*
Job is routine	Research	27	64	9	0	0
	Student	19	43	14	19	5
	Operational	36	46	0	18	0
Multiple skills are needed	Research	0	0	0	18	82
	Student	0	0	0	62	38
	Operational	0	0	0	27	73

Question 13 asked if knowing multiple skills were a part of the job. As might be anticipated from the non-routine nature of the jobs indicated in the responses to the first question, all three groups had a positive reaction to this question. This was the only survey question that received unanimous agreement. All three groups said that their jobs required multiple skills, with 82% of the research group, 38% of the students, and 73% of the operational group strongly affirming this.

8. Exchange With Others

One question dealt with exchange between workers, to determine the extent to which groups are formed and used in the organization, as shown in Table 9 on page 45. Question 9 asked respondents if problems in their organizations were solved by group effort. This question drew a mixed response from all three groups. In the research group, 73% reported that problems were solved jointly, but only 9% strongly felt this was the case. Of the student group, 53% answered positively, 19% were undecided, and 28% responded negatively. For the operators, 55% said they had group problem solving, 27% were undecided, and 18% said they did not.

Table 9. GROUP EXCHANGE (IN PERCENTAGES)

Question	*Group*	*Strong Disagree*	*Disagree*	*Undecided*	*Agree*	*Strong Agree*
Problems solved by groups	Research	0	9	18	64	9
	Student	5	23	19	43	10
	Operational	9	9	27	37	18

9. Positive Aspects of the DDN

The questionnaire contained two open-ended questions. Question 18 asked the respondents what they liked most about the DDN. For scientists and engineers, the greatest perceived asset was the electronic mail feature of the DDN. Half of the respondents listed this as what they liked best. The next greatest attraction was the speed of the network. One respondent commented favorably on the speed of the DDN as compared to the Naval message system, and noted that it helped alleviate busy AUTOVON lines. Along that line, eliminating "phone tag" was mentioned as a boon. Another respondent liked the fact that information could be dealt with at one's convenience, not in the forced immediacy of a phone conversation. Finally, the broad access to diverse data sources, such as directories and distant supercomputers, was rated highly.

The student group touted the distributed aspect of the DDN as its most positive aspect. As one respondent stated, the best part is ". . . the relative ease of communicating with the world." The next most popular feature of the network was electronic mail, and the speed with which it allowed communication to occur. Several students

considered the file transfer capabilities to be the top characteristic. The reliability of transmissions rounded out the slate of student favorites.

Members of the operational group reported world-wide connectivity as the single greatest feature of the DDN. The second most popular aspect was the high speed of communicating, though one respondent specified that this speed was contingent on usage during non-peak hours. Electronic mail and the transfer and maintenance of files were also mentioned by several respondents as the top features of the DDN. Finally, one operator considered the DDN's security features to be its best aspect.

10. Negative Aspects of the DDN

The second open-ended question, question 17, asked respondents what they disliked most about the DDN. Members of the research group had no clear consensus of dislikes. Several respondents commented on the difficult or cumbersome procedures required to access the DDN. This, as one respondent pointed out, is not a problem with the backbone DDN, but rather a function of the software utilized at the individual site. One person described this as "being at the mercy of vendor-X operating system." One respondent said that documentation is not readily available. Another criticized the lack of secure lines. Two commented on the slow response time during peak hours. The difficulty in obtaining passwords for remote accessing also drew the criticism of one respondent.

The biggest drawback of the DDN for the student group was the slow response time during periods of peak usage. The next biggest complaint was against the word processing system installed at the local site. Several respondents cited the lack of a more visually-oriented system as a detriment, specifically advocating a menu-driven system. Similarly, one respondent disliked the on-line help function, saying that it was difficult to determine where in the system you were in order to get help. Several of the respondents criticized the written documentation, citing a lack of readable, comprehensive text.

The operational group registered a variety of complaints. Several respondents disliked the lack of standards for transmission format and sequence. These were too dependent upon the varied group of diverse vendors who make the host computers. Training was regarded as inadequate for a novice computer user, and not implemented on a wide enough basis. Two respondents said that the long lead time required to install the DDN was a detriment. The high cost, approximately $25,000, for local site hardware and software was another dislike. The local site word processing software and slow

response times were also cited here as negative features. Finally, management and administration of the DDN at the organization were criticized as being disorganized. One respondent stated that no one had the authority to get anything done without weeks of delay.

