

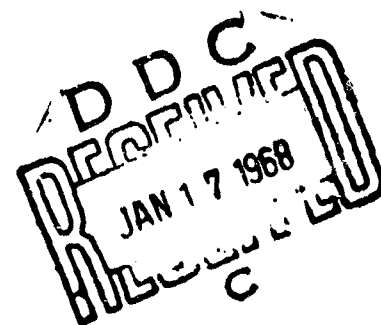
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DEVELOPMENT  
OF COMPUTER  
ASSISTED  
INFORMATION  
SUPPORT  
SYSTEMS FOR  
COMMAND  
AND CONTROL



A STUDENT THESIS BY:

Captain John E. Engel

**SCHOOL OF SYSTEMS AND LOGISTICS  
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DEVELOPMENT OF COMPUTER ASSISTED INFORMATION  
SUPPORT SYSTEMS FOR COMMAND AND CONTROL

A Thesis

Presented to the Faculty of the School of Systems and Logistics  
of the Air Force Institute of Technology  
Air University

In Partial Fulfillment of the Requirements for the  
Degree of Master of Science in Logistics Management

By

John E. Engel, B.S.  
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August 1967

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This thesis, written by

Captain John E. Engel

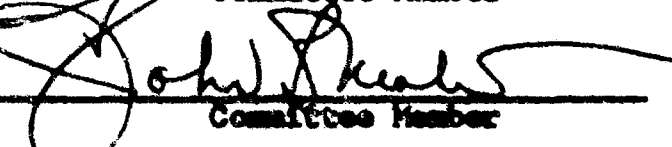
and approved in an oral examination, has been accepted by the undersigned on behalf of the faculty of the School of Systems and Logistics in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN LOGISTICS MANAGEMENT

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## CHAPTER I

### INTRODUCTION

#### Background of the Problem

Military commanders have always required information. Since the advent of electronic computers, however, the demand for more current and usable information has been steadily increasing. More often does one hear the words "information support" and "command and control." It is as though they represent a new concept in management -- and, in a sense, they do. Yet, when one looks at the overall information requirements, he finds that they are as old as management systems themselves, and that it is only the speed at which the information is provided, the amount and detail of the information that is available, and the methods of presentation that have changed. But, even though information is being provided at lightning speeds and more tasks are being performed by automated systems, management still remains the function of human beings. While an information system is certainly a tool of management, it cannot, in and of itself, manage (54:5).

One major problem since the new computerized systems have been put into operation is that there is now a tendency to satisfy requests with as much information as possible rather than to determine and present only that which is

required (62:53). Consequently, information support systems often burden the decision-maker with vast quantities of data rather than assist him by providing timely, pertinent information. Even when specific information requirements are known, the format or presentation of the data is often inadequate.

In command and control, especially at the major command level and above, computers are not satisfying the information requirements as well as originally intended (12:109). They are not providing the necessary information at the proper time, or with sufficient speed, accuracy, reliability, or ease of accessibility well enough to adequately satisfy the needs of the commander or his staff. Computers, of course, do provide much needed information support, but they still have not been applied as effectively as is required in the command and control system environment. This is often caused by the computer not being set up or programmed to provide the desired information (2:77).

In order to determine the general requirements, one must first understand what a command and control system is. As defined in the Joint Dictionary (JCS Pub 1), it is "an arrangement of personnel, facilities and the means of information acquisition, processing and dissemination employed by a commander in planning, directing and controlling operations." A representative definition of the civilian counterpart -- the management information system -- would be: a communication process in which data are recorded, revised,

and presented to support management decisions for planning, operating, and controlling (35:4). Command and control, then, can be considered as the ordinary day to day task of accomplishing the assigned mission (22). It involves the entire spectrum of facilities, people, and equipment which permit the staff to provide information to a commander with which he can make a decision. It is a management information system that works in two directions: data comes in, and management decisions and direction go out (33). The procedures and equipment used have changed rapidly throughout the years, but the basic concepts have remained the same. The commander still must have the pertinent facts, alternative courses of action applicable to different situations and plans, projections of present facts into future plans of the greatest probable utility, and a means to correlate all of these into the best decision possible (60:1).

A 1961 Department of Defense sponsored study on the application of digital computers asserts that:

A major barrier limiting the usefulness of computers in command systems is the relative lack of attention being given to research and analysis directed at understanding specific problems of the commands. A few examples of the specific command problems needing investigation are:

- (1) How compatible is the command's present staff structure with the capabilities of computer systems?
  - (2) How much and what type of information are needed?
  - (3) How is intelligence information best stored, retrieved, processed and used in the command?
  - (4) How can computers aid a given command in plan development, evaluation, and modification?
- (18:57-58)

The objective of this thesis is to determine and present the criteria and concepts for the effective development of an automated information support system used for command and control.

### Scope

Since there are many current problems concerning automated information support systems, each worthy of a thesis in its own right, it would be impossible to adequately cover them all in one study. This thesis will concentrate on computer software requirements and application, and on identification and establishment of information support capabilities.

When analyzing command and control operations, it becomes possible to categorize the activities into four basic functions: monitoring, assessing, planning, and controlling (59:5-6). These are the functions that an information system must support. These functions will be described in Chapter II.

Once the purpose of the command and control system is understood, it becomes necessary to identify the general information requirements and characteristics needed to support this overall system. Chapter III discusses these information criteria.

Chapter IV concentrates on computer software. This chapter presents the desired features and capabilities of an effective computer language and data management system for use in command and control. Even though information may be

stored within the computer, it cannot be extracted or presented effectively without an adequate computer software system.

Once the functions of command and control have been identified, the general information requirements have been defined, and the computer software requirements have been satisfied, it then becomes necessary to establish procedures for the development and operation of specific support capabilities. These procedures are contained in Chapter V. They are concerned primarily with identifying, implementing, operating, and modifying information support capabilities to assist the commander and his staff.

Chapter VI contains the general conclusions of this thesis.

#### Related Factors

In 1963, there were twenty-one individual command and control systems supporting the defense of the United States (61:25). These constituted the World-Wide Military Command and Control System. This system, established by Department of Defense Directive S-5100.30, attempts to provide an integrated command system at the highest level. The hub of this operation is the National Military Command System. In the words of Secretary of Defense McNamara:

The national military command system (NMCS) is the primary component of the worldwide military command and control system. It was established specifically to provide the national command authorities with the means to provide strategic direction to the Armed Forces under all conditions. . . . (6:43)

The NMCS is, in turn, supported by the other individual command and control systems. In addition to growing in number since 1963, these systems are increasing their use of computer assisted information support, thereby creating more of a demand for adequate development concepts.

As these computer systems have taken on more importance it has become necessary to analyze more thoroughly the importance of non-automated actions and to determine the most effective manner in which automated assistance can support the non-automated activity. Failure to analyze the requirements for information support may result in the computer system providing information without any real utility.

In the 1940's and early 1950's punched card accounting machines were the new concept in data processing. They provided a capability for data manipulation coupled with increased speed that was, until the late 1950's, the main method of processing and displaying information. Organizations requiring this type of information support, naturally, developed concepts and procedures affecting this capability. With the advent of the electronic computer much greater speed and flexibility were obtained. Today, computers are operating within speeds of one billionth of a second and are capable of performing several different tasks concurrently. With the concepts and procedures of the old punched card systems still in effect, however, the capabilities of the new equipment are not being fully utilized. It is now necessary to develop new concepts and procedures -- a

difficult and long process. The key to a dynamic and usable system of information support lies in doing away with these old accounting procedures and in conceiving information as it relates to the functions of command and control. Accounting and statistical techniques are well defined and developed, but information systems for the more general area of management are still a relatively unexplored horizon (4:113).

Even when the specific information needs of a command are known, a problem exists not only in satisfying that need but also in satisfying it such that the information is compatible with the other systems. It is a responsibility of each command to satisfy its needs in a way that its solution will, if applicable, satisfy the needs of other commands. There must be an exchange of information and capability between the different command systems if extensive duplication of effort is to be avoided. System compatibility and standardization are such important aspects of integrated command and control that a special group, the Joint Command and Control Requirements Group (JCCRG), was established at the Pentagon to integrate and standardize, as much as possible, the different command and control systems. Chief of Staff of the Air Force, General John P. McConnell has stated that such integration is necessary to permit the all-important control of our military power (16:61). These attempts to integrate systems are just beginning, and much work remains.

In an effort to help identify the general criteria and to help determine the best approach to the orderly

development of the individual supporting systems, several research studies have been sponsored. The first significant effort was the digital computer application study titled Computers in Command and Control (18). This study, performed in 1961 by the Institute for Defense Analyses (IDA) and sponsored by the Director of Defense Research and Engineering (DDR&E), presented the prime requirements for command system integration and evolution. It is still used as a basic guide in command and control system development.

Considerable research effort is also being performed by the Electronic Systems Division of the Air Force Systems Command in conjunction with the MITRE Corporation and the System Development Corporation (SDC). MITRE Corporation has developed AESOP, a general-purpose approach to real-time, direct access management information systems (45). SDC has developed a new system called LIGHTNING, a time-shared data management system (47). These new systems, when analyzed with the current, operational computer languages, indicate some approaches to solving the present computer software problems.

### Hypotheses

Development of this thesis is based on three primary hypotheses.

First Hypothesis. The first hypothesis is that the computer programming system (software) has more effect on overall system performance and acceptance than does the physical computer equipment (hardware). The conversational

ability, error detection and correction capability, flexibility, responsiveness, and operating ease of the computer system software play decisive roles in the success of the system. More can be accomplished by an older computer using effective software than can be accomplished by the newest, most advanced computer without a sufficient software system to support it.

Second Hypothesis. The second hypothesis is that to be effective, an automated command and control system must be developed in an operational, evolutionary environment and not in a static, theoretical one. In several past cases, the system requirements were defined and then contracted for production and delivery to the command for implementation. This process generally took one or more years to complete, and too often, by that time, some of the original requirements were no longer valid, and the intended users of the system would hesitate to accept or take advantage of its capabilities.

Third Hypothesis. The final hypothesis is that definitive, detailed information requirements must be clearly stated before successful development of an automated command and control system is possible. Stating simply that a requirement exists for data in a particular functional area may be fine for manual systems, but because of the vastness and complexities of a computerized system, specific, detailed requirements are necessary.

Expounding these three hypotheses will establish the basic criteria for the effective development of an automated information support system for command and control.

