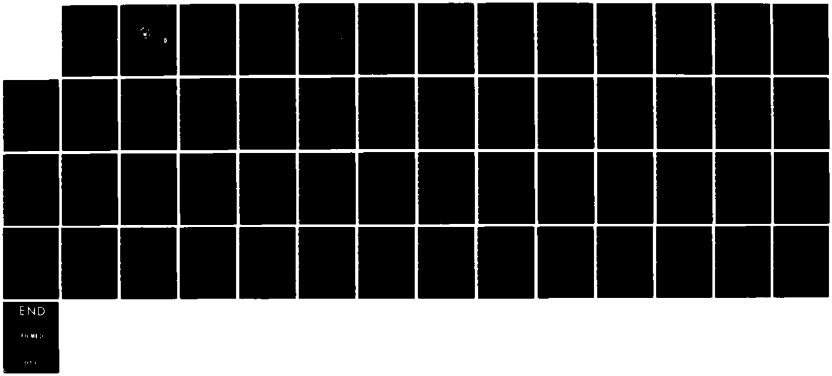
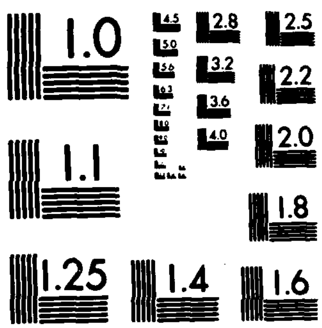
AD-A149 075 MAN-MACHINE INTERACTION: OPERATOR(U) NAVAL POSTGRADUATE SCHOOL MONTEREY CA S K HARDING JUN 84 1/1

UNCLASSIFIED F/G 5/8 NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

NAVAL POSTGRADUATE SCHOOL

Monterey, California

THESIS

MAN-MACHINE INTERACTION: OPERATOR

by

Susan K. Harding

June 1984

Thesis Advisor: Alan A. Ross

Approved for public release; distribution unlimited

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Man-Machine Interaction: Operator		5. TYPE OF REPORT & PERIOD COVERED Master's Thesis June 1984
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Susan K. Harding		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Postgraduate School Monterey, California 93943		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Postgraduate School Monterey, California 93943		12. REPORT DATE June 1984
		13. NUMBER OF PAGES 53
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

man-machine interaction, operator interface

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

More people than ever before are using computers. Some use only the home computer while others use large mainframes or both. All computers have an interface with which the person must interact to operate the system correctly. This interface must be designed so that the operator can use the system without wasting time and money. This thesis describes some of the issues which should be considered when designing a man-machine interface, and defines some types of operators and their environments. (Continued)

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

S N 0102- LF- 014- 6601

 SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

ABSTRACT (Continued)

The issues and their resolution are illustrated by a case study which describes the man-machine interface of an actual United States Navy system in use today.

Man-Machine Interaction: Operator

by

Susan K. Harding
Lieutenant, United States Navy
B.S., University of Southern Mississippi, 1979

Submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN COMPUTER SCIENCE

from the

NAVAL POSTGRADUATE SCHOOL
June 1984

Author: ______________________

Approved by: ______________________
Thesis Advisor

____
Co-Advisor

____
Chairman, Department of Computer Science

____
Dean of Information and Policy Sciences

ABSTRACT

More people than ever before are using computers. Some use only the home computer while others use large mainframes or both. All computers have an interface with which the person must interact to operate the system correctly. This interface must be designed so that the operator can use the system without wasting time and money. This thesis describes some of the issues which should be considered when designing a man-machine interface, and defines some types of operators and their environments. The issues and their resolution are illustrated by a case study which describes the man-machine interface of an actual United States Navy system in use today.

TABLE OF CONTENTS

I. INTRODUCTION

Any reasonably complex system requires a true interaction between man or woman and the other parts of the system, which may be computers, other human beings or combinations of these. Some way must be found for thinking about the functions of computers and the functions of men and women within a framework which makes possible the relation of these two kinds of functions to common goals. Even in a system as familiar and as relatively simple as the automobile, it is easy to see that the goal of transporting passengers over roads requires not only the functions of the machine itself but also a considerable variety of human functions performed by the operator. The design of a system which is to be successful in achieving some specific defined purpose requires thorough and continued consideration of the interacting functions of both operators and machines, of which computers are the most complex example.

Computers are tools developed to fulfill some human purpose or intended use. They may have distinctly civilian social purposes such as those of an airport-to-city transportation system, a mail-sorting system, a check-cashing system or a sales transaction. But computers, of course, are not only used in civilian businesses. They are also used frequently in military applications. Their purpose may be to protect against enemy military attack or to harass or to destroy an enemy in wartime. Most systems require an operator of some sort to input data or monitor the equipment. This operator is an important part of the system [Ref. 1].

There are many different types of operators. Some are well trained while others are not. There are intelligent and unintelligent operators and programming-oriented and non-programming-oriented. Many operators are in love with computers while others are terrified of them. While a system is being designed the type of operator must be known and the job he or she is expected to accomplish must be fully and clearly expressed. These operators may be dedicated assistants to management, slaphappy sales clerks, trained specialists in an information room or military screen-watchers in a windowless building watching the affairs of the world [Ref. 2].

Knowing the type of operator and what these operators must accomplish in systems, and expressing these accomplishments as functions makes it possible to accurately describe the operator's required capabilities. These accounts in turn permit conclusions to be made concerning the various techniques needed to develop these human capabilities, whether they be matters of selecting operators, training them or providing them with adequate environments for their work. These techniques rest upon decisions that concern human factors, human capabilities and the relationship between the human being and the computer.

In order to fulfill a purpose, a system must meet certain standards often expressed (particularly in military systems) as criteria of operational effectiveness. System developers have been known to take the point of view that if only the hardware can be made to run, operators with the proper characteristics will be found and 'fitted into' the system. Such a view has many drawbacks. In most cases it is not possible to employ only 'operators with proper characteristics' especially in the military services. This view also places too much dependence on the range of human talents and on the extent of human adaptability. This restricted view of systems and system development leads to failures, breakdowns, costly programs of retrofitting and even to total abandonment. No system is complete until it can be shown to operate within a total setting that includes the operators; no system can truly be said to be successful until its operational effectiveness is demonstrated by the operator. The best system development is that which includes consideration of system operation (rather than merely hardware operability) from the very beginning of the system design. Equipment design which consciously takes advantage of human capabilities and constrains itself within human limitations amplifies and increases system output. If it does not, system performance is reduced and the purpose for which the equipment was designed is endangered. This consideration is even more significant today than in the past because the highly complex systems that we develop are pushing human functions more and more to the limits of efficient performance.