11. Statistical Inference

The sample means and standard deviations for the questionnaire are presented in Table 10.

Table 10. SAMPLE MEANS AND STANDARD DEVIATIONS

Question	*Research*		*Student*		*Operational*	
	Mean	SD	Mean	SD	Mean	SD
Materials are clear	3.8	0.9	4.6	1.2	3.3	1.6
Training adequate	3.6	1.8	4.8	1.3	5.1	2.1
Reduces media	4.4	2.5	4.0	1.2	4.9	2.1
Improves performance	4.3	1.9	3.8	1.3	4.4	1.7
Comfort with use	3.9	1.6	5.4	1.0	6.1	1.1
Reward for Skills	2.5	1.2	3.9	1.3	3.7	1.9
Career Goals	6.1	0.8	6.4	0.8	5.0	2.0
Self Regulated	6.4	0.6	5.8	0.9	5.8	1.7
More Judgement	4.3	1.5	5.6	1.4	5.8	1.2
Know Responsibilities	6.4	0.5	5.7	1.3	6.2	1.2
Routine Job	2.1	0.9	3.0	1.7	2.4	1.4
Multiple Skills	6.8	0.4	6.1	0.7	6.4	0.9
Group Effort	5.0	1.3	4.4	1.5	4.5	1.8

All means were tested to the 95% confidence level against the null hypothesis that the mean was equal to the "undecided" value, that is, 4. This was done using the student's t-distribution test. On the average, the research group reported that members were autonomous, had task variety, felt their jobs were in line with their career goals, and had exchange in solving problems. They did not feel they were rewarded for their skills in using the DDN. The student group felt that members exhibited autonomy, had task variety, and considered their jobs in line with their career goals. The operational group also reported autonomy, were comfortable with using the DDN, and had task variety. They also felt that instructional materials were not easy to understand. Resulting means

for the remaining questions for all three groups were not statistically different from the value representing an undecided response.

The next step in the analysis was to examine the relationships between the variables included in the questionnaire. This was done through zero-order correlations. These correlations give an idea of the extent of the relationships between the variables, a higher value indicating a greater relationship. These higher values are used as the basis to determine which questions should be used for regression analysis.

The measures of performances hypothesized to be of interest to management--the extent to which use of the DDN reduces use of other media and the extent to which DDN use improves work performance--were used as the dependent variables in the regression analysis. They were regressed on those questions with which they had the strongest correlation coefficients. Each resulting R^2 value denotes the percentage of the variability of the performance measure that is explained by the question on which it was regressed. The results are given in Table 11 on page 49.

The first variable regressed was the impact of the DDN in reducing the use of other media. The research group showed medium correlation between this factor and the factor of having enough training to use the DDN well. The resulting R^2 was 56%; this was significant only at an 80% confidence level. The low significance value was probably due to the large standard deviation (2.5) of the variable mean value for this group. The student group showed a strong negative correlation between use of the DDN and the routine nature of tasks. That is, the less routine the tasks are, the more the DDN was used instead of other media. Regression analysis produced an R^2 of 46.9%, significant at a 99% confidence level. The operational group showed strong correlation between DDN use and being rewarded for DDN skills. The R^2 for this was 58.7% at a 99% confidence level.

The next variable regressed was the impact of the DDN on improving work performance. The research group showed strong correlation between this factor and having enough training to use the DDN well. Training accounted for 46% of the variation, although this was significant only at an 80% confidence level for this group. The student group did not show any strong correlations between improved performance and the other questions. This is probably not a good measure for this group because the students have not had much reason to use the DDN for other than coursework. A possible substitute variable for use in estimating how effective they feel they are with the DDN is the question asking how comfortable they feel using the DDN. The response

to this question showed medium correlation between comfort and having enough training to use the DDN well. Regression analysis gave an R^2 of 28% at a 99% confidence level. The operational group showed strong correlation between improved performance and both having enough training and being rewarded for DDN skills. The R^2 for these two questions explained 79.2% of the variation, at a 90% confidence level.