#### Nature and Sources of Data

Several sources were used in acquiring data for this thesis. Information on current system concepts, capabilities and operational procedures were obtained from the following:

1. Air Force Integrated Command and Control System
2. Department of the Army Command and Control System
3. National Military Command System
4. Naval Command System Support Activity
5. USSTRICOM Command Control System

Data were obtained from documents produced by these organizations and from personal interviews with the managers and developers of these systems. Documentation was in the form of system philosophies, system descriptions, operational capability plans, operational requirement specifications, and user information guides.

Computer programming languages were analyzed by using the information manuals and specifications provided by the developers and by interviewing selected, individual programmers and users of these languages. The following language systems, listed with their developers, were studied for their general operating and programming characteristics:

1. AESOP -- MITRE Corporation
2. CCL -- USSTRICOM and NAVCOSSACT
3. JOVIAL -- System Development Corporation
4. LIGHTNING -- System Development Corporation
5. NIPS -- National Military Command Center
6. OUR -- Air Force Integrated Command and Control System

The analysis and presentation of this data will provide the general criteria for the effective development of computer assisted information support systems for command and control. The presentation of developmental and operational concepts will also indicate several areas requiring further independent research.

## CHAPTER II

### THE FUNCTIONS OF COMMAND AND CONTROL

#### General

One of the most important questions that should be asked by managers and analysts when developing a new information support system is for what purpose the computer will be used. A paper presented on this subject at the 1965 Fall Joint Computer Conference began:

The computer has been so widely accepted as a tool of management that there is no longer any debate about its ability to serve the needs of management. But, unfortunately, the introduction of a computer does not in itself guarantee increased effectiveness, efficiencies, or profits in the firm. Rather, the computer must be viewed as still another management resource from which certain benefits can be extracted but these advantages do not automatically result from installation of the device. . . . Today, the question is not should a computer be used, but rather how management can best use the computer to serve its needs (10:145).

Questions should be asked concerning what information the information support system should provide, to whom it should be available, and in what format and by what means it should be presented. Perhaps many of today's problems in the command and control area could be diminished if, instead of just taking available information and structuring it into a presentable format, more time were spent on analyzing the intended purpose of the information and in insuring that the

information presented satisfies some sort of functional need. If the functional categories and objectives of a command and control system can be identified, it will be easier to determine both what information is required and how it can best be presented.

The main objective of an automated information system is to support the commander and his staff (69). To do this, the system must provide the information needed for setting objectives, shaping and evaluating alternative strategies, measuring and interpreting results, and for making decisions and issuing directives (19:28).

The Department of the Navy identifies the general management functions as:

1. Determining objectives and missions
2. Planning
3. Programming
4. Directing
5. Taking action
6. Observing
7. Evaluating
8. Controlling (53:H-8--H-10)

On the other hand, the United States Strike Command states that there are four basic functions of a command control system. They are:

1. Monitoring
2. Assessing
3. Planning
4. Controlling (59:5-6)

Analysis of these two lists of functions shows that they are really the same. The only difference is that the Navy has expanded the four basic functions identified by USSTRICOM. This expansion is shown in Figure 1.

| USSTRICOM   | Dept. of the Navy                                                 |
|-------------|-------------------------------------------------------------------|
| Planning    | Determining Objectives<br>and Missions<br>Planning<br>Programming |
| Controlling | Directing<br>Taking Action<br>Controlling                         |
| Monitoring  | Observing                                                         |
| Assessing   | Evaluating                                                        |

Fig. 1. USSTRICOM and Department of the Navy Versions of the Functions of Command and Control

The four functions identified by USSTRICOM are those that will be used throughout the remainder of this thesis. It is these functions that an information system must support. Each will be analyzed according to its role in a command and control system.

#### The Monitoring Function

Monitoring is the process of maintaining environmental cognizance. It provides the primary information interface with other commands and agencies. Information collected through monitoring provides the commander and his staff with the status and condition of his forces and with the overall political, economic, social, technological, scientific, and military situations. The monitoring tasks directly feed information to the assessment function, which in turn provides the planning and control functions with information upon which long-range plans, immediate actions, and

alternative selections can be based (59:5). Monitoring includes the following tasks:

1. operations monitoring
2. situation monitoring
3. resource monitoring
4. policy monitoring
5. plans monitoring (58:B-1)

Operations monitoring provides information support concerning the activities of a military operation. It permits observance of the overall situation and provides for the allocation of resources as required.

Situation monitoring is the monitoring of events and conditions that are not involved in a military operation. Here, the concern is monitoring political, social, and economic situations for possible actions to be taken. The physical environment, including geographical, geological, and climatological factors, must also be monitored. Situation monitoring therefore, permits the commander and his staff to keep abreast of the environment. It is most commonly referred to as the intelligence information.

Resource monitoring supports command and control by providing information on the status of forces and their associated logistic support resources. This monitoring is applicable to both friendly and opposing forces. The purpose here is to know what is available and where it is located if action is to be taken.

Policy monitoring includes keeping abreast of orders, events, and conditions of a directive nature. This monitoring helps determine if the contemplated action is in

accordance with the policies of higher authority.

Plans monitoring, the last of the monitoring functions, entails keeping both current and available the plans and supporting plans for all contemplated or contingent actions. This will help keep the commander informed on both the actions to be taken and the forces to be involved once a plan is placed in operation.

### The Assessment Function

The second function -- assessment -- permits the evaluation of events, situations, and conditions against an established criteria. It provides the basis for selection of courses of action. These selected courses of action in turn provide for the development of the concept of operations. Assessment of plans feasibility permits evaluating the adequacy of the resultant plan to meet various possible situations. This is followed by the assessment of the interaction of different plans on the assignment of forces and allocation of logistic resources. Assessment of the situation versus the plans provides an indication that initiation of operations may be appropriate. These operations can then be further assessed on the basis of applicable plans, the allocation of resources, and the impact of related situations (59:6-15).

Assessment includes the following tasks:

1. operations assessment
2. environmental assessment
3. operational readiness assessment  
(58:B-3)

Operations assessment is the evaluation of military operations against the current plans and policies. It is here where the execution of operations is compared with the planned accomplishment of objectives, where both current and future operations requirements are compared with the allocation of forces and resources, and where the influence of the operation on related situations is evaluated. In short, this is the area of determining whether current courses of action are accomplishing the planned objectives.

Environmental assessment provides for the evaluation of current and predicted situations against present policies. It is this comparison that results in the generation of courses of action for support of long-range planning. The environmental situation must be compared with the current plans to anticipate requirements for initiation of military operations and to indicate where new plans must be developed. The influence of the environment on military operations is also evaluated in this assessment area. It is through the assessment of environmental situations that plans and policies are modified and military operations are initiated.

Readiness assessment is the process of evaluating the capability to perform required operations against an established criteria. To do this, the feasibility and adequacy of the plan to meet the situation must be assessed, the allocation of resources to current plans must be evaluated, the readiness of the forces assigned to specific plans must be determined, and the logistic readiness must be known. The

general purpose of readiness assessment is to determine the ability to perform a planned operation.

### The Planning Function

The third function of a command and control system is planning. Planning includes the development and maintenance of concepts, programs, procedures, and operation plans. In general, the planning function involves the generating, reviewing, maintaining, and modifying of operational plans and policies, manuals, SOP's, operating instructions, directives, and regulations (59:6-15). Planning falls into the two following general categories:

1. long-range planning
2. short-range planning (58:B-3)

Long-range planning is that planning accomplished before the initiation of an operation. The activities include: formulating policy and procedure, preparing operational plans, reviewing supporting plans, revising and updating plans, and correlating plans.

Short-range planning, on the other hand, entails the selection and modification of plans required to meet the changing operational situation and the issuing of operational orders, including the allocation of resources. The currency of the information is much more critical in short-range planning and must therefore be disseminated as quickly as possible.

### The Controlling Function

Control, the last of the command and control functions, is a continuous process of directing the courses of action. This function encompasses the classic military decision-making processes, application of the decision-maker's authority, and the coordination between the commander and his staff with external organizations. All of these must be accomplished in light of the mission, objectives, and operational requirements (59:6-16). Those areas to which the control function pertains are:

1. operations control
2. resources control
3. command liaison and coordination
4. internal organization control  
(58:B-3)

Operations control is the control and direction of ongoing operations by the commander. This area includes controlling the tactical operations and the movement of both forces and resources during the operations phase. It is the process of determining the best courses of action, reviewing and approving plans, and comparing and evaluating alternatives.

Resources control is the control of the forces and logistic support available for an operation prior to initiation of the operation. Here the concern is with planning directives, allocation of vehicles for resource movement, establishing priorities, and developing inspection, alert, and communications procedures.