How can one ensure that the computer and the computer operations are actually designed for human use? Behavioral data, principles, and recommendations - in short, the human factors discipline - must be translated into meaningful design practices. Concepts like ease of operation or error-free performance must be interpretable in hardware and system terms [Ref. 1].

The term human factors has several meanings which can lead to confusion unless these different meanings are carefully differentiated. There are four basic meanings to the term human factors.

First, human factors are elements such as equipment, environment, and tasks, which influence the efficiency with which people can use equipment to accomplish the functions of that equipment.

Second, the term human factors can also refer to the number and type of personnel selected to run the system and how they function. This includes number of operators and maintenance technicians in the system, their skill level, the functions and tasks they must perform in controlling their equipment and how they perform their tasks.

A third implication of the term human factors is its reference to the manner in which personnel perform when using the equipment and the effect of that performance on other system elements or on over-all system goals.

A fourth way in which the term human factors can be used is to refer to the psychological effect of the over-all system upon its personnel elements. The system of which the operator is a part may influence his performance, his health, and his attitudes toward nonwork related activities. Working at a job which is intellectually and emotionally demanding may create frustrations which affect the worker's attitudes toward his family, friends and society in general [Ref. 3].

There have been several attempts to describe the place of the operator within a system. Man's functioning enters into complex systems at many points and in many particular ways. Furthermore, the display and amount of information, the controls to which the individual responds, and the mechanisms which provide the transformations for these components of the system are of considerable variety. It would be a mistake to think that because the operator typically 'occupies a space' between machine displays and controls, his functioning can be related in a constant set of ways to such inputs and outputs. The fact is, neither the input nor the output by themselves will tell us the nature of man's functioning. There are different kinds of transformations which may be performed (by the human nervous system) in turning inputs into outputs. To understand the variety of these transformations, we must first recognize that there are internal functional units in man, some of which may be active or inactive for any particular kind of functioning which the system may require. The science of psychology may be considered as having the purpose of discovering and defining the functions of these internal units, as well as their relationships [Ref. 1].

This thesis describes some important factors which should be given significant consideration when designing a man-machine interface. It seems as though many systems have been designed without consideration of the type of operator who will use the system, the environment the operator will have to work in and how the system effects the people who work with it.

There are many different types of operators. Chapter two discusses five different categories of operators and the environmental factors which should be considered when designing a man-machine interface for a system. Both the type of operator and the environment in which he or she works directly effects the efficiency and performance of the system involved. The wrong operator in an uncomfortable or awkward environment performs poorly.

Chapter three discusses the operator as a component of the system. The operator maybe any single type or some combination of the types discussed in chapter two, and this typing affects many portions of the system. He or she must be a part of the system from the design phase through the developing plase. In summary, chapter two will address the design of a portion of the system, the man-machine interface, while chapter three addresses the total system's performance and how it depends on how well the operator(s) and the machine fit together.

Chapter four discusses the issues mentioned in chapters two and three with respect to an actual system. This system is used by the United States Navy today. The information was obtained through interviews with operators and support personnel who interact with the system on a daily basis. The chapter describes some of the problems the operators must deal with and some solutions to these problems. Chapter five presents a brief summary of the thesis.

II. THE OPERATOR AND HIS/HER ENVIRONMENT

A. THE OPERATOR

The designer of any system which includes a man-machine interface must have the operator clearly in mind. He must know the answers to questions such as: What is this particular operator capable of?; How much training can he or she be given?; Will the operator have a specialized background such as a knowledge of programming or familiarity with computers?; How often will he or she use the terminal?; The interface must be designed based on the specific class of operators.

Which type of operator? There are several. Some of the major classifications are:

1. Dedicated or Casual Operator

A casual operator is a person who spends most of his day doing something entirely different from using the computer such as selling merchandise or managing a store. This person is not highly trained in computer usage. He is easily confused by unclear terminal responses and easily frustrated by lengthy response times. For the operator, the man-machine interface must be designed to appear as natural as possible, or his bewilderment will quickly turn into annoyance, criticism, or behavior that amounts to rejection of the system.

On some systems the operator is a dedicated user. A dedicated operator is a person who spends his whole working day in front of a terminal. This type of operator is typical of computer center environments and military organizations. Many military watch-standers spend their full eight hour shift in front of a terminal connected to a real-time system. The operator is usually specially trained for the particular job, perhaps with a lengthy training program. In many other situations the operator's training is limited and on-the-job training is the major training element. This particular type of operator will have plenty of time to practice his interaction with the machine, to learn its language and to become accustomed to its idiosyncrasies. Also, as the dedicated operator becomes familiar with the system the level of training can increase and be more complex due to his increasing understanding of the system.

2. Programming-oriented Operator.

In some systems the operator uses a programming language. It may be one of the standard programming languages or a special set of program statements devised specifically for the application. If the operator is programming-oriented then an existing language can be adapted for the man-machine interface dialogue. This will eliminate the need for a new interface language. If the operator is not programming-oriented, however, a language or dialogue has to be developed so the operator can learn to use the terminal and perform her job. This interface should be easy to learn at the terminal, and enable the operator to build her expertise without causing the system to crash.

A warning must be given to the designer of the interface. If she is a programmer, she must be careful not to associate her own skills with those of the proposed operator. There is sometimes an overwhelming tendency to do this.

3. Intelligent Operator

As alarming as it may sound, the intelligence of the operator must be considered when designing the interface between a human and a computerized system. If the system is to be operated by the 'general public' then the designer must develop an interface which can be understood by a person with little or no education, as well as a person with a large amount of education. The interface must be easy to work with and in a language the operator can understand such as English. If, however, the operator is always going to have a computer background with experience in programming languages then the interface does not have to be so simple. If the operator is not familiar with the language which the interface is written, his experience and capabilities enable him to quickly learn the language. Interface structures can be designed that are suitable for all classes of operators. The IQ bracket of the operator is important in determining the interface. Overestimating the operators' capabilities for logic, short-term memory, or association is a sure way to land the system in trouble.

Differences in IQ are measured on a relatively small scale. Difference in capability, however, can range over a lengthy scale. In one day, for example, a highly competent programmer with interactive programming can accomplish a hundred times more than a person without skill or aptitude. In a language capable of handling complex and subtle operations a person lower on the scale will simply never learn to use its more complex features. The designer must be aware of these capabilities of the operators.

4. Highly Trained Operator

Not all operators can be given lengthy and detailed training. Of course, good training is desirable in any system, but sometimes it is not possible. Not all operators need a detailed training course. Some may already have experience in the area and not need any more than an introduction session. There are others, however, who have never been close to a computer and need extensive training. The interface can be designed very differently if the operator is to have extensive training. In some cases the terminal itself has been used to assist in the training. The operator can learn how to use it in a 'computer-assisted instruction' mode. If the user forgets certain operations, the computer may remind her or give her a lesson on the spot. In a real-time situation, however, the time it takes to reteach the operator may be critical or unavailable. Therefore, the formal training given to operators who will be working in a time-sensitive job is extremely important.