Table 11. RELATIONSHIPS BETWEEN PERFORMANCE MEASURES AND SELECTED QUESTIONS

Measure of Performance	*Group*	*Question*	*Corr. Coef.*	*R^2 %*
Reduced use of other media	Research	Enough training to use DDN	0.462	55.6
	Student	Job is routine	-0.685	46.9
	Operational	Rewarded for DDN skills	0.766	58.7
Improves work performance	Research	Enough training to use DDN	0.681	46
	Student	Enough training to use DDN	0.530	28
	Operational	Enough training to use DDN	0.715	79.2
		Rewarded for DDN skills	0.766	

C. SUMMARY

The results of the questionnaire indicate that DDN users, as exemplified by the three groups, vary widely in experience, position, and purpose for using the system. None the less, they share several traits in common. The majority of the users utilize the DDN to perform less than 10% of their jobs. The users have a strong sense of autonomy, both as a job characteristic and as a desired condition. Their jobs are not routine, and require multiple skills to perform. These traits can be indicative of workers with a high degree of responsibility and pride in their work [Ref. 14:pp. 49-51]. To a large extent, respondents feel that their jobs are in line with their career aspirations, contributing to a sense of a meaningful future.

How much individuals learn about the DDN varies from organization to organization. The majority of personnel queried at the Naval Weapons Center do not use the DDN, and those who do use it learned to do so on the job. Formal classroom is used as an instructional method for only one of the groups. The student group considered

such training effective and also beneficial for further learning. The operational group, which also primarily learned to use the DDN on the job, reported that formal training would be a good means of improving expertise with the system. Instructional materials on the DDN were not widely perceived to be easy to read or understand. Over one-third of the members of each group do not feel they have enough training to use the DDN well.

The research group does not feel comfortable with using the DDN, while both the student and operational groups do. Very few of the respondents from any of the groups felt that the organization rewarded them for their DDN skills.

Electronic mail, speed of communication, file transfer and maintenance, and world-wide connectivity were favored as the most positive aspects of the DDN. On the downside, cumbersome local operating systems (especially word processing software) were perceived as problems. Slow response time during peak hours, dependence on diverse vendors, poor documentation and on-line help features, and training in general were all considered negative aspects of the DDN as it is implemented at the organization.

Results of responses to questions related to the measures of performance proposed here for potential use by management vary widely among the three groups. Two-thirds of the research and operational groups reported that using the DDN reduces their use of other communication media. However, one-third of each group did not feel that it did. The student group was about evenly split between thinking that it did, undecided, and thinking it did not. A large proportion of the research and operational groups reported that using the DDN improved their work performance (46% and 55%, respectively). However, when those who were undecided are grouped together with those who did not think that their performance was improved by using the DDN, over half of the research group and nearly that many of the operational group fall in this category, along with an even higher proportion of the student group.

Several factors appear to be strong predictors of the two selected measures of performance. The strongest predictor for both measures is having adequate training. The next strongest predictor is being rewarded for DDN skills. In addition, the extent to which tasks are not considered routine has a predictive value for determining how much the use of other communication media is supplanted by DDN use.

VI. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

The purpose of this study has been to examine the application of the principles of sociotechnical theory to the implementation and administration of the DDN in military organizations. This was done by assessing to what extent six major sociotechnical conditions (autonomy, learning, variety, group exchange, meaningful job contributions, and a meaningful future) are present in military organizations with access to the DDN. During the course of this study several issues became apparent that are of critical interest to management for the successful introduction of the DDN into an organization.

1. Presence of Sociotechnical Conditions

Based on the results of this study, it may be concluded that DDN users are strongly autonomous, and have jobs that incorporate a great deal of variety. These jobs for the most part are on track with the users' career goals. However, users are not rewarded for their DDN skills. For many of the users, the DDN makes a meaningful contribution to their job, but a sizable number do not perceive it as reducing their use of other communication media or improving their work performance. Exchange with others occurs in problem solving and training, but not to a high degree. The methods used to facilitate the learning process have weaknesses that alienate some of the users. Thus, it can be concluded that two of the sociotechnical conditions (autonomy and variety) are strongly present. The other four are also present, but in varying degrees.