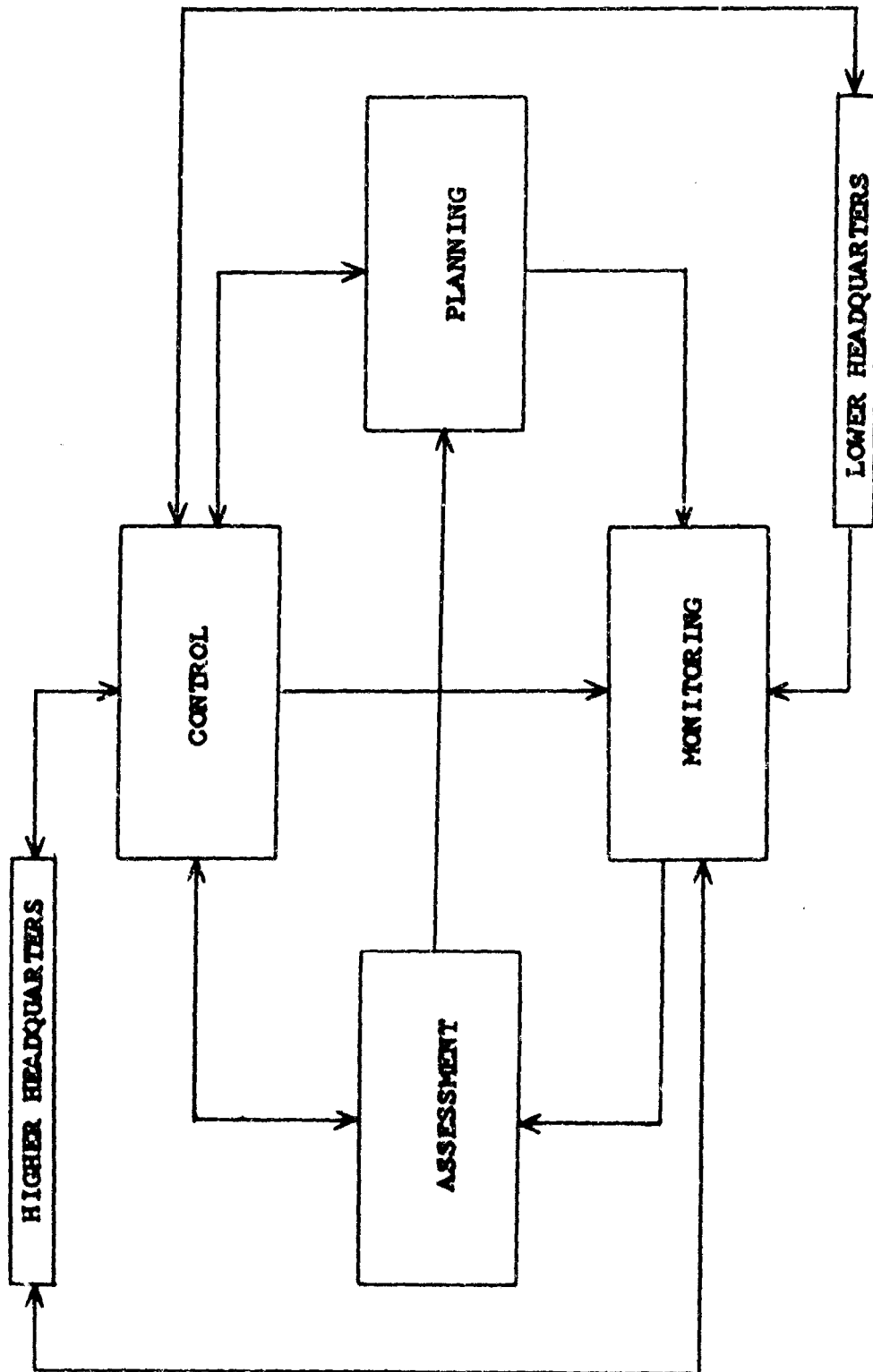


Fig. 2. Command and Control Functions

The other two control areas, command liaison and coordination, and internal organization control, are involved in coordinating operations with other organizations and in controlling the internal organization and activities.

#### Summary

These four main functions -- monitoring, assessing, planning, and controlling -- are the basic functions of a command and control system. Figure 2 graphically shows the interrelationship between these functions. The exercise of effective command and control, and thus the work of the commander and his staff, revolve around these general functions.

The effective performance of these functions, however, can only be accomplished through the receipt of adequate and timely information. No profitable decision can be made without first analyzing the available information bearing on the problem. The requirements and characteristics of this information, in support of the monitoring, assessing, planning, and control functions of command and control, are the subjects of Chapter III.

# CHAPTER III

## INFORMATION REQUIREMENTS AND CHARACTERISTICS

### General

Just as people are the key component of any command and control system, information is the key ingredient.

The three elements which form the significant core of the decision-making process include the element of information. The decision-making process is the sum of a person's experience plus the creative thinking he applies to the problem or question at hand, plus the information he brings to bear on the problem. Consequently, profitable decisions can be shown as a formula: decision equals experience, plus creative thinking, plus information (39:61).

Information is the life blood of the system. It provides the fuel for the decision-making process and permits the all-important interfaces between higher, lateral, and lower echelons of command. The exercise of command and control is dependent upon the availability and exchange of required information.

Not all representations of human knowledge can be considered as information -- at least not for the purposes of this thesis. A distinction should be made between the terms "data" and "information" in order to insure proper understanding of the processing functions involved. Data are the raw facts or the unprocessed items representing some knowledge or intelligence. Only when these data have been

processed and combined in such a way as to have utility in one of the command and control functions can they be called information. The amount of data that could be accumulated in a major command and control system is astronomical. The choice of just what data are to be stored in the system and what information is to be provided from them is an important command decision in itself (49:228). Only by insuring that the proper data are in the system does it become possible to provide the necessary information.

This information is provided through use of an information system, which is defined as any organized and established procedure for gathering and combining data in such a way as to provide useful information (44:652). To do this, three general requirements must be satisfied: first, based on a known information need, a capability must be established for determining and then gathering the required data; second, a vehicle -- either manual or automated -- is needed to collate and process these data into meaningful information; and third, a means must be provided whereby the needed information can be presented to those requiring it.

#### Types of Information Systems

In a command and control system two general types of information systems are used -- operating systems and reporting systems (35:28). Each has its own purpose and requirements. In addition to these two types of systems, information is separated into two basic levels. The first

level -- the detailed information level -- fulfills most of the decision-making needs of middle and lower staff management. The second level -- the generalized information level -- flows mostly at the higher staff levels within the command. "It is the crucial stuff -- sometimes intuitive and vague -- out of which executive decisions are often carved" (50:26). There is a definite need for both detailed and generalized information since they are generally used for two different audiences (30).

Operating systems are used primarily in the monitoring, assessment, and control functions. The information provided is primarily at the generalized level, although some detailed information may also be used. The information is usually current -- no more than a day or two old -- and has been extensively processed to omit extraneous data. Command centers, combat operations centers, and emergency action centers are examples of where such systems are used. These operating systems are directly associated with the performance of the assigned mission. They provide the vehicle through which the commander obtains a current awareness of the situation and through which he controls his forces and operations (21:69).

Reporting systems, on the other hand, since they usually provide the more detailed information, are used more by staff personnel than by commanders. These systems are used in all four of the command and control functions. The information provided is detailed and consists more of

historical and objective type data rather than the current and subjective type data of the operating systems. Reporting systems incorporate most of the periodic data requirements and form the basis of the information processing system data bank. These data, once processed, are often used as inputs to the operating system. Reporting systems are geared more toward the planning function while operating systems emphasize the controlling function.

#### Long-Range Objectives

Throughout the previous discussion, information systems were emphasized. In order to more fully appreciate the impact that these systems are having, it is important to consider the objectives, or, more correctly, the long-range effect of the automated information system. The Department of the Navy identifies the long-range objectives of an automated system, stated in terms of characteristics, as:

1. Organization Integration
2. Management Function Integration
3. Resources Integration
4. Language Integration
5. Information Selectivity
6. Maximum Automatic Information Control
7. Appropriate Use of Management Sciences
8. Economic Balance
9. Man/machine Balance (53:H-1--H-4)

These characteristics, because of their futuristic if not cosmic objectives, are discussed further. The remainder of this section is a synopsis of Appendix H, "Principles and Concepts," SECNAVINST 10462.7B, Automatic Data Processing Program.

Organizational integration requires an interconnection of all data sources, processing units, and users. In effect, there would be one large data base, without duplication of data and with access for all required users. The objective is neither centralization nor decentralization of management but rather providing a system that will accommodate either one. This would entail consistency of communications equipment, language, timing, and media as a consequent part of this objective.

Management function integration provides a constant comparison between what "is" and that which "should be" or "can be" within each management level's cognizance. This refers to an integration of related information created within the four command control functions. It implies the same language, categorization, degree of detail, and channel for both operating system and reporting system information.

Resources integration combines data on personnel, material, tools, facilities, time, that which was to be done, that which was done, and the dollar values represented by each, plus any other pertinent unique, natural, or environmental factors. The objective is to identify with each bit or item of data all of the significantly interrelated data pertaining to it. The purpose is to design data not just to show the past history of an asset but rather to show how much usefulness and liability remain. This concept will produce information concerning what can and cannot be done in the future, when, where and with what the inventory must

be modified, and just what logistics provisions will be involved.

Language integration has as its objective the ability to record, transfer, process, summarize, analyze, store, recall, and display information with a minimum of human intervention. This requires a complete standardization of codes, functions, symbols, and information content along with the utilization of universal or standard programs.

Information selectivity is the automatic screening and selection out of the full store of data, and the automatic delivery of only that data which is necessary to each particular organizational unit and level.

Maximum automatic management control implies relegating to machines all mechanical decisions, leaving for human consideration only those things requiring mental faculties no machine has yet been constructed to duplicate. This would produce a more accurate, more consistent, and generally better work product. It would also permit more time for management to devote to exceptions, creative thinking, basic planning, and self-improvement.

Appropriate use of management sciences includes the development and use of such scientific techniques as linear programming, dynamic programming, queuing theory, probability theory, game theory, information theory, statistical methods, and others yet to be developed. The objective is to use the most advanced scientific techniques and equipment for computation and simulation that will assist management in

determining the most rational or optimal combinations and sequences in the use of resources for any given result desired.

Economic balance requires an optimal use of resources allocated to information systems as well as an optimal balance between resources allocated to information systems and resources allocated to all other things. The point of best total economic balance is reached when any further change in resources for information systems will decrease the effectiveness of the entire service with all of its resources.

Man/machine balance, the last of the long-range objectives, refers to optimal balance in the utilization of non-human and human resources in both information systems and management. This requires a balance between capability of equipment, capability of personnel to make the equipment do all that it can, and capability of management to understand, specify, and use the information product that will be of greatest utility.

Although these long-range objectives will not be realized in the near future -- if ever -- they do provide a perspective and appreciation for the potential of automated information systems. They provide either a goal or something to be avoided, depending on one's point of view. In either case, it is still necessary to identify the general information requirements and characteristics, which follows.

### Information Requirements

The automated information support system furnishes the commander and his staff with the information required to make decisions and conduct the general operations of the command. The main purpose is to provide needed information, not merely to marshal mounds of data (11:565).

The role of information in command and control is based upon certain contributing factors, some well defined, others rather obscure. Certain basic requirements, such as the disposition of forces or the availability of resources, have been rather well established throughout the years. The personal requirements of the commander and his staff as to the degree of detail and the format of desired information, however, is rather obscure until specified by the individual user. Therefore, it is impossible to specify a complete set of information requirements that will satisfy everyone (56:4). The range of detail of information is extreme, varying from the general and implicit to the explicit definition of a single data item. The job of directly relating information requirements to the basic functions of command and control, considering the volume of potentially useful information, consequently, becomes tremendously complex.