5. Active and Passive Operators

An active operator is one who initiates computer operations such as making enquiries, entering data or initiating processing. A passive operator is one who takes action after it is initiated by the computer, as for example, when the computer requests information or informs a special assistant that it has detected an error. Some operators have both passive and active functions. Some operators may be present only to serve the machine and may have no active functions. These operators are often called slave operators. Some operators are present to intercept invalid, unprocessable or questionable transactions that are relayed to them by the computer. These are called intercept operators. These categories of operators need to be interlinked into the most suitable man-machine complex.

The designer of a system must know not only the type of operator but also the working conditions under which this specific operator will be required to work. Some operators, such as military watch-standers, work under time pressure. Many military operators receive valuable information which must be reported immediately to the proper authorities. This operator must be able to accomplish his task within a specified time frame without interference from the computer. The man-machine interface must be efficient and easy to work with. Any complicated steps could cause quite a bit of work and a loss of time.

Some operators have other people talking to them or harassing them while they work. This causes a distraction and complicates the interface between the operator and the computer. The interface must be brief, simple and unconfusing if distractions are expected to occur frequently.

In other cases the operator may work in the seclusion of her own office away from continuous interruptions. This interface may or may not be more complicated depending again on the type of operator. A high executive of a firm would want to check on the firm's progress without having to take complicated steps. On the other hand, a database manager in the firm would want the capability to work with the files in many different, possibly complicated, ways. The interface between the operator and the computer depends largely on the type of operator and the work he or she is expected to accomplish [Ref. 2].

B. THE OPERATOR'S ENVIRONMENT

When designing a system not only should the operator be kept in mind but also the environment which the system and operator will have to work in. Environmental factors have a direct bearing on operator performance. Performance suffers if the environment does not provide adequate lighting; it also suffers in an environment containing high ambient noise levels. The environment may also cause physiological stresses which indirectly affect sensory or motor performance. Temperature, atmospheric contamination and inadequate oxygen fall in this category. To some extent, a single environmental condition may operate both directly and indirectly upon human performance.

1. Temperature

Temperature is a stress which does not interfere directly with a sensory or motor mechanism but influences the general comfort and psychological functioning of an individual. Human comfort is certainly as important a consideration in the design of a system as is measured human proficiency. Today's computer systems need to remain cool in order to run properly. Therefore, many computer centers and military installations are very cold. This provides an uncomfortable environment for the operator to work in. In many situations the operators and their terminals could be placed in a separate warmer room where they could continue monitoring the system in comfort. In other cases the operator would prefer to work closer to the computers in order to watch the network and be right there when something goes wrong. If this is the case proper clothing should be authorized so that the operator can perform his duties in some comfort.

2. Lighting

A fundamental objective of lighting practice is to provide illumination upon a visual task so that it can be seen quickly, accurately and easily. Lighting a room correctly for a group of people to work in is not as easy to do as setting the temperature of the room. Eyes are extremely sensitive and vary a great deal from one person to the next. Some people can work in a room with fluorescent lights without difficulty while others develop severe headaches or burning sensations in the eyes after a short time. The same is true about terminal screens. Some operators can work in front of a terminal for hours without any discomfort while others can not work more than an hour. The correct lighting in a room with computer terminals is very important. Most terminals have brightness knobs so each individual operator can control the screen's lighting while he or she is using it. Most terminals also have glare resistant glass. THe lighting in the room still has affects on the operator's eyes. If the room is too bright it is difficult on the eyes of the operator. The amount of light in a room and the location of the fixtures with respect to the terminals is a very important consideration [Ref. 4].

C. EQUIPMENT

Since equipment characteristics (e.g., arrangement of controls and displays) function as user stimuli, it follows that certain arrangements of these characteristics/stimuli will be more efficiently responded to by personnel than will others. Thus, if equipment characteristics are matched to the capabilities and limitations of men, the performance of the latter should be more efficient.

The number of controls, displays, and internal components which the operator must work with directly affects his or her performance. The larger the number of screens the operator must watch, the greater the likelihood of error. An operator of a real-time system should not be required to watch and work with more terminals than he or she can handle.

The arrangement of equipment can also increase the probability of error in operator performance. The layout of terminals with respect to other system components and lighting must be considered. If an operator is required to control more than one terminal at a time the location of the terminals is very important. The terminals must be set at the best possible angle so that the operator can see at a glance what is being displayed on each screen. The operator must also be able to change a tape on a tape drive or put paper in a printer without being too far from his or her position. If the tape drives or printers are in a separate room, the operator can not keep an eye on what is happening on the terminals.

Operator performance is also affected by the demands imposed by the equipment. Some systems require only visual checks while others require an in-depth knowledge of the system in order to operate it correctly. Other systems require interaction between the operator and the system. The perceptual requirements, cognitive requirements, and motor requirements directly affect the operator's job performance. The response the operator must make also produces a change in his or her performance. How accurate the response must be, how frequent and how fast the response must be given all affect the performance of the operator. The greater the demand from the equipment the poorer the performance [Ref. 3].

It is cheaper and easier to adapt equipment to human capabilities than it is to modify human capabilities to equipment requirements. It is easier to select different components or to arrange them differently than it is to add more sensitive visual acuity to human, endow him or her with more than his or her native intelligence, or change his or her physical dimensions to a more suitable size.

Why not select people more discriminatly for equipment operating jobs? or train them longer and more intensely? Higher selection standards and more intense training are an ideal solution as long as one is designing only for a few highly qualified people such as astronauts or test pilots. This solution falls apart, however, as soon as larger numbers of people are needed as equipment operators.

Moreover, the complexity of our modern technological devices does not respect even the highly selected and trained. Aircraft pilots are both highly selected and intensively trained, and yet many aircraft accidents result from human error. The goal is, therefore, to optimize the design of equipment from the standpoint of the operator so that his efficiency will be at its greatest.

It follows from all this that a primary influence, although not the only one, on the way in which humans operate and maintain machines is the efficiency with which computers are developed [Ref. 5]. Even with today's technology an operator is involved in one way or another in every system. If they do not actually operate computers, operators will continue to install, maintain, and monitor the performance of complex systems. Operators as well as individual equipment components are part of the 'total system.' Since mechanical and electronic components are now available with very high speeds and capacities, the design engineer's task of integrating operators and computers into smoothly functioning systems has become more difficult. If the limitations and capabilities of humans are known and understood, and the purpose of the operator is well defined for the engineer designing the system then better man machine systems will be designed and built.