2. Issues for Managerial Concern

Three issues warrant further managerial attention. The first is that of training. Adequate training, based on the groups studied, is for the most part not being provided. Over one-third of those queried said that they did not have enough training to use the system well. This indicates a problem. It could be the result of several things: (1) documentation is considered poor, (2) there is no formal classroom training, and (3) there is not enough regard for the novice computer user. A program that addresses these shortcomings is needed. The close association of training to the studied measures of performance underscores its importance to the health of the organization.

The second issue of importance to management is the reward system. Employees in any organization are quick to determine what behaviors and skills are beneficial to their careers. If management wants a workforce proficient in using the DDN, then

those skills must be encouraged by rewarding them. As the study found, there is a strong connection between rewards and improved performance. However, giving rewards for DDN skills does not appear to be a policy in the groups studied. In the DOD, rewards cannot be in the form of additional pay. Despite this, there is considerable latitude for recognizing and supporting superior performance in using the DDN. Management should re-examine this apparent discrepancy between the performance that is desired and the means used to reach this end.

The third important issue is the form and efficiency of DDN management. Managerial practices at a DDN site largely determine the acceptance of a system, what it is used for, and who has access to it. All of these were found to be important in computer-mediated communications systems. In the groups surveyed, the majority of things liked about the DDN, such as speed of communication, connectivity, and data access, are inherent results of data network technology, and are obtained simply by installing the system. On the other hand, the majority of things disliked about the DDN, such as training, local operating systems, and slow response time during peak hours, are factors directly controllable by management. Management at each site must set policies that help, not hinder, better performance with the DDN.

B. RECOMMENDATIONS

Three major organizational changes can be recommended as a result of this study. First, self-managed work teams should be considered for the facilitation of better training, reward systems, and a management structure that is well tailored to the conditions that exist at the individual DDN site. Based on the groups queried, three of the four principles considered necessary in Reference 9 are already present among DDN users. These are (1) specific responsibilities, (2) self-regulation, and (3) jobs requiring multiple skills. The one that appears to be lacking, skill-based rewards, could be the focus of a self-managed work team.

Second, team-building activities are needed to create the participative, decentralized form of organizational structure that is widely endorsed for improving performance, especially in a dynamic environment. Computer-mediated communication encourages decentralized flow of information and ease of establishing communication; these foster effective group performance. This potential for improved performance should be realized through the use of established team-building techniques.

Third, participative management should be encouraged. Participation, besides giving workers an input in their own destiny, also creates a greater sense of involvement

and commitment. It has been shown to be a facilitating factor in motivation and the reduction of boredom on the job [Ref. 41]. The autonomous nature of each working group, already shown to be a major attribute in the groups sampled, can result in unique group needs that cannot be foreseen by upper management. However, group members can provide solutions to many of their own and the organization's problems, given the opportunity. These solutions can be responsive to the needs of both the organization and the workers. For example, the problem of high cost and slow response time during peak hours could be mitigated by the use of flextime or telecommuting, solutions that might not be practical for the organization as a whole, but ideal for a small group. The central thrust of the team concept is that the teams can be well suited for determining effective methods for implementing the DDN in the organization.

Electronic communications open a door to new possibilities for fast, reliable, world-wide communication. Enlightened management can encourage the attainment of the full benefits of this system. The decentralized, evolutionary nature of computer-mediated communications make it a perfect area for applying the principles of sociotechnical design. Many of the key conditions are already present in the organizations using the DDN. The final step is for management to implement the DDN under the work team concept.

C. SUGGESTED FURTHER RESEARCH

Several topics related to this study warrant further research. First, research is needed to determine why some employees who have access to the DDN still do not use it. Such research would provide valuable insight into the type of training and programs that would overcome barriers to the use of computer communications. This research could be done through on-site interviews at various organizations which have DDN access.

Second, potential costing plans for DDN usage should be investigated. This would include the cost and relative effectiveness of local site hardware and software, along with transaction costs. This research could include a cost benefit analysis of DDN use versus the use of other media.

A third area recommended for research is a comparison of the organizational structure at DDN sites that seem to be successfully implementing the system with those that appear not to be doing well. The results of this study would be of interest to the many organizations who will become DDN sites in the near future.