One approach in attempting to satisfy this requirement is the "input-oriented" approach. This system is designed to gather all the data available, to store them in some organized fashion, and then to try to satisfy information requests as they arise (11:566). The problem with this

approach is that the resultant data base will not be able to satisfy many of the information requirements. In other words, it will not be complete enough to provide satisfactory information support -- especially at the higher management levels. The data base will only contain information that is easily obtainable and that can be stored economically and maintained centrally. There is much more information that management will need (5:72). This "input-oriented" approach, therefore, may satisfy a great deal of the reporting system requirements but will not provide satisfactory support in the operating system area.

Another approach to satisfying information requirements is to analyze the tasks performed by selected individuals and to try to determine the specific information they need. This "specific-requirement" approach, although it is the one used in many of the command and control systems operating today, has several disadvantages. First, management must spend an inordinate amount of time trying to communicate its needs. Second, the time between the request for information and the satisfying of the request is usually too long. This is because of the many steps involved in interpreting, processing, and reporting. Finally, and the most important of all, if management had not previously specified a similar, if not identical, requirement, the data would probably not be available with which to provide the information (11:565).

The third approach to this information support problem is the "output-oriented" approach. This approach

concentrates on the general outputs needed and attempts to provide the data necessary to produce these outputs. This system requires advanced planning about the general kinds of information wanted and about the input data needed to establish the basic data files. It differs from the "input-oriented" system in that the input data are more carefully selected and may not always be readily available. It differs from the "specific-requirement" approach in that the data are more comprehensive, and the outputs are more general in nature.

Although this third approach appears to be the more advantageous, the main problem with it and the reason it is not used extensively in the present command and control systems is that, currently, no adequate, general-purpose data management and information retrieval system is available for satisfying the requirements of this "input-oriented" or "generalized" approach (41:92; 57:23; 30). Until an acceptable, generalized data processing system is made available, the "specific-requirements" approach will prevail in command and control systems -- and so will its inefficiencies.

#### Information Characteristics

The collecting and processing of data and the presentation of resultant information does not, in itself, insure that the information requirements are being met. Once the general requirements have been determined, the necessary data have been obtained, and an adequate vehicle for manipulating the data and presenting the information has been

established, the system may still provide totally unacceptable information support. This may occur because one or more of the essential elements of information have not been sufficiently satisfied. Those elements are that information should be:

1. tailored to the user's needs
2. in the right amount
3. in the right format
4. considered in the proper time frame
5. presented to the right person
6. understandable
7. cost effective
8. accurate
9. essential
10. usable
11. easily accessible (54:5; 1:272; 56:6; 19:29)

Each individual user has his own personal preferences and his own specific needs for information. Therefore, a standard output format will not satisfy the needs of all users. Information must be tailored to provide the user with his own specific, personalized support.

The amount of information provided is also important. Too little information will result in decisions based on incomplete facts, and too much information will either be ignored or will retard the decision-making process.

Another element to be considered is format. A vice-president of Bell Telephone Company has said:

The information which pours onto management desks has been compared to a daily newspaper printed without headlines, capital letters, or spacing between lines and words -- in effect, an incomprehensible mass and not a message! The vital news may be there, but it lies buried almost beyond human retrieval (50:22).

When information is presented, it must be arranged such that

it imparts the meaning for which it was intended. Information presented in indistinguishable form serves no acceptable purpose.

Information, to be of value, must also be timely. Provided too late, it is of no use. Often, because of the delays involved in requesting, processing, and presenting the information, it arrives after the need for it has passed. Information presented at times other than when it is needed will, in most cases, be ignored.

Insuring that information is presented to the right person is a problem that is often overlooked. Many man-months of time can be spent determining specific requirements, collecting data, writing computer programs, and developing presentation methods only to have the resultant product fail to reach the individual who could benefit from it most. It is not uncommon for lower level staff officers to prevent needed information from reaching the higher echelons. Because of this, the knowledge of many of our senior military officers concerning what is really going on in their organizations is often inaccurate or misinformed (49:222). This is not to say that he should receive all the information available but that care should be exercised in omitting and compiling lower levels of information for his use.

Information must also be understandable. Excessive coding and symbolizing will detract from the information's utility. Heavy pedantic style and the removal of

information from its proper context will probably add a level of confusion to what may already be a perplexing situation. It serves no useful purpose to provide a user with information he cannot interpret or understand.

Cost effectiveness is a term that is often used within the defense structure and applies here as well as in other areas. The value of the information must be considered against the cost of obtaining and processing the data required to produce it (11:573). Economic considerations play an important role in the development of information support systems and, therefore, restrict the amount of data that can be collected and stored. Expensive data and sophisticated processing should provide worthwhile information returns if the system is to be permitted to continue functioning.

Accuracy of information is a goal which should be constantly strived for but which cannot efficiently be completely obtained. Inaccurate transposition of data, physical loss during transmission and processing, misinterpretation within the reporting or processing chain, and stringent time compressions all tend to generate error (56:7). Acceptable tolerances in this error level is a function of the value of the information to the overall mission. Decision makers in command and control systems must, through necessity, make decisions based on less than completely accurate data. The greater the accuracy, however, the greater will be the user's confidence and acceptability of the information presented to him.

Essential information is that information required by the commander and his staff in order to make a decision. There is often a tendency to store and output as much data as is physically possible or to simply extract from the computer exactly the same information that was put into it. The computer should not be used merely as a huge filing cabinet from which to produce mounds of non-essential information (30). Non-essential information contributes nothing to the decision-making process and is therefore irrelevant. Experience has proved that the mere flow of essential information will tax communication capabilities and that the introduction of non-essential information can be expected to saturate it (56:5). A concerted effort must be made to process only that information which relates directly to and supports the operation.

Usable information is that which can be applied to the performance of one or more of the command and control functions. Everything required of the information may be present, but, because of outdated procedures, prejudicial opinions, or plain inability of the information recipient, it may not be applied or included in the necessary decision processes. Usability is primarily a function of management and requires flexible procedures combined with trained, competent users. If the information cannot be applied then there is no valid reason for the information support system to continue to exist.

The last desired characteristic of information is that it should be easily accessible. Unless the information is critical, the user will not bother to obtain it if he must endure complicated or time-consuming procedures, wait an inordinate amount of time, or remove himself from his familiar working area to go to some basement dungeon where the equipment is located. One of the current operational systems states that simple information retrievals may be made by using the standard retrieval programs. When one tries to do this, however, he finds a fifty page book explaining how to use the system and discovers that sixteen punched cards may be needed just to define what is wanted within the system capability. It is doubtful that such a system will be used by other than the most skillful programmer. Likewise, if an individual must wait days instead of minutes for information, he will find ways of operating without it.

If an information system is to be acceptable, all of the characteristics discussed in this section should be understood and strived for. Effective storage, retrieval, and presentation of timely, adequate information are indispensable preconditions to achieving a useful and acceptable automated information support system (54:5).

#### Summary

The information requirements and characteristics discussed in this chapter must be considered throughout the design, development, and operation of any information support system if that system is to adequately and effectively

contribute to the command and control operation. Decision-making requires information. To make the best decision accurate and useful information is required. It is not a question of quantity but of the quality, timeliness, and availability of the information (19:28). The purpose of the information support system is to provide the commander and his staff with adequate information to monitor, assess, plan, and control so that they may determine the best courses of action and make the best allocation of forces and resources necessary to accomplish their mission.

## CHAPTER IV

### COMPUTER SOFTWARE REQUIREMENTS AND CONCEPTS

#### General

Electronic data processing has made vast quantities of information available for today's managers. While much improvement can yet be made in command and control systems, particularly in the automated information support area, a commander and his staff still have more information available to them today than they have ever had in the past. To produce this information, an electronic data processing system, controlled and directed by computer software, is necessary. This software system is defined as the totality of computer programs and routines used with the data processing equipment, data collection equipment, and data display equipment. It includes compilers, assemblers, translators, emulators, programs, and subroutines, as well as the overall operating and control systems.

The purpose of the software system is to permit the storage of large quantities of data, the selective retrieval of specific information, calculations and manipulations of the data to produce special combinations of information, and the presentation of information (55:9). Without such a system, the available data and the computer equipment cannot be put to use. It is the software system that provides the

interface between the user and the equipment and that accomplishes the actual retrieval and presentation tasks. The computer, without an adequate software package to go with it, can do nothing more than stand there and use electricity.

To be effective in a command and control environment, a comprehensive software package designed to meet the requirements of the user is needed. A complete software package will include the following programming and operating capabilities:

1. A basic machine code for direct communication with the computer
2. Assembly programs for converting mnemonic codes and symbolic addresses into basic machine code
3. Macro instructions which generate several additional machine coded instructions
4. A subroutine library which defines standard mathematical and logical operations
5. Generator routines which provide a specific series of instructions based on input parameters
6. An operating system which controls the processing of programs, input and output operations, and overall equipment control
7. Utility programs that provide debugging and housekeeping operations
8. A compiler which translates programs expressed in pseudo-coded instructions into machine-coded instructions
9. A problem-oriented language which is tailored for the specific computer application
10. A query language for direct communication with the user
11. A library of program packages that satisfy specific information requirements  
(11:475)

At present, a great deal of attention is being devoted to developing comprehensive software packages for use in command and control. These new software systems all contain the standard eleven items listed above, but still, none of them provides an overall programming system which can be

considered adequate on the basis of general command and control applicability and wide user acceptance (57:23). Therefore, the requirements and characteristics of an overall computer software package is the subject of this chapter.

### General Operating Requirements

In September, 1966, the Secretary of Defense directed the Joint Chiefs of Staff to conduct a study to define the major requirements for automatic data processing equipment and software for the World-Wide Military Command and Control System (WWMCCS) (52). A Joint Study Group composed of representatives from the Defense Communications Agency, the Defense Intelligence Agency, and the Military Services was formed and conducted the study under the chairmanship of the Joint Command and Control Requirements Group. The general operating requirements, as stated by the Joint Study are:

1. Batch Processing
2. Real-time Processing
3. Multi-programming
4. Multi-processing
5. Remote Terminal Operations
6. Special Security
7. Display Processing
8. Communications Interface
9. Maintenance Diagnostic Software
10. On-line Program Checkout and Debug  
(57:7)

These requirements are derived from present and projected WWMCCS capabilities and indicate the general software needs. Each requirement is discussed further.

Batch processing is the sequential processing of more than one data record by the same program or series of programs. The updating of a data file by processing a series

of cards or tape records, all containing transactions or other update information, is an example of batch processing. In this case, the necessary programs are loaded into the computer, a batch of update information is loaded into the input device, and the entire updating job is run to completion. This type of processing is used when a substantial number of items are to be updated, and when the updating is done on a periodic basis.