III. OPERATORS AS COMPONENTS OF SYSTEMS

Today's systems are designed as 'total systems' rather than as individual components put together to form a system. This method of design produces better systems. When an operator is a component of the system, design engineers face a multitude of human factors considerations. No matter what type of operator, as discussed in the previous chapter, the designer must keep the operator in mind when designing a system. Three of the major steps in designing any system are the following:

a. developing the system concept

b. assignment of the system's subtasks to component elements and

c. deciding how to link the various system components together.

These are the steps where human factors considerations have a special impact on the design of the man-machine systems.

A. DEVELOPING THE SYSTEM CONCEPT.

The system must be clearly defined before any design decisions can be made. This is a statement of the purpose of the system - that is, the job the system is supposed to perform. The description must include such items as the list of tasks to be accomplished and the speed and accuracy requirements for each subtask. The environment in which the system will operate should be carefully described (e.g., lighting and temperature). This part of the definition should also include how many operators will be needed for operating and maintaining the system, training procedures, maintenance instructions, and updating of the system. In other words, the definition of the system's purpose should not be specified in general terms. The definition must include all the specific things that may occur.

Man-machine systems range widely in their complexity. Some systems are composed of many men and women and many machines. Others consist of a single operator and one machine. For example, a computer center composed of many operators and many terminals is a man-machine system. Any one of the terminals within the center is also a man-machine system. This illustrates the fact that there are levels of systems. Thus, defining and describing the system must be done with care and precision as the essential groundwork for good systems design.

B. ASSIGNMENT OF THE SYSTEM SUBTASKS TO COMPONENT ELEMENTS.

After the mission of the system has been defined, the designer has to make decisions about which of the system's subtasks should be done by various component elements. The first choice is usually "operator or machine?" Once this decision is made, the problem becomes "which machine element?" or "what type of operator?" Many things influence the designer (e.g., cost and availability of components). It is important to recognize that the operator, as well as the machine components, must be judged in terms of these criteria. For example, operators may or may not need training, or they may or may not be carefully chosen. In military environments there may be many different types of operators using the same system.

In addition to the above considerations a very important criterion in the selection of components is that of getting the most out of each in terms of its capabilities. Each component - operator or machine - should be used to do the task it can perform best. The component's limitations must not be exceeded.

Finally, not only do the characteristics of the components dictate whether or not they should be used for certain tasks but these same characteristics also prescribe the ways in which components are linked to each other.

C. DECIDING HOW TO LINK VARIOUS SYSTEM COMPONENTS TOGETHER

Links in systems are points of transfer of energy or information between components. As much attention should be given to designing such linkages between operator and the machine as is given to designing linkages between mechanical components. Traditionally, the human component has been the last to be fitted into new systems with the result being less than maximum system performance. The links between the human and machine system components must be optimized.

D. MAN AS A SYSTEM COMPONENT

Many books exist which explain the characteristics of mechanical and electronic system components and this literature provides the basis of design decisions concerning these components. The human operator is quite a different kind of component. Although there are many things about the human component that just is not known, scientists have found some characteristics of the human component which the designer should be aware. The following is a partial list of what is known about the human being as a systems component:

1. capability for data sensing
2. capability for data processing
3. capability for motor activity
4. capability for learning
5. physical and psychological needs

6. coordinated action
7. differences among individuals

It is important to be aware of how a human being fits into a system. Each of the above characteristics will be discussed below. A brief statement will be made about the nature of the characteristic in man. Then some system design implication of the particular characteristic will be given.

1. <u>Capability for Data Sensing</u>

Man gathers information through his senses. Human senses tend to be inconsistent. Such things as a person's general health, or fatigue, affect his sensory ability. Background conditions - noise from a printer, or a supervisor giving directions - influence and may adversely affect the senses. Man's ability to perform is affected if two or more of his sense channels are stimulated at the same time. In some cases, however, sensory interaction may boost performance as, for example, when one receives the same message simultaneously through visual and auditory means.

The human senses rarely operate by themselves. Man usually does more than simply serve as a receiver of information; he acquires data - sounds, sights - and interprets it as it arrives. Experience plays an important role here. As a terminal operator becomes more familiar with the computer system he tends to make fewer mistakes. The operator senses the facts which are presented to him and imposes interpretations on what he does sense. His ability to perceive the world in terms of a context is a tremendous advantage because it enables him to get a great deal of information out of a sketchy amount of data.

Man has several sensory input channels. Overloading any one or two sense modes should be avoided if possible when designing a man-machine system. Displays used to present information to human system components should be compatible with man's sensory abilities. Dial and function key markings should be readable under operating conditions. For example, if an operator is expected to read a display in comparative darkness, the markings should not blend in with the keys.

Man has certain perceptual expectations which should be remembered and utilized in display design. For example, an indicator should rise and not fall to indicate a climb. When a display behaves contrary to these expectations, errors in interpretation are likely.

2. Capability for Data Processing

In addition to his ability to act as a data sensor, man processes information: he thinks. This capability is the most important single characteristic of man as a system component. Not much of man's data processing characteristics are known because the area of human thought is perhaps the most complicated and least well understood in science. The very richness and variety of man's ability to handle and utilize information makes it almost impossible to characterize completely. Among the types of thinking operations people perform are: arithmetic calculations, quantitative and qualitative estimations, comparative judgment, translation, coding, memorization and recall, prediction and decision making. These processes range in complexity from a child counting his fingers to a genius contemplating an unsolved problem of the universe.

A major characteristic of man as a data processor is his flexibility. People do not require extensive or precise preprogramming. Men can deal with changing situations and unforeseen problems in the absence of a specific program. Unlike a computer, man can constantly develop and modify his own programming: he learns. The flexibility of thought makes improvisation another uniquely human characteristic. There are many different solutions to complex problems. The number of different ways an idea can be expressed in words is a case in point.

Judgment is another ability that man can exercise. Probably this skill comes from man's long-term storage (memory) and his ability to recall certain facts at the right time. Few people, if any, remember everything they see or hear but an amazingly large amount of material can be recalled years after it has been acquired. In exercising judgment an experienced operator makes decisions in new situations which resemble, but are not exactly the same as, earlier experiences he has had. Computer operators are faced with many different errors during their shift, few of which are exactly the same. Good operators draw on their experiences and are able to resolve these problems accurately and quickly. Man can grasp complex situations and make decisions about appropriate courses of action.

When designing a system, man's versatility as a data processor should be taken full advantage of. While computers can do in minutes what people take days or years to do, computers are relatively inflexible. Machines only carry out instructions of humans. And finally, cost and space factors involved in most computers can be staggering. To build a computer with any intelligence would cost more money then one can imagine plus take up a large amount of space. The investment would not be worth it when a man-machine system could be built to accomplish the same task for less money and space.

