AD NUMBER
AD463574
NEW LIMITATION CHANGE
TO Approved for public release, distribution unlimited
FROM Distribution authorized to U.S. Gov't. agencies and their contractors; Administrative/Operational Use; MAR 1965. Other requests shall be referred to Office of Naval Research, Arlington, VA 22203.
AUTHORITY
ONR ltr dtd 4 May 1977

UNCLASSIFIED

AD. 463574

DEFENSE DOCUMENTATION CENTER
FOR
SCIENTIFIC AND TECHNICAL INFORMATION

CAMERON STATION ALEXANDRIA, VIRGINIA

UNCLASSIFIED

SSD65-175(434)

Final Report

A STUDY OF METHODS FOR THE QUANTITATIVE ANALYSIS OF TRAINING REQUIREMENTS IN STRATEGIC COMMAND AND CONTROL SYSTEMS

March 1965

Submitted to:

Naval Analysis Group
Office of Naval Research
Department of the Navy
Washington, D. C.

In accordance with
Contract No. Nonr 4168(00)

Dunlap and Associates, Inc.
Darien, Connecticut

Final Report

A STUDY OF METHODS FOR THE QUANTITATIVE ANALYSIS OF TRAINING REQUIREMENTS IN STRATEGIC COMMAND AND CONTROL SYSTEMS

FOREWORD

This report summarizes a study that was initiated in June 1963 and completed in December 1963. The study was sponsored by the Office of Naval Research, as part of a program to develop training requirements for complex strategic command-control systems. Such systems make demands on Naval officers which are somewhat different from other aspects of Naval service, and their exploration is important if the full potentiality of modern technology as applied to command-control is to be exploited. The study itself was concerned with the application of quantitative methods to development of such training requirements. Quantitative methods exist, and have been used successfully on a variety of Naval systems. The object of the study was to test these methods on strategic command-control systems, and, if they were not useful, to attempt to modify them or extend them, or to suggest substitutes for them.

In the conduct of this study essential guidance and data were provided by many persons in the Navy. The following were especially helpful in providing direction and constructive criticism: Mr. Ralph G. Tuttle, ONR - Project Scientific Officer; Capt. John C. Hill, II, OpNav 35; and Capt. William Laliberte, OIC FOCCLANT.

TABLE OF CONTENTS

A Study of Methods for the Quantitative Analysis of Training Requirements in Strategic Command and Control Systems

I. OBJECTIVES OF THE STUDY

Command and Control of Naval forces to accomplish specified missions is a basic function of any Naval unit. It underlies the operational functions and provides the necessary guidance for effective utilization of the operational capability. Command and control increases in complexity with the size of the unit being managed and with the complexity of the environment in which the unit is operating. This complexity can be conveniently thought of in terms of the amount of information that is pertinent to command. Large units operating in large, complex environments force upon the commander large quantities of interrelated information for his consideration in every decision. This has led naturally to the adoption of mechanized techniques for handling information and the burgeoning technology of data handling has made available faster and more varied means for information handling. Thus, it has become feasible for strategic commands to cope with an amount of information not before possible and to process this information in ways that heretofore have been only approximated if attempted at all. These information handling systems are, however, only tools to be used by command personnel; they do not replace any command function, they only support it. Like any tool they are effective only when the user understands and can manipulate their capabilities. A special class of training needs exists, then, at the interface between command personnel and the information handling systems that can be provided to support them. Command personnel must establish an effective partnership with these systems to exploit current capability as well as to direct the future development of the systems. The required man-system partnership is of course developed by training and the establishment of objectives and criteria for such training is a critically important task for the system planner.

Traditional techniques for analyzing training requirements appear to be less than optimum for this application because of their emphasis on task (rather than total system) output and especially because of their common lack of quantification. Recently, quantitative techniques have been developed to clarify training objectives, criteria, and priorities in weapon systems. The objective of this study was to determine whether these techniques could be applied to strategic command and control systems and, if not, to determine if new or modified techniques could be suggested. If such techniques could be developed they would be valuable aids in reaching timely and effective decisions in the utilization and allocation of training resources.

II. APPROACH

The approach to this study was essentially an empirical one. A sample of strategic Naval command operations was assembled in a logical model to reflect future utilization of automatic data processing and this model served as the vehicle for assessing the pertinence and value of quantitative analytical techniques. The model was derived from the Navy planning document NWP 11 (ref. 2)* and from a direct examination of the CINCLANFLT OPCON CENTER. The application of automatic data processing to the model was based on the experience available to the contractor from work on such systems as the Air Force's 473L and 433L systems.