Real-time processing, on the other hand, is the processing of data as it becomes available. Instead of collecting all of the update data and then processing it at one time, each individual update is handled separately. This means that if ten transactions are to be added to a data file of stock balances, the programs required to add the transactions would be operated ten separate times rather than just once. Although there are several other definitions of real-time processing, they apply more to weapon systems and to automatic mechanical control systems than they do to command and control. Real-time processing permits continuous operation of a computer and allows several different jobs to be sequentially performed without human intervention. The software system itself automatically loads the necessary pre-stored programs needed to accomplish the job. This type of processing will provide a faster response to demands and will produce a more current data base, all else being equal. The most important point here, however, is that once the data is made available, it is

immediately placed into the system instead of being held until some later time.

Multi-programming is defined as maintaining multiple tasks in an active status with interleaved processing according to some schedule. In multi-programming, several computer operations are kept in an active state. At various times each operation is given control of some part of the computer system until it or another operation is completed, or until a new operation is brought in to replace an older one. Multi-programming results in the capability to conduct several processes, such as computation and input/output operations, simultaneously, with the objective being to keep the computer as busy as possible. This can be done by switching control to another task when one operation is forced to wait for the completion of an activity in some other part of the computer, for example while waiting for a card to be punched or a line of information to be printed. Since input and output speeds are usually slower than the internal processing speeds, the central processing unit is often waiting for the data transfer to be completed. If, instead of waiting, some other operation could be started, the result would be a reduction in the overall processing time. Multi-programming will accomplish this task.

Multi-processing is the simultaneous processing of two or more tasks within a computer configuration consisting of two or more central processing units. The purpose is to simultaneously share the processing load. A multi-processing

capability employs several central processing units, all attached to common storage and input/output devices. In this way, one unit can be performing the input task, and the other can handle the output tasks. The overall effect, just as in multi-programming, is reduced processing time.

It can be seen, however, that multi-programming is primarily a programming technique involving software, while multi-processing is primarily a processor technique involving the equipment. It is possible to combine the two techniques and to perform multi-programming on a multi-processing system. In addition to providing still faster processing speeds, the system becomes more reliable since if one unit fails the system will still be able to operate, although at reduced capability.

Remote terminal operations provide the capability for multiple access to a common computer system. User input/output devices are connected via some communication link to a remotely located computer system. In this way, the user is not required to leave his general work area to make use of the system. Instead, he can communicate with the system and obtain his desired information via a nearby console. Remote stations also permit a means for directly providing update data to a system instead of requiring the data to be handled several times before it reaches its destination. Providing for remote terminal operations will facilitate the operation and acceptance of an information processing system.

A special security requirement is needed to protect certain sensitive information by insuring that only qualified users are given access to it. With several users being able to retrieve information from the system, a special coding or identifying system must prevent the unauthorized disclosure of certain, selected data.

Display processing is another vital part of the software system. With an automated system a large amount of information is readily available. Much of this information must be summarized and translated into graphic, pictorial, and symbolic images for presentation on a cathode ray tube or some other visual display device. The processing of this data for presentation and the control of the display device itself are both operational software requirements. The advantages of automated displays include: reduction of time required to present the information, selectivity of information content and format on a single display surface, several different display units being able to present the same information at the same time, rapid retrieval of information from a large data base, increased capacity for information handling, and a reduced expenditure of resources.

A communications interface between the transmitting and receiving device and the computer system is also required. The exercise of command and control is dependent upon the exchange of essential information between subordinate, lateral, and higher authorities. If this exchange is to be timely and effective, a method must be provided to

quickly pass computer produced information from one command and control system to another. With the Automatic Digital Network (AUTODIN) already transmitting and distributing much of the data used in command and control systems, direct insertion of this data into the information processing system becomes highly desirable.

A system that will satisfy the requirements discussed above will most certainly be quite complex. To manually check each piece of equipment for proper operation would be an impossible task. Instead, the software system must include the ability to automatically check every operation on every piece of equipment and to diagnose any problem. In this way, an entire system can be completely tested when signs of trouble appear.

On-line program checkout and debugging allows a programmer to directly communicate with the computer and to obtain computer assistance in isolating and correcting program logic and coding errors. The existence of such a programming aid will reduce program development time and will help to provide a more error-free system. Generally, the better the program checkout and debug capability, the better the software reliability.

Each of the operational software requirements previously discussed contributes to the effectiveness and acceptability of an overall data processing system. It is, of course, not necessary to satisfy all of the items to have a successful system. Those items which are required depend on the size

and application of the individual system involved. For command and control use, at least for those systems that are part of the World-Wide Military Command and Control System, all of these capabilities are desired. This is not to say that they are all currently available.

### Software Concepts

When developing a software system for information support, one must first establish the general operating philosophy and development concepts to be used. Those concepts which are necessary for effective software development are identified by the terms general-purpose, user-oriented, modular construction, and evolutionary development. These terms characterize the software system and affect its success and acceptance.

If a really successful system is to be developed, a generalized approach is required (30). Present systems operate under one of the two following concepts: special-purpose and general-purpose. The special-purpose system uses the concept of programming each computer product for operational use (hereafter called an operational capability) so that it will satisfy only one clearly defined requirement. This capability is usually programmed in a symbolic or problem-oriented language, thus requiring the services of an experienced programmer and involving weeks or months of programming time. This method of development is most applicable to the "specific-requirement" approach for satisfying information demands as discussed in Chapter III. Its main

advantage is that once a capability is fully developed it can be operated with relative computer efficiency. The disadvantages are: information requirements must be specified in advance and in detail; it requires a relatively long lead-time to develop the program; the capability will only satisfy one specific requirement; and modifications will often require reprogramming and thus start the cycle all over again. In command and control, where requirements are constantly changing and where long lead-times are often out of the question, a special-purpose system may become so enveloped in its own modifications and crash programs that it will require too many people and too much time to satisfy a majority of the requirements efficiently.

A general-purpose system, on the other hand, consists of many small programs, each designed to perform a different general task, and a special executive program to link these smaller programs together and to handle the general overall operations. Each small program may contain hundreds of actual computer instructions. These instructions can be performed by using only the code needed to identify that particular program. In this way, as long as these sub-programs are comprehensive, many programs can be written in minutes or hours rather than in days or weeks. One problem with such a generalized system is that, because of all the control processes involved and the time required to call each individual program into operation, the overall response time has been slow. In other words, it will take longer for the

program to operate. With improved programming techniques and with the faster operating speeds of the new computers, this is no longer a problem, however. The other main problem is obtaining a really comprehensive collection of sub-programs to be able to perform all of the tasks that might be needed. This is really a continual problem since, as people use the system, new requirements are constantly being identified. The answer is to initially develop a good basic system and then to add these additional sub-programs as they are identified and developed.

To obtain the desired acceptance and use by the staff, the system must also be user-oriented. That is, it must be geared toward the requirements of the user and must be able to assist him in obtaining his required outputs. It must be remembered that the user is not specifically interested in the internal workings of the computer or in its sophistication, but in the solution to his problem and response to his need for information (55:12). If remote stations are to be used and if the staff officers are to communicate directly with the equipment, then the software should not be designed only for experienced programmers and should not be so syntactically rigid that mounds of rules must be remembered. Computer programs must often be adjusted to individual personalities, and the user should be able to make the minor adjustments and develop the more simple queries himself (30). This requires a flexible and comprehensive conversational level language with which the staff user can communicate.

In a panel discussion on future computer systems at the 1965 Fall Joint Computer Conference, Mr. Tom Steel of the System Development Corporation said:

One thing we don't need is the FORTRAN compiler or the PL/1 compiler. We must have some much simpler, problem-oriented language -- more like the kinds of languages, notations, etc., that the user ordinarily employs. . . . We haven't attempted to integrate the various techniques that are available for solving problems. We do not have systems that have a simple, quick calculation mechanism coupled with a data file retrieval system. . . . But there is no really good reason why, with careful design and thinking ahead, it isn't possible to put these things together into a comprehensive package (41:92).

FORTRAN, COBOL, ALGOL, PL/1, NIPS, and many other "problem-oriented" level language systems do not provide adequate user flexibility or interface to satisfy the need in command and control systems. They may satisfy specific requirements, given enough lead-time, but they cannot satisfy the overall, long-term requirements necessary for an effective system. Two civilian corporations, the System Development Corporation and the MITRE Corporation, have both tried to develop new languages to satisfy this need. SDC has developed LIGHTNING and JOVIAL-3, and MITRE has produced C-10, ADAM, and AESOP. While each programming system contains several worthwhile concepts and approaches, none of these languages has been, or does it appear likely that it will be, accepted for operational use in command and control. One of the reasons for this is that once development work started, it was continued in a theoretical environment instead of in an actual operational one. Consequently, the

technicians began having more to say about the language characteristics than did the intended users, resulting in a product that lost much of its originally intended user-orientation. The most promising computer language system for command and control presently being developed in an actual operational environment is the Computer Control Language (CCL). It is currently used by the United States Strike Command and the Naval Command Systems Support Activity and appears to be more successful in user participation and acceptance than have past systems. Unfortunately, support is limited since both organizations are using IBM 1410 computers, which do not have the speed, capacity, or peripheral equipment necessary to provide truly adequate support. The concept of operational development to insure effective user orientation and operation is still a valid one, however, and should be encouraged on a larger scale with more up-to-date equipment. It is unlikely that anyone will develop an acceptable, effective system from theory alone. A programming system may be technically efficient and theoretically correct, yet still be operationally inadequate for one reason or another. Both practical user application and technical considerations are necessary in order to guide the development of any operational software package.

Another important concept in software systems is modularity. A modular system is one that contains several different programs or groups of programs, each performing a certain function, upon which the system is built. In this

way, individual program modules may be added, removed, or modified so that growth and technological change may be accomplished. The need for continuous modification and extension of the system as a result of new requirements and experience must be anticipated in the design.

Closely related to modularity is the concept of evolution. An evolutionary system is one in which new designs or techniques are incorporated into the system as they become feasible and applicable. A modular design will greatly enhance this evolutionary development. Many systems have gone out of use because they did not or could not keep up with the latest programming techniques and capabilities. Time-sharing, for example, is a new programming technique that must be incorporated into present systems if they are to continue to be used. If this cannot be done, then a new programming system will eventually replace it. For a software system to serve the needs of a command over an extended period of time it must have sufficient flexibility and adaptability so that it can evolve in an orderly fashion to satisfy the changing requirements.