Since his speed, accuracy, and capacity differs widely with particular data processing tasks, a man should be assigned to system tasks very carefully. A human is not very effective in performing routine calculations - he is slow and is likely to make errors. A computer, on the other hand, is fast and accurate. A man's memory is not capable of handling large bodies of concrete facts and details quickly and reliably. He should be replaced or supplemented by automatic devices in performing tasks like these.

Man and the computer are not rivals. The computer can take over a great many of man's chores, especially the more routine ones, and man can be freed to devote more of his or her time and energy to his or her specifically human activities of planning, supervision, and creative thought. Man and the computer (in fact man and any machine) should be thought of as team members rather than competitors. Each has certain strengths and weaknesses. Effective system design should compose the team so as to have each team member compensate for the other's shortcomings. This is done, for example, in the case where the computer is used to make routine calculations which a man needs to make over-all decisions, or where the computer is used to make rough sorts among a large number of alternatives when the man is assigned the job of making the final decision among the screened alternatives remaining.

3. Capability for Motor Activity

In addition to data sensing and data processing, man also performs certain motor activities. He can move his arms, legs, hands and do other muscular actions. Speech is also in this category here. These motor activity capabilities enable man to act upon the environment by manipulating controls, changing his position and location, transmitting information verbally to others, and by lifting and moving objects.

The ability of man to make movements is limited in both power and speed. There is a time delay between the instant when he decides to make a movement and the time the movement occurs. Man is also limited as to the kind of movements he can make. He can reach in some directions and not in others, and there are limits to the distances he can reach or extend his hand. The consistency with which man can apply force is also limited; his muscles fatigue rapidly. The precision with which he can apply force is also limited.

The motor tasks assigned to men in systems should be compatible with men's abilities to perform them at the levels demanded by task and system requirements. Control devices requiring that people maintain consistent forces over long periods of time should be eliminated if possible. If human speech is required for a system task, the noise level of the work area can not be excessive. If there is more than one operator using a system they may have to communicate orally in order to perform a systems task.

Motor task requirements of human system components should be designed for efficient accomplishment. Pushbuttons, cranks, joysticks, control panels, and knobs should be built for easy use. Men have several motor output mechanisms. Tasks requiring human motor activity should be distributed among the different mechanisms. These output mechanisms should not be overloaded. The use of foot pedals, knee switches, voice triggered relays are examples of ways that the hands and arms can be relieved of motor control activity.

4. Capability for Learning

One of man's most important basic abilities, an attribute that clearly differentiates him from machines, is that he can learn. Given enough time, man can improve his performance in almost any task. In spite of the tremendous value of this ability to acquire better methods and new knowledge and skill, learning takes time. The time required for the learning process will generally vary with the complexity of the material or task he is trying to learn.

Much of human learning involves a trial-and-error process. If one thing does not work, man will try another. The learning process is usually accelerated if there is feedback or knowledge of results. If man gets this kind of information, he can quickly figure out new approaches, drop the old unsuccessful ones and keep the ones that worked.

The use of simulators illustrates another fact about human learning: men are somehow able to transfer skills acquired in one situation to another similar, but not identical, situation.

The system tasks which the operator is expected to do should be designed with the intent of minimizing the time required to learn to perform them. No matter how poorly planned the system tasks are, most can be overcome if people have enough time in training. The effective performance of a new system can be accelerated if the need for excessive preparation of human components is eliminated. Some training time can be reduced by designing new tasks so that they bear resemblance to tasks already known.

5. Physical and Psychological Needs

There are certain physiological needs of human system components that must be satisfied or their performance will be degraded. Food, sleep, and maintenance of health are critical human physiolgical needs. There also are certain psychological needs which have effects on system design. Morale, motivation, and job satisfaction affect over-all system capability and they should be considered by the designer of man-machine systems.

If system tasks performed by men are of long duration - more than the customary eight-hour shift - provisions made for meeting physiological needs assume special importance.

Morale is adversely affected by routine, repetitive tasks. Most people tend to lose interest and become bored in such situations. Their work becomes less efficient. If possible, repetitive tasks should be done by machines instead of people. If a person must do the task then other functions should be added to break up the monotony, perhaps even unnecessary ones.

6. Coordinated Action

Man behaves as an integrated unit. His many capabilities work in combination and concurrently. At the same time he is sending information, a person may also be processing information and performing certain motor activities. As a system compontent, man selects from his abilities the one most appropriate to the situation he is in and he acts accordingly. He can operate in a simple or in a very complex manner.

Man can perform several kinds of tasks simultaneously or in rapid succession and keep them all integrated. He can direct his own effort. He can shift his attention to a very narrow aspect of the total situation, or he can distribute it over many aspects of the situation, giving only a minimal amount of attention to each. There is, however, a limit to all this. There is a point at which the addition of tasks and responsibilities outstrips man's versatility. This is when something gets neglected. While this is not a desirable situation, it is at least a point in his favor that man, as compared to a machine, will not simply go on functioning blindly until he breaks down, but will probably attempt to focus on selecting and performing the most critical tasks and thus saving the situation to some degree.

When designing systems it is important to use man's versatility and his ability to perform many tasks simultaneously. The operator's ability to coordinate his actions should not be exceeded. However, if the tasks get too heavy, man, unlike computers, has the ability to decide which tasks are the most important and should be done first. In general, the number of simultaneous tasks should be kept low, work spaces should be designed to make shifts from one task to another easy, and compatible displays and controls should be provided.

7. Differences Among Individuals

One of the most troublesome things about man as a system component is the fact that, as a class, he is not very well standardized. In terms of each of the characteristics described above - data sensing, data processing, capability for learning, etc. - men differ widely from one another. Within limits, men differ in their sensory skill levels, their ability to utilize information, their motor skills, their ability to learn, the strengths and types of their physical and psychological needs, their ability to coordinate their own activities and abilities, and their ability to keep their performance from being affected by their emotions, needs and hardships.

Not only do people differ from each other in terms of specific factors, but there are wide differences in patterns or combinations of human characteristics. Two men of identical height and weight do not necessarily have similar perceptual or learning skills.

It is important to note that most human characteristics are distributed in a "normal" fashion. While there are extremes of all types in the population, the design engineer should keep in mind that there are far more people who are "average," in terms of most human abilities, than there are extreme cases. The designer should plan human system tasks with an "average" user in mind. The user population must be defined precisely and accurately. Typical user populations might be: older people, first-term military enlistees, and so forth. Accurate figures do exist on the distributions of human abilities and characteristics. The designer should not assume that men good at one type of task will also be skilled in another. If possible the design plans should be in terms of specific types rather than of a mythical, general "all-American boy" operator [Ref. 6].