APPENDIX A. GLOSSARY OF ACRONYMS

AHIP	ARPANET Host Interface Protocol
ARPANET	Advanced Research Project Agency Network
BBN	Bolt, Beranek, and Newman
DARPA	Defense Advanced Research Projects Agency
DCA	Defense Communications Agency
DDN	Defense Data Network
DOD	Department of Defense
DSNET	Defense Secure Network
DTE	Data Terminal Equipment
FTP	File Transfer Protocol
GENSER	General Service
IP	Internet Protocol
ISO	International Standards Organization
MILNET	Military Network
NARDAC	Navy Regional Data Center

NIC	Network Information Center
OJT	On the Job Training
OSI	Open Systems Interconnection
PC	Personal Computer
PSN	Packet Switching Node
SCINET	Sensitive Compartmented Information Network
SMPT	Simple Mail Transfer Protocol
SOP	Standard Operating Procedure
TAC	Terminal Access Controller
TCP	*Transfer Control Protocol*
TELNET	Telecommunications Network
WINCS	WWMCCS Information Network Communication Subsystem
WWMCCS	World Wide Military Command and Control System

APPENDIX B. DEFENSE DATA NETWORK QUESTIONNAIRE

Current job title .....

Amount of time in this position .....yrs. .....mos.

Prior experience with computers .....yrs. .....mos.

Number of individuals you supervise .....

For the next two questions, mark yes or no as appropriate.

- Have you ever heard of the Defense Data Network, sometimes referred to as the DDN, Arpanet or Milnet? ....yes ....no
- Have you ever used the Defense Data Network, Arpanet or Milnet? ....yes ....no
- If yes, amount of time working with DDN .....yrs. .....mos.

If you answered "no" to either of the above two questions, please turn in your questionnaire. DO NOT answer any other questions.

For questions 1 through 7, circle the number that best represents your experiences with the Defense Data Network (DDN), Arpanet, or Milnet.

1. The percentage of my job I accomplish using the DDN is

1	2	3	4	5	6	7
< 10	10-20	20-30	30-40	40-50	50-60	> 60

2. The DDN has reduced my use of the phone, mail and message systems.

1	2	3	4	5	6	7
strongly disagree			undecided			strongly agree

3. Using the DDN has improved my work performance.

1	2	3	4	5	6	7
strongly disagree			undecided			strongly agree

4. I have enough training to use the DDN well.

1	2	3	4	5	6	7
strongly disagree			undecided			strongly agree

5. I feel generally comfortable using the DDN.

1	2	3	4	5	6	7
strongly disagree			undecided			strongly agree

6. Instructional materials are easy to read and understand.

1	2	3	4	5	6	7
strongly disagree			undecided			strongly agree

7. I am rewarded for my skills in using the DDN.

1	2	3	4	5	6	7
strongly disagree			undecided			strongly agree

For questions 8 through 14, circle the number that most closely relates to your overall job.

8. I know what I am responsible for with respect to my job.

1	2	3	4	5	6	7
strongly disagree			undecided			strongly agree

9. Problems in my organization are solved by group effort.

1	2	3	4	5	6	7
strongly disagree			undecided			strongly agree

10. I am self-regulated in accomplishing my tasks.

1	2	3	4	5	6	7
strongly disagree			undecided			strongly agree

11. Exercising more of my own judgement would improve the quality of my work.

1	2	3	4	5	6	7
strongly disagree			undecided			strongly agree

12. The nature of my overall job tasks is routine.

1	2	3	4	5	6	7
strongly disagree			undecided			strongly agree

13. Knowing multiple skills is a part of my job.

1	2	3	4	5	6	7
strongly disagree			undecided			strongly agree

14. My present overall job is in line with my career goals.

1	2	3	4	5	6	7
strongly disagree			undecided			strongly agree

15. Rank these in order of greatest benefit on how you learned to use the DDN: (i.e., =1 = most important)

....on the job training ....formal classroom ....supervisors
...standard operating procedures ....self taught ....coworkers
....other (write in).....

16. Rank these in order of potential usefulness in improving your use of the DDN: (i.e., =1 = most useful)

....on the job training ....formal classroom ....supervisors
...standard operating procedures ....self taught ....coworkers
....other (write in).....

17. What do you like least about the DDN?

18. What do you like most about the DDN?

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