#### Language Levels

In computer software there are four general language levels. They are the machine level, the symbolic level, the problem-oriented level, and the conversational level. Each has its purpose and use in a computer system.

The machine language level is the lowest and most exacting of the language levels. It is this language which

the computer "understands" and which causes the many different computer operations to take place. All other language levels must be reduced to machine language before any computer action can occur. This language is also often called the object language. When computers were first developed all programming was done at this level, but, because of the tediousness and time required, another language level -- the symbolic level -- was developed.

Symbolic programming is the second language level and is often called the "intermediate" or "mnemonic" level. At this level, the programmer can use symbols in place of actual machine instructions and addresses. The computer, acting under the control of a previously written machine language program, can then translate these symbolic instructions into actual machine coded instructions to perform the desired operations. It is possible for one symbolic instruction to generate a whole series of machine instructions. This kind of symbolic is called a "macro-instruction" and is the type generally used today. Through the use of symbolics, programming becomes much easier, and fewer instructions are needed. The translator program will automatically convert the symbolics into as many machine coded instructions as necessary. This symbolic language, however, consists of many codes and includes many rules for their use. It still requires thorough training before an individual can become proficient in its use.

To further reduce this level of detail and amount of training needed, still higher level languages -- the problem-oriented languages (POL's) -- were developed. At this level, the language itself is conceived in terms of the problems to be solved and the results to be obtained instead of in terms of technical features of the computer. Standard examples of this kind of language are FORTRAN for mathematical problems and COBOL for business problems. Each is specifically tailored for expressing and solving its own general class of problems. To convert these procedure-oriented programs into machine coded instructions, a process known as "compiling" is accomplished. In this process a group of programs written in symbolic language converts each of the "high level" terms into a series of symbolic codes which are, in turn, translated into the machine language. This language level is the one used most often in today's larger programming systems. It provides a relatively low lead-time for program development and reduces still further the level of detail and training required.

In most programming environments the problem-oriented language is adequate, but in command and control two problems exist. First, the programs must be written, punched, and compiled before they can be operated. Second, there is no adequate, simple interface between the computer and the staff user. For these reasons, a fourth language level -- the conversational level -- is needed. This conversational capability, if it is comprehensive and flexible, will:

allow bilateral conversation in terms the user can understand; require little or no special training of the user; provide the user with constant and adequate feedback regarding the formulation and solution of his problem; allow the user to be "on-line" and to interact via his own remote console; allow user-input data to be stored on-line; assist the user in the formulation as well as the solution of his problem and permit him to concentrate on solutions and decisions rather than on system mechanics; and, as much as possible, isolate the user from the many details of the computer software system (41:90). Clearly, good conversational programming software, when added to an adequate problem-oriented language, can greatly improve the capability of the command and control system.

#### Summary

Computer software is the vehicle through which the computer provides the commander and his staff with needed information. To be effective, a software system should embody the feature of general-purposeness, be oriented toward the user, and be modular and evolutionary in its design and development. It should have a wide range of applicability and flexibility with respect to the types of data it can process and the operations it can perform on that data. It should also allow for growth and extension as better understanding of requirements is obtained and as experiences with its use dictate. It should be built with the user in mind and should not only be adapted to the user's specific needs but

also be easily changed as those needs change. Finally, it should be a system that not only includes a problem-oriented language for satisfying low lead-time off-line programming of the more complex problems but also includes a good conversational programming capability to allow on-line user queries and programming of the more simple everyday requirements.

## CHAPTER V

### SYSTEM DEVELOPMENT

#### General Development Principles

An operating command and control system is a complex combination of people, procedures, and equipment. It is "the commander and his staff plus all of the facilities, equipment, and management tools that serve the commander's purpose" (28). It is a dynamic, ever changing system in which new requirements are constantly being identified, new techniques and procedures are often being implemented, people and personalities regularly are being moved from position to position, and new objectives and mission requirements are frequently being introduced. Command and control is a highly objective process which cannot always be precisely predicted or planned (24). It is not a puzzle in which each piece neatly and clearly fits.

There is a popular myth that an organization has a fixed set of objectives, that, once these objectives are made explicit, the work of the organization can be structured in a rational way and the organization can then accomplish its task. There is some truth to this at the lower organizational levels. . . . At the higher levels, however, it is certainly not the case. The inseparable activities of structuring the situation and clarifying objectives constitute the essence of the activities of the higher headquarters. Although the functional specialists make unique contributions and permit the

efficiencies of parallel information processing, the various staff offices cannot work apart as if the overall task were set beforehand and could be accomplished by the assembly of various pieces (57:71).

The traditional approach to developing automated command and control systems has been to identify what management needs (or says it needs), collect the data required, and program the computers to supply the information in a series of standardized reports. This is a process which, if applied to the entirety of an automated system, could involve an elapsed time between the initial analysis and the finished products of up to three or four years (3:41). Of course, this method of development can be applied to a portion of the system. The more complicated and standardized type of information requirement can be satisfied by this procedure. These capabilities, however, constitute only a part of the required computer output. There are other relatively uncomplicated day-to-day requirements that must also be satisfied. These requirements, because of their constantly changing character and rather short reaction times, need a different development approach. The traditional approach requires just too many people and takes too much time to be responsive to all the needs of a command. Command and control systems are often not effective because there are just too many people trying to accomplish the job in too long a time (31).

In particular, our command and control systems are not responsive to the rapidly changing environment, capabilities and objectives of the user. In fact, the principal result of all the

push in command and control to date is the proliferation of organizations inserted between the ultimate user and his computer. There is the EDP office of the using command, his counterpart in the procuring command, the system monitors, the contractor's project office and finally the programming and design people. It is in the interest of each of these offices to seal the system requirements years before its operational date and see to it that the most efficient -- and thus necessarily the most immutable -- configuration of programs and equipment are provided. For example, soon after the initiation of one of the Air Force systems, it became evident that the requirements stated in the request for proposal (by then 15 months old) did not take cognizance of their user's trends and plans for reorganization. The system contractor duly recommended a rather complete reorientation in his effort. Not only was this recommendation ignored, but 10 months later, 6 months after a reorganization of the user that made the work statement obsolete, the system contractor was required to deliver a detailed systems design and establish by detailed analysis that it filled, but did not go beyond, obsolete requirements of a nonexistent organization (49:226).

A development approach must be used that will permit both long lead-time development of the more complicated capabilities and quick reaction to the more immediate needs. A system must not be permitted to become so immutable that it fails to satisfy the requirements of the users. It also must not become so complicated that only skilled engineers and technicians can operate or expand its capability. The system must be designed to satisfy the needs of the commander and his staff and to permit them to make the changes they deem necessary.

Before establishing a development procedure, it is necessary to identify some of the problem areas of today's

systems. Generally, these are:

1. Overall responsiveness to changing requirements
2. Inability of the user to adequately communicate his requirements to the programmers
3. User accessibility to the computer and its products
4. Availability of data
5. Trained user personnel
6. Acceptable computer outputs (32; 34)

These problem areas must be considered when developing or modifying an automated system. They affect both software and operational capability development procedures and are discussed throughout the remainder of this chapter.

The development of an automated information support system for command and control should be viewed as modifying or augmenting an existing system and not as establishing a whole new system about which all else revolves (74:1.3). There are three basic principles which appear to be accepted for effective command system development: first, system growth should be evolutionary and should take place within the context of the using command; second, user participation is essential throughout all phases of system development; and third, compatibility of data and programs among subsystems of the World-Wide Military Command and Control System is desirable (74:1.2).

An evolutionary approach is one in which modifications and new capabilities are introduced into a system as they are developed or needed. They do not represent a great departure from the existing system but are closely related in concept and approach (38:334). Evolution is a gradual but constant change of methods and capabilities and provides a

feasible answer to continued development (67). Systems must be able to change if they are to continue to satisfy the needs of the user.

All too often, though not universally, the manager is confronted with report formats that he may have agreed to, reluctantly, two or three years earlier. He has changed his requirements in evolutionary patterns and will continue to change as his grasp of the job improves or as the area he controls undergoes change. He cannot use what the computer now spews out in great quantity at frequent intervals, and his requests for different reports are met by shocked references to reprogramming costs or by promises that the changes can surely be made within the next year if all goes well (3:41).

System development is a long, evolutionary process involving persistent work, in a never-ending cycle, on the part of both users and technicians (17:77). Evolution must be accepted and understood by the users and must be made possible and economical by the technicians if changing requirements are to be effectively satisfied.

The principle of user participation tends to reduce the number of unacceptable computer outputs, improve communication of requirements, and automatically provide some of the needed user training. Users do not normally care about the equipment or procedures; they simply want results. The system, therefore, must meet the demands of the users (11:214). To do this, staff personnel, by means of an active development process, must be included in the development of the system. For the computer to be effective in the decision-making process, management must provide the rules (53:VI-2--VI-3).

In brief, only command/management can circumscribe valid management information systems requirements in the ultimate sense. It alone sets and modifies the basic objectives of the enterprise. It originates the ultimate decision rules; evolving its priorities, its weighted values, and its critical thresholds of responsible interest. It operates as the supreme court of appeals with respect to resolving conflicts of interest. . . . Finally, it evaluates the effectiveness of the total enterprise, and makes new decisions accordingly. . . . It is vital that they be aware of the system's potential; keep abreast of, guide, and encourage its development; and, above all, provide the vision of the ultimate objective and the impetus for attaining it (53:VI-3).

The users of the system must determine the requirements and guide the development of each capability necessary for operational support. If these tasks are left to the technicians alone, and the intended users do not participate, then adequate operational support will most likely not be provided.