E. SUMMARY

Having examined man in some detail as a system component, there are some summary remarks that can be made with respect to using this information in the design process. There is a tendency to categorize human and machine elements in terms of "what man can do best" and "what machines can do best." Since this kind of summarizing is not very profitable in terms of specific problems facing the design engineer, about the best thing to do is to underline the earlier-stated notion that men and machines are not competitors. Within limits of what is available and, more important, cost considerations, the system designer should consider the characteristics of both men and machines relative to the specific system problem facing him. The two classes of components should be wed in such a way that the respective strengths of each complement the weaknesses of the other. Following are some general remarks about man as a system component:

1. Man is a highly versatile component. He can fulfill a wide range of functions that usually require very complex and large mechanical or electronic counterparts. Some of man's versatile capacities cannot be duplicated by nonhuman components.

2. Compared with machines, men are generalists or jacks-of-all-trades. This versatility is extremely useful but, at times, it can be troublesome because of man's somewhat unpredictable nature.

3. Man has a great deal of built-in variability. It is difficult to predict with great accuracy exactly how a man will perform in any specific situation. Depending upon the particular task, and also upon many changing factors - motivation, state of health, experience - man's performance may be outstanding on one occasion and very poor on another.

4. Man has very definite limits on what he can do. Unlike mechanical components which can be expanded on a module basis, man reaches saturation both in terms of the number of things he can do simultaneously and the duration of his effort. While this sounds obvious, it is the one thing that is most often overlooked in the system design process.

5. The human component has many vulnerabilities. Many environmental conditions influence man's behavior: his health, his age, and his physical stamina are all examples of man's non-foolproof nature. He must be utilized with care.

6. In spite of notions to the contrary, man is a costly component. In terms of training costs, maintenance costs, and replacement costs, the human as a system component may be far more expensive than a casual investigation indicates.

Chapter two described types or categories of operators and this chapter discussed how these operators fit as a component into the "total system." The next chapter will apply this general discussion to a particular computer system used by the United States Navy.

IV. CASE STUDY

The previous two chapters provide a background and overview of most of the issues and concerns in designing an interface between an operator and a computer system. This chapter will provide a discussion of these issues in the context of an actual system. The system already exists, and the discussion will be from the perspective of a survey of existing problems and recommendations for modifications and corrections.

The United States Navy utilizes many special, complex, real-time computer systems which require operator interaction for operation and maintenance. In this chapter, we will describe the structure of a specific example of this type of system. The system is operated continuously twenty-four hours a day, three hundred sixty-five days a year. At least three operators, a CDP operator, an EDP operator, and an ER operator are needed to run the system during a regular eight-hour shift. The operators are responsible for ensuring the computer collects and processes real-time data and transmits correct reports to the proper users.

The CDP operator is responsible for setting up the computer. All the information needed to properly set up the computer is provided to the operator by outside sources through a paper report. The operator takes this data and inserts the information into the computer. The information includes a date-time-group, and the time limits on a particular run. To insert the information the operator answers a large number of questions generated by the computer. Each time the computer has to be set up, the operator must answer the same questions. Most of the answers do not change and the operator eventually just memorizes the sequence of answers without reading the questions. This type of interface can cause boredom and carelessness on the operator's part. When the computer has processed all the desired data the CDP operator performs the proper operations so the computer will terminate the current run and prepare to start over again.

The second operator, called the EDP operator, monitors the system. He does this by watching a continuous presentation of a file, called a day-file, which gives a step-by-step description of the computer's actions. This dayfile is taken directly from the operating system of the computer and is not rewritten before the operator sees it. Therefore, the description is written in the vendor's operating system terms. The EDP operator also changes tapes on the tape drives, adds paper to the printer, and other miscellaneous jobs needed to be performed for processing.

The third position is the Evaluation and Reporting (ER) position. The ER operator evaluates all of the reports processed and transmitted by the computer. He checks for any reports that are wrong, makes corrections if possible and cancels those which are erroneous. This operator also performs some analysis. When the computer is unable to automatically generate a report, the ER operator attempts to gather outside information to support the computer. If the operator can complete the process, he manually generates a report of the information.

A. TYPE OF OPERATOR

The type of operators used to operate this particular system may be any combination of the types discussed earlier in chapter two. The operators work six eight-hour shifts in five days. The CDP and the EDP operators spend their entire shift working with computer terminals. They are therefore categorized as dedicated operators. The CDP's entire job is performed in front of the terminal. The CDP operator is both an active and a passive operator. As an active operator, he enters data into the computer and initiates processing. The CDP operator enters data into the computer by answering questions provided by the computer. This makes him a passive operator. The EDP operator is only a passive operator. He does not interact with the system unless the computer malfunctions. Although the ER operator also uses a terminal, he spends a large amount of time doing paperwork. He is therefore a part-time casual operator and a part-time dedicated operator. When the workload is heavy the operator spends most of his shift at the keyboard and the paperwork is put aside until it is convenient.

The operator's backgrounds vary a great deal. Many of the operators join the Navy directly after high school graduation. If they become cryptology technicians (CT) when they enlist, they go through the appropriate training course directly after bootcamp. Other operators have been in the Navy but in a different field, such as intelligence specialist or aviation mechanic. These operators transfer into the CT field through one of the Navy's re-enlistment programs. They also attend the training course. All of these operators receive the same sixteen week training course. The course does not teach programming languages. It provides training on how to use the system and a general understanding of computers. A majority of the operators do not have any programming or computer experience. For those not interested in computers the sixteen week training course is all the education they receive. The initial lack of experience indicates that the man-machine interface should be written in an informal language which the operator can understand. The Navy can not afford to spend the time or money needed to provide the operators with a more thorough training program. If the interface is written in an easy to understand, informal language then the training course can provide a better education of the system instead of merely the interface language. This way once the operator arrives at her duty station she can spend her first few watches learning the "local procedures" instead of being retrained on the system. This would save time and money for the U. S. Navy and the individual field sites.

In summary, the type of operator used for running this system is dedicated, nonprogramming-oriented, and not highly trained, and the man-machine interface should be designed for this type of operator. It should be easy to learn and understand and should provide status and request input in an informal language, not in operating system terms. It should also require enough interaction between the operator and the computer to make the operator feel he is a part of the system and not an unneeded component.

B. POSITIONS

The computer is operated from three positions which are manned by watchstanders. Each position has a different interface which the operator must learn to work with. Each position also has its own problems. The following paragraphs describe the problems with respect to each position.

The operators and the hardware of the system are physically located in two separate rooms. The separation was deliberate and will not change in the future. Thus, if there is a system malfunction the CDP operator must leave his terminal and go to another room to check on the problem. This means the terminal is unmanned for the time the operator is in the hardware room. Since the operator position will not be moved into the same room as the hardware, an intercom system should be set up. This way the CDP operator could communicate with someone in the hardware room and stay at the terminal, or go to the hardware room and communicate with someone else at the terminal. The CDP operator would still have control over the system at his terminal and he can check on the system in the hardware room.