The last principle to be considered for effective development is that of compatibility among systems. The World-Wide Military Command and Control System is comprised of several individual sub-systems. These sub-systems are primarily the command and control systems of the major service commands and the different unified and specified commands. Each of these, while certainly having different missions and objectives, have many common data and software requirements. Because of these many similar requirements, compatibility between systems would permit a greater capability than would be possible if each system were totally different. This is not to say that each system must be identical. Each may be unique while still being sufficiently standardized to provide for compatibility of data

and software capabilities (66). In this light, common software becomes much more important than common equipment (71). If a common programming system is used by the different command and control systems then much of the needed compatibility is automatically provided. Use of the same equipment, however, simply guarantees a physical compatibility since different programming systems may still be used. Compatibility among systems can best be provided by establishing a common, basic, modular set of computer programs and operational capabilities and then permitting each participating command to tailor the system by adding the other programs and capabilities it requires. This could be done as long as the integrity of the basic system were maintained. This concept is currently being used with the Air Force Integrated Command and Control System (51). Unfortunately, the AFICCS system appears to have been designed primarily by and for the computer specialist rather than the commanders and their staffs. There is currently no adequate problem-oriented or conversational level language included in the system, thereby reducing evolution and user-participation to the point where the system generally becomes ineffective. The concept, nevertheless, still appears valid.

The development of an effective command and control system is a complicated process in which many of the objectives and needs cannot be identified beforehand. In addition, the system must be responsive to continuously changing requirements, the users may not be adequately trained

to operate the system or converse with the computer specialists, needed data may not be available in a readily usable format, and management may not fully understand or support the development effort. To overcome these obstacles, it is necessary to adhere to the principles of evolutionary growth, user participation, and inter-system compatibility.

#### Overall System Characteristics

The effectiveness of a computer system is based on its design and operation. Those characteristics which can be associated with an effective system are: simplicity, flexibility, reliability, and acceptability (15:104-105).

The keynote to user acceptance and use is simplicity (30). An effective system does not have to be a complicated one. The more rules and restrictions involved in system operation, the better the chance for error. A simple system will enhance the learning process and will make the overall operation more efficient. There is often a positive correlation between simplicity and reliability (15:105). When operating a system, the user should only be concerned with what helps him solve his problem and not with rigid syntactical rules or technical limitations (41:91). In short, the system must be simple enough for the user to understand how to operate it and how to obtain useful information from it.

One of the most discouraging situations that can arise in a newly developed system is to discover that an initially specified requirement is subject to minor modifications and that the effort required to make these changes is almost as

great as the original development. The result is that the system capabilities often appear inadequate to the user's needs (20:3-4). To provide this needed flexibility, operational capabilities should be written in a problem-oriented or a conversational level language. In fact, a good conversational level language is, in itself, one of the more flexible of programming tools. The system must be flexible enough to allow minor modifications to be easily made by those who desire them.

Systems must also be reliable. Once a user has learned to operate the system, he must receive consistent results and standard performance. When new capabilities are being developed, unexpected or irregular performance may occur. Even though the system is in a constant state of flux due to the evolutionary process, every program must be tested thoroughly to insure a consistent, reliable operation. Many potential supporters of a system have been lost because of embarrassing and unexpected system performance.

Any system, regardless of its sophistication or design, is worthless if the intended users will not accept or operate it. The users must feel that they can benefit from the system and that it is worth their time and effort to try to understand it. If they don't think it is worthwhile, if they are pressured into using it, or if they are simply opposed to it, the system will not work. This is why it is so important for user-participation to be a part of the development process (15:106). An effective automated information

support system is one that is simple, flexible, reliable, and otherwise generally acceptable to those for whom it was intended to be used.

### The Development Process

In developing an automated information support system, one must guard against too ambitious an undertaking. Many little things can be done first to gain the user's confidence and to establish rapport and interest. After the user has accepted the system to some degree, the larger, more complicated capabilities can be attempted (42:53; 32). Regardless of the complexity or time involved in developing a capability, some sort of plan should be developed so that everyone within the command can be aware of what is being attempted and how long it will take. One approach for accomplishing this task is the operational capability plan (OCP) produced by the United States Strike Command. The plan includes a pictorial diagram of capabilities currently available in the system, a list of the program modules included in the programming system, descriptions of new operational capabilities and basic programming system extensions nominated for development, manpower estimates to accomplish each task, and the names of the staff users and computer specialists doing the development. Because of an active evolutionary process, a new OCP is produced every six months. This six month OCP cycle is a good vehicle for development since the staff can understand what is being accomplished, and developers can implement most of the items (24).

A basic requirement for orderly system development is a good development plan coupled with workable development procedures. To satisfy this requirement, it is necessary to be familiar with both the different types of development and the development cycle. Within an information support system two types of development are necessary. They are the development of the basic program set (BPS) and the development of operational capabilities (OPCAP's). Each will be discussed after presentation of the basic development cycle.

#### The Basic Development Cycle

The basic development cycle as shown in Figure 3 includes the stages of:

1. identification
2. validation
3. approval
4. specification
5. programming
6. testing
7. documentation
8. training
9. acceptance
10. use
11. modification

This cycle assures that each new capability or modification is supported by actual requirements, developed in the proper context, and integrated into the system without a negative effect on other operational areas.

Identification of specific requirements must emanate from the user. Trying to second-guess the needs of a user is a hit or miss proposition that usually misses. If the user cannot determine what his information requirements are, then he is not ready to make use of the system anyway. Users

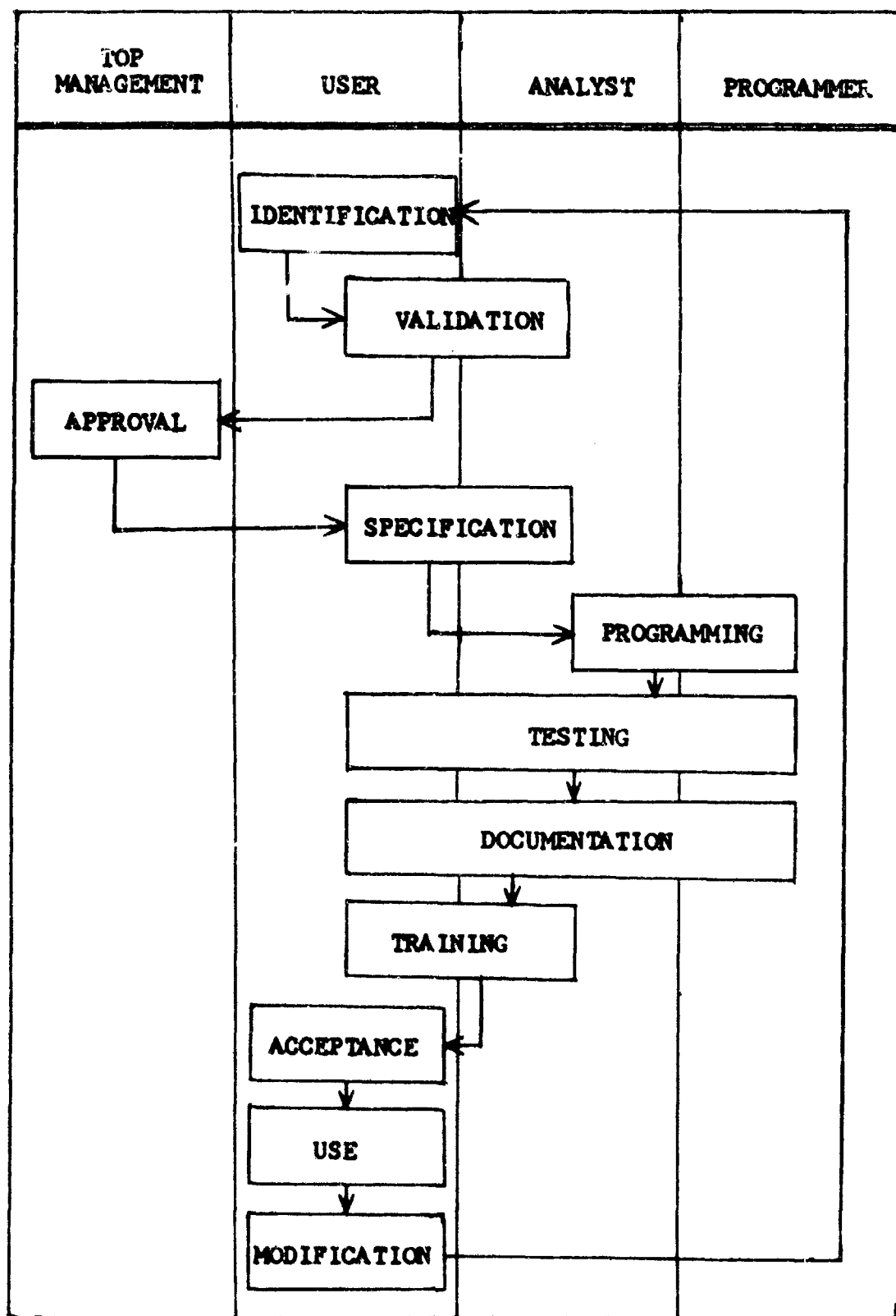


Fig. 3. The Basic Development Cycle

are funny people; they will only use what they want. A major problem today is the lack of understanding by many of the staff as to what command and control is and just what information support systems are supposed to do. All staff officers have information requirements. If they are not being identified then there is something wrong with the system and not with the users.

Validation of a user's requirement is an important step in the development cycle. Before work is actually started on satisfying the requirement, it should be determined that the user has not misstated his requirement or misinterpreted some directive or policy and that the capability for satisfying it is not already available. Of course, this must be done carefully so as not to antagonize the user. To prevent manpower from being expended on the development of a capability that is not really needed or that is already in existence, validation of the requirement must first be accomplished.

There may often be more requirements than there are people available to satisfy them. In order to reduce inter- and intra-departmental problems if this situation exists, top management should assign priorities and select the requirements to be satisfied. To each user, his requirements are the most important. Only higher level management can determine what should be satisfied first, establish priorities, and provide the approval to complete the development cycle.

The next step is to specify, for those who will be accomplishing the actual programming, just what is needed and what procedures are to be followed. The detail of this specification will depend on the complexity of the problem and on the programming level used. It may be a specification involving fifty or more pages that have been closely coordinated among many staff or using organizations, or it may be a simple one or two sentence statement involving a minimum number of people. In either case, care should be taken to avoid over-specifying or under-specifying the requirement.

Programming is the logical combination of instructions to permit the computer to perform the operations necessary to satisfy the requirement. It may be done by the user himself, with a problem-oriented or a conversational level language; it may be done by a highly skilled systems programmer using symbolic or basic machine code; or it may be done at any level between. The language level used and the type of programmer involved, once again, depend on the complexity and the type of program to be written.

Once the initial programming has been done, those responsible for developing the capability must test it to see that the program performs satisfactorily. It must provide proper results, be sufficiently responsive, and satisfy the requirements of both the user and the software system. If any of these conditions are not met, then re-programming is necessary. This programming and testing sub-cycle should

continue until the desired product is obtained.

Once it is determined that the program is providing satisfactory results, it must be properly documented. This is necessary for proper program maintenance and capability operation. The detail and type of documentation should be in consonance with the program specification. Documentation is one of the most troublesome problems in today's systems. There is either so much of it that it loses its perspective, or there is so little that it satisfies no one. This is usually the result of an organization having only one documentation format and not realizing that there are many different types of documentation necessary. Each document must be oriented toward the needs of the intended recipients, be they top management, staff users, system developers, analysts, or programmers. Each requires a different format and a different level of detail. No one document can satisfy the needs of all.

Training the user personnel how to obtain needed information is a vital step to system effectiveness. Staff personnel must not only know what is available to them but also how they may obtain it. Of all the problems in command and control development, lack of staff training has been mentioned more than any other.

The major problem in command and control is the lack of staff training and experience in automated systems. It is a failure to see the whole picture and to realize that requirements are different at different levels (33).

A substantial investment is often made to develop a capability, and then, because of the lack of training, you find yourself in need of someone who knows how to use and apply it (30).

The major problem in a command and control system is the lack of knowledge of the staff (31).

The biggest problem in command and control systems is the lack of training. High ranking officers are not aware of what the system can do or of just what is available to them (25).

To improve our command control systems we must have more staff training (28).

Clearly, the training phase of the development cycle is one of the more important and critical ones. The most comprehensive and sophisticated system of all may be available, but if no one is trained to operate it, it is of no use.

The initial development effort ends with the formal acceptance of the capability. Final acceptance should be accomplished by the people who will be operating the capability once it becomes a part of the operational system. Completion of this step removes the capability from the development category and places it in an operational status. If for no other reason, this step informs potential users that the capability is now available for their use.

The use phase is simply that period in which the capability is satisfying a requirement for one or more users.

After a period of time, an operational capability or program, because of changing requirements or techniques, may no longer fully satisfy a user's requirement. At this time, modification or revision of the capability may be needed.

The user identifies what should be changed, and the development cycle begins again. It should be noted that modification does not include the maintenance of a program that is not functioning correctly. Program maintenance is performed on an exception basis and does not constitute part of the development cycle.

Each of the steps in the development cycle need not necessarily be accomplished separately or in the same level of detail. The actual development process will, of course, vary from situation to situation. This development cycle is, however, a good general guide. Further discussion on computer software and operational capability development follows.

#### Computer Software Development

Of the four different language levels used in an information support system, only the two highest levels -- the problem-oriented and the conversational levels -- are subject to development by the using command. The machine and symbolic levels are more computer oriented and should be developed by the computer manufacturer (30). It is not necessary that the initial development of a higher level language be accomplished by the user, but he must be able to modify the language whenever new requirements dictate. In this case, a programming language specialist should perform most of the functions in the development cycle. It is he who can best determine what additional programming modules or modifications are needed to provide a more responsive programming

system and, consequently, provide better staff user support. He must, however, receive feedback information from the language users. The computer programmers, since they perform most of the problem-oriented level programming, can best identify the deficiencies and required modifications in the problem-oriented language. The staff users, on the other hand, can indicate areas for improvement in the conversational language. The language specialist can then, in view of the intricacies and interrelations of the total programming system, determine the best technique and approach for accomplishing the task. Computer software development should follow the basic development cycle except that most of the functions are performed by a specialist in the programming language system.

#### Operational Capability Development

There are four different kinds of operational capabilities, each requiring a somewhat different method of development. These capabilities are:

1. Standard Periodic Reports
2. Pre-programmed Parametric Capabilities
3. On-line-developed Capabilities
4. Simple Query

Standard periodic reports are those capabilities which provide results in exactly the same format by using exactly the same procedures each time they are operated. With the possible exception of a computer operator, once it has been indicated to the computer that the report is to be produced, no further human intervention is necessary. Examples of

this kind of report would be a standard status of forces report, a standard aircraft availability report, or a standard list of personnel currently assigned to the command. In developing this kind of capability, the basic development cycle can be used except that the training phase may be de-emphasized if not eliminated. This capability is the least flexible of all but is also the most automatic. When exactly the same reports are being requested time after time, this type of capability is the most efficient.

The pre-programmed parametric capability differs from the standard report in that several options and/or parameters are included. For example, several different output formats may be available, and different procedures or data items may be selected. In this case, the user must indicate precisely what options he wants performed and what parameters he wants used. To do this, the user must be thoroughly trained in the operation of the capability and be familiar with the different options available. This type of capability provides greater flexibility when compared to the standard report but also requires more human intervention. The basic development cycle is most applicable to development of this kind of capability.

A third type of capability is the kind that is developed on-line. The user communicates directly with the computer and, with the assistance of the computer software system, proceeds from logical operation to logical operation until he has obtained his desired output. A comprehensive

and effective conversational language is needed if on-line capabilities are to be developed by the user. Once the user can directly "converse" with the system and make his requirements known, he need not go through a series of middle-men before he obtains his desired information. In this situation, the development cycle is accomplished wholly by the user, working in conjunction with the software system. The user will train himself as he operates the system and will automatically be informed of what is available to him. The ability to develop on-line user capabilities can contribute much to system acceptance and user understanding.

The last type of capability is the simple query. Once a user becomes familiar with the language and operation of the system, he can simply enter one or two sentence-like statements via a console of some sort and receive the desired output. This differs from on-line development in that, first, the language used is more problem-oriented than it is conversational; and second, a complete statement of what is to be done is entered at one time rather than in small logical steps. A simple query capability is oriented more toward basic information selection and retrieval than it is toward data manipulation. As in on-line development, the development cycle is performed wholly by the user.

These four types of capabilities, if available in an automated information support system, should provide enough flexibility and responsiveness in the development process so

as to improve the overall adequacy and effectiveness of the command and control system.

### Summary

Satisfactory development of an information support system cannot be accomplished in the same manner as development of a weapon system. The "turn-key" approach cannot be used. Computer technicians working independently of the commander and his staff often cannot fully appreciate the pressures or operational situations involved. The commander and his staff, on the other hand, are reluctant to make changes in their operations until they are satisfied that the changes will be to their benefit (43:8).

The crucial problem in the development of an information support system is the maintenance of a relevant, consistent, and valid context within the command and control environment (49:229).

The system must be the staff's system, not a universal system, not a standard system, but one that is recognized as what it is, inconsistent with all others, to a degree irrelevant to all others, and thus free to be responsive to the sense of relevance of its staff, the purpose of its commander and administrator. . . .

This is a very different kind of system than the great data systems and automated control systems. It is a system that allows direct access in natural language, it is a system whose files and formats, whose inputs and vocabulary are always changing, continuously changing (49:229-230).

System development is a function of both the computer programming system and the operational capabilities. It must be evolutionary, be oriented toward the needs of the

user, and have at least enough commonality to be compatible with other similar systems. It involves both technical and operational considerations and must be a joint effort among all members of the commander's staff. System development must include people, procedures, and equipment and must enhance the ability to provide meaningful information when and where it is needed.

## CHAPTER VI

### CONCLUSION

Command and control is not a new concept, but the present methods, procedures, and technology are. The system is not simply a collection of programs and equipment; rather, it is a carefully planned and organized arrangement of the commander, his staff, and the means by which they obtain information necessary to accomplish their mission. The system is not personnel, equipment, and procedures taken separately but is an integrated, flexible combination of all staffs and their activities. It must serve the needs of the staff as they support the commander and must provide timely and accurate information for the decision-making process.

The main objective of an automated information system is to support the commander and his staff in monitoring, assessing, planning, and controlling. Effective command and control revolves around these four general functions. Adequate performance of these functions requires both information and the men to make use of it. No information system can by itself insure efficient management or valid decisions. It can only support the functions of command and control through application by a knowledgeable user.

Information requirements are constantly changing. Therefore, to provide adequate information support, the

system must be responsive to new demands, be comprehensive in its capability, and must provide a wide range of user options. This requires a software system that is evolutionary, flexible, and user-oriented.

Development of a computer assisted information support system for command and control is a continuing process involving both the user and the technician. It is a process in which both the operational outputs and the computer language undergo frequent changes. It is these changes that affect overall system performance and acceptance. For this reason, the computer software system plays a more important role in providing information support than does the equipment itself. The first hypothesis -- that the computer programming system has more effect on overall system performance and acceptance than does the physical computer equipment -- must be accepted. The software system permits the user to communicate with the equipment and to express his information requirements. It is the vehicle through which raw data is processed and converted into meaningful information in support of the decision-making officers.

The second hypothesis -- that to be effective, an automated command and control system must be developed in an operational, evolutionary environment and not in a static, theoretical one -- must also be accepted. Because of the constant change of requirements and the need for user acceptance and operation, systems must be developed within the context of the using command. Each system must be tailored

to satisfy the individual needs of its command. This requires that the system be developed by and for the users.

The final hypothesis -- that definitive, detailed information requirements must be clearly stated before successful development of an automated command and control system is possible -- cannot be fully accepted. The requirement for detailed specifications diminishes as the degree of on-line user development increases. For the more complicated, standardized requirements, detailed specifications are certainly needed, but for the more simple, user developed capabilities, they often are not. The amount and degree of requirements specification needed is a function of complexity, development methods, criticality, and desired immutability.

To develop an effective, acceptable automated information support system, it is necessary to combine men, programs, and equipment in an evolutionary environment for the stated purpose of enhancing the decision-making process and for providing adequate information in support of the command and control functions. This development must take place in an operational environment and must be accomplished by the personnel who will use the resultant products. In this way, development of computer assisted information support systems for command and control will provide the commander and his staff with an efficient and effective tool for accomplishing their planned missions and objectives.

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| 13. ABSTRACT<br>The objective of an automated information system is to support a commander and his staff in the command and control functions of monitoring, assessing, planning, and controlling. Information requirements are constantly changing. Therefore, to provide adequate information support, an automated system must be responsive to new demands, be comprehensive in its capability, and must provide a wide range of user options. Development of such a system requires that the using staff officers participate in the development effort, that development be conducted in an operational environment, and that the programming system be general-purpose, user-oriented, evolutionary, and modular.<br><br><u>Key Words:</u><br><br>Command and Control Information System<br><br>Information System |  |                                                                                |                 |

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