The CDP operator has a dedicated Hewlett-Packard microprocessor and terminal next to her position. It is dedicated to a graphical representation of the computer links and operation. The display is slower than the system it replaced because it takes longer for a computer program to execute than for lights to turn on. The old system was a bulky display panel with many lights. The lights simply were on or off showing the CDP operator whether or not the connections were made. The HP terminal displays a picture of the equipment with the links. In addition, the major problem with the HP is it is not reliable. For instance, at one time part of the computer system was not functioning and the HP terminal showed that it was. It also happens the opposite way. The terminal is an ideal component for the CDP position. Given the time and money spent on this status terminal, it should be reliable, or more resource should be spent to make it reliable. Also, some of the operators have made changes to the HP terminal programs which have benefitted the watch standers. These changes should be shared with other field stations so that everyone can benefit from them.

The regular terminals that the operators use have many capabilities which presently are not being used. There are function keys at the top of the keyboard which could be used to perform some of the repetitive operations. There also is a set of keys on the right side of the keyboard which can be used to enter numbers. Any of these keys could be used to speed up interaction with the computer. Presently, it takes approximately five minutes to perform the set up of the computer. In the future there may not be five minutes available to prepare the computer for the next run.

The CDP operator enters data into the computer and he can, of course, easily make mistakes. The error messages he receives are in operating system terms. For example, the error message "LP7A" is suppose to tell the operator that the line printer he requested is not available. In addition to learning how to use the terminal to run the computer, the operator must memorize the meaning of many error messages. There is a manual which lists all of the error messages and the causes but the operator does not always have time to look them up. The error messages should be rewritten in a language the operators can understand and they should relate to the actual application and program.

The EDP operator monitors the computer through a file called a dayfile. The file automatically updates itself and repeats the messages over and over again. Basically, it provides a long sequence of operating system status messages which give the operator the message: "I'm okay, I'm okay, etc..." until something goes wrong. When an error occurs, the error message will be buried in the sequence of other status messages. operating system terms. If the operator is experienced she can easily find the messages in the file which tell her how the system is doing. An unexperienced operator may miss an important message because she can not interpret the file. The file should be written in a language the operators can easily read and understand.

The ER position is extremely active. In addition to checking reports and making corrections, this operator must also shuffle a large amount of papers. He is responsible for ripping, sorting and filing messages received from other locations. He actually uses only a small amount of the messages which are received. The rest, used mostly for background information, are placed on clip boards for everyone to read. This task is tedious and could be divided among the other operators.

The messages the ER operator uses contain more information than the operator needs. For example, out of a possible ten columns of information only one or two columns may be used. Many times these columns are spread out instead of located near each other for ease of reading. The operator must first find the correct columns of information and attempt to read the correct row in each one. A characteristic of database systems is that columns of data can be easily moved around. The printouts should have the columns of information most often used on the far left and grouped together so the operator can read them quickly and easily. If the rest of the data is not needed then it should be deleted, or at least stored without being printed. If there are times when all the information is needed then it should be available to the operator on request, but only on request.

The information on the printouts is extremely technical. The ER operators should receive some basic training so that he can perform his job proficiently. The training would enable the operator to read and recognize the data without having to look it up in a pile of manuals. It would also give him a better understanding of the action that is taking place.

Today all updating of the database is done manually by the operators. If this update was done automatically it would speed up processing. The operator would be free to do other tasks and not spend the time updating the system. Correct automatic updating would also ensure that the correct and most current analysis was performed. If it could not be done automatically perhaps it could be performed by query from the computer to the operator to verify the update. This would ensure that incorrect data did not replace correct, up-to-date information.

Many times the ER operator gets behind because of the large amount of processing being done. Presently, there is no separation of high interest items and routine processing. If there were more terminals available for the operators at the ER position then one operator could process just the high interest items at one terminal. The routine items could be processed at a second terminal by another operator. The important information would be processed and the routine items would not get backlogged.

Everyone needs some form of feedback, whether good or bad, to perform a job well. The operators need feedback from the support personnel and the support personnel need feedback from the operators. The communication lines need to be opened and kept opened so that the site as a whole can perform at its best. At least one field station has an outstanding relationship between the operators and the support personnel. The end product it produces is well received by the users as a result.

The system changes frequently. Any future changes concerning the terminals should take advantage of the capabilities which already exist. There are many possible uses for the extra keys on the terminals. Using the keys instead of adding more CRTs to the CDP position would make the operator's tasks easier and take less time. Consideration should, however, be given to adding a terminal to the ER position. The ER position would utilize a second terminal more effectively than the CDP.

C. THE ENVIRONMENT

The operator must be comfortable in her environment to perform her "best." She must be able to move freely and quickly to respond to unexpected events, such as system failures. She must be able to read the terminal screen easily without causing unnecessary strain on her eyes. The environment the operator works in has a direct effect on her performance.

1. Temperature

As mentioned in chapter two, improper environmental temperature can cause physiological stresses which indirectly affect sensory or motor performance. The computers require cold rooms in order to function properly and not overheat. The hardware of this system is in one room and the operators, terminals, and peripheral devices are in another. This separation of equipment and operator should make it convenient to keep the working environment comfortable for the operators. However, both rooms are extremely cold. The low temperature is perfect for the equipment but uncomfortable for the operator. The room is so cold the operators wear additional pieces of clothing, such as sweaters and coats, to keep warm. This extra clothing is awkward and prevents the operator from responding quickly to computer requirements. It is also uncomfortable to wear heavy clothing the entire eight-hour shift. In order for the operator to perform at her "best" she must be able to move freely without being constrained by a bundle of clothes which are needed to keep warm. A large effort was made to separate the equipment and the operators. The same effort should be made to make the operators comfortable in their working environment.

2. <u>Lighting</u>

Presently the rooms are lit with rows of lights across the ceiling of the room. The light switches are wired so that when one switch is turned on an entire row of lights in the room come on. It is not possible to only turn on a light over the supervisor's desk or over the analyst's desk. The rooms are arranged with the supervisor's desk at the operators back. If the row of lights is turned on over the supervisor's desk then there is a glare on the operator's terminals. The glare causes a strain on the operator's eyes which directly effects the operator's performance. The light is required for the supervisor but not the operators. The lights could be rewired so that it is possible to turn specific lights on and keep others off. Another possible change would be to add the capability of dimming the lights to cut down on the glare. Either change would eliminate some of the strain placed on the operator's eyes during his shift.

D. TRAINING

The training course is sixteen weeks in length and is taught five times a year. The total of five hundred fifty hours per class is divided into classroom and laboratory sessions. The classroom and laboratory sessions are intertwined with two hundred forty-one hours of classroom lectures and three hundred nine hours spent in the laboratory.

The instructors use blackboards and handouts for teaching the students during the classroom lectures. This is a difficult way of teaching first-time computer users how to interact with a computer terminal. Seeing an example on a CRT screen is different than seeing it on paper. People remember actual experiences easier than something written on paper and handed to them. If at all possible a room with a terminal for each student should be provided for the classroom lectures. The terminal room would give the instructors the capability of introducing the students to computers before placing them in the laboratory. It would make the students more comfortable with CRTs and give them a better understanding of how to interact with the terminals.

The training course gives the students too much theory on computers. An operator does not need a detailed explanation of how bits and bytes work in order to operate the system. The time spent on theory could be better spent on problem solving or perhaps spend less time in the classroom and more time in the laboratory. The students need to understand how the components are linked together to form the total system and how to interact with them. The students can learn about the internal components of the system after the course in the working environment.

The laboratory represents a "perfect" system. The operator is shown how to set up the computer and then how to wrap up the process. Nothing is said about the problems which occur between setup and wrapup. No system runs perfectly all of the time. The students need some introduction to problems which may occur during an actual watch. There are several ways to achieve this. One way is to allow the students to stand watches with the operators on the real-time system. The on-line training would show the students what actually happens and what to expect during a shift. The instructors could also stand watches with their students. This would keep the responsibility of the students in the instructors hands and out of the shift supervisor's. It would also provide the instructors with a method of evaluating the students. The on-line training would also enable the instructors to keep up-to-date with the system.

A second way of teaching problem solving is through simulation of errors. Software programs could be written to simulate problems encountered while operating the computer system. Obviously not all the problems can be presented to the students but a large majority of them can. The simple errors such as misspelling of commands could easily be simulated. Simulation of errors would provide the student with a better understanding of his expected tasks and teach him how to undo his mistakes without turning everything off and starting over.

After sixteen weeks of training the students should be capable of sitting in front of a terminal and running the system. However, one field station gives each new operator an additional two months of training before they sit the position. Each of the field stations have local procedures which must be learned in order to operate the system. However, two months is too long for just learning local procedures. Either the station is wrong and providing more training than necessary or the training course does not provide the appropriate information to the students.

E. CONCLUSION

The system designers should be responsible for making some of the suggested changes. The programming of the function keys should be performed by the designers before they add more terminals to the positions. The designers should also rewrite the dayfile and the error messages so that the operators can understand them without having to memorize their meanings.

Although the designers should be responsible for some alterations, the individual field stations can make a majority of the changes. The tasking of the operators can be uniformly divided so that one operator is not idle while another is overloaded. Messages that need ripping and filing can easily be done by the EDP operator instead of the ER operator.

An intercom system can easily be arranged between the CDP position and the hardware room. The maintenance personnel could possibly find this system useful also. If equipment which is located in one room but is operated in another malfunctions, two maintenance personnel could work on the problem without having to physically go back and forth between the two rooms. They could communicate over the intercom.

The training course needs to be reconstructed or at least a few changes should be considered. Less theory and more training on operational procedures should be given. The laboratory sessions could be more realistic and provide more problem solving examples.

Making the changes to the system and the interface would enable the operators to perform better. It would provide a better environment to work in and the operators would be more comfortable. The overall output of the system would be processed faster and be more accurate, also benefiting the users.

V. CONCLUSION

In summary, the success of a system in achieving a specific purpose depends largely on the interface the operators must use to communicate with the computer. In order to design the man-machine interface there are a few facts the designer must be fully familiar with. These facts include the type of operator, the environment in which theoperator must work and the equipment the operator must use to run the system. The type of operator varies a great deal, as is explained in detail in chapter two. The designer must know how often the operator will interface with the system, what the operator's background is, and how much interaction will be needed to run the system. All of these facts must be known and thoroughly understood before starting to design the interface of a system.

The environment in which the system exists and the operator must work directly affects the performance the operator achieves. Therefore, it must be constructed to ensure the operator is comfortable while she works. The environment issues include the temperature of the room, the lighting of the room, and the physical arrangement of equipment.

The most important issue which must be designed with the operator in mind is the actual equipment the operator works. The number of controls and displays the operator must operate or watch should be kept to a minimum so that the operator is not responsible for more components than he can handle efficiently.

An operator is not a piece of equipment which can be connected to other parts of a system without careful planning. The operator's capabilities are limited and must be considered before placing her into a system. Chapter three discussed the capabilities of the human being as a component of a system. These capabilities include the ability to learn, sense, process, and react to given situations. Electronic and mechanical systems can not respond in the same manner as mankind and thus the characteristics are different. Therefore, the designers must consider the operator's capabilities as well as the system's.

The case study was done to give an example of how the lack of a thorough understanding of the man-machine interaction affects the performance of the system and to provide some reccamendations on how to improve the interface. It is extremely important to completely define and thoroughly understand how the operators will interface with a computer.

LIST OF REFERENCES

1. Gagne', Robert M., Psychological Principles in System Development, Holt, Rinehart and Winston, 1962

2. Martin, James, Design of Man-Computer Dialogue, Prentice-Hall, 1973

3. Meister, David, Human Factors: Theory and Practice, Wiley, 1971

4. Bernet, E., Degan, J., and Spiegel, J., Human Factors in Technology, McGraw-Hill, 1963

5. Meister, David and Rabideau, Gerald F., Human Factors Evaluation in System Development, Wiley, 1965

6. Sinaiko, H. Wallace, and Buckley, E. P., Human Factors in the Design of Systems, Naval Research Laboratory Report 4996, Naval Research Laboratory, Washington, D.C., August 1957

INITIAL DISTRIBUTION LIST

		No. Copies
1.	Defense Technical Information Center Cameron Station Alexandria, Virginia 22314	2
2.	Dudley Knox Library, Code 0142 Naval Postgraduate School Monterey, California 93943	2
3.	Office of Research Administration Code 012A Naval Postgraduate School Monterey, California 93943	1
4.	Computer Technologies Curricular Office Code 37 Naval Postgraduate School Monterey, California 93943	1
5.	Susan K. Harding 1315 East Capitol Street, SE Washington, District of Columbia 20003	2
6.	CDR. Richard R. Rowe, USN, Code 9110 Naval Research Laboratory 4555 Overlook Avenue, SW Washington, District of Columbia 20375	2
7.	LtCol. Alan A. Ross, USAF, Code 52Rs Department of Computer Science Naval Postgraduate School Monterey, California 93943	3
8.	Herschel H. Loomis, Professor, Code 62Lm Department of Electrical Engineering Naval Postgraduate School Monterey, California 93943	2

END

FILMED

2-85

DTIC