Concurrently with the categorization and exploration of the nature of modern command control systems at the strategy level was an appraisal of the possibilities of quantification and analysis, and the extent to which it was capable of describing the real world.

To summarize, the approach consisted of three closely related, often parallel, efforts:

1. The development of a model strategic command-control system, to serve as a test bed for any quantitative methods suggested.

2. The consideration of the extent to which quantitative, analytical methods of any kind could truly guide training for strategic command-control systems.

3. The test of existing methods and development of modified methods for the analytical development of training requirements.

The results of each of these steps are presented in the following sections of this report. There is a discussion of results from each step which is followed by a presentation of the conclusions and recommendations generated by the study.

*References are listed in the bibliography at the end of the report.

III. DISCUSSION OF RESULTS

A. A Representative System Model

In order for this study to develop logically it was necessary to establish early in its progress a description of the command and control processes that were to be the subject of the study. As noted in the description of the approach this was accomplished by reference to Navy Planning Documents and observation of the CINCLANTFLT OPCON CENTER. The resulting system description presents a representative sequence of strategic command activities as they would be performed utilizing automated data processing in the near-to-middle future (i. e., 1970).

The description, which follows, consists of a summary of the functions of the system, a description of the kinds of tasks involved in the system, and an operational sequence diagram (OSD) in which the command and control tasks are described in a temporal and functional sequence. The OSD includes a diagram and a narrative description keyed to the diagram by number. (Page 22 of this report.)

1. Summary Description of Functions

A Naval strategic command and control system contains four functional elements which are described below.

a. Commander

The Commander is responsible for all command functions pertinent to the forces and resources assigned to his command. Specifically, he must remain aware of the disposition of forces and resources, plans for their deployment, and anticipate events that could create a demand on them. He integrates and evaluates all situations that may require a response by his command.

In deciding the nature of the response, he is responsible for providing an interpretation of policy to be implemented in the process of generating assignments of forces and resources and orders for movement. Under appropriate circumstances, the authority for assignment of forces and resources to many operations can be delegated to lower echelons of command (e. g., SAR, ASW, AEW), but not the responsibility. In a situation of sufficient importance the commander participates directly in the control and assignment of forces and resources.

b. Commander's Staff

The Commander's Staff functions as a group of specialists to advise the commander on problems in their area of specialization (operations, planning, intelligence, logistics). On a day-to-day basis, the staff undertakes studies to evaluate the command position with respect to problems and situations in their respective areas. In times of national or international crisis, representatives from the operations, planning, intelligence, and logistics staffs unite to form a working nucleus, the "Battle Staff." The formation of this working group provides an expedient means of developing unified recommendations for action by the commander.

c. Operations Control Center

This center has responsibility for collecting, processing, and transmitting pertinent data to the commander and his staff to assist them in the completion of their functions, and for transmitting the commander's orders, directives, etc., to the fleet.

In particular, this center is responsible for the operation of specialized data gathering and display systems (plots) for position and movement of forces with respect to particular operations such as: Air Early Warning Barrier, Antisubmarine Warfare, and Search and Rescue; in addition, this center is responsible for monitoring the activities of Naval and all other vessels and aircraft of interest in the commander's area of responsibility. This facility also provides briefings for the commander and staff as required. There are three main groups within the Operations Control Center:

i. Command Post

The Command Post is the facility within the Operations Control Center for collecting, processing and evaluating information about the command environment of the system. The personnel of the Command Post are continually monitoring external communications sources, and are prepared to relay information, deemed of sufficient importance, to the commander and/or his staff. In addition, the Command Post serves as an information relay from the commander and his staff to the fleet and other external addressees.

ii. Communications Section

This facility provides and maintains the capabilities for receiving information for input to the command system. Specifically, the receivers (RATT, TTY, radio, telephones) for all incoming data (Navy and military communications nets as well as commercial news) are maintained by this group. Incoming information is directed to the Command Post, or to the Command Support Center for storage and/or display, and later recall.

iii. Presentations Section

This section prepares and presents briefings (on request or as required) to the commander, his staff, and Command Post personnel.

d. Command Support Center

The Command Support Center provides all the data processing necessary for the command system to carry out its functions. In particular, it provides data processing support of:

i. The commander's development of recommendations for action to be taken by the command, and

ii. the Operations Control Center's daily functioning, including specialized data stores and displays, such as sea surveillance.

Data processing by computer serves to transform the input data into the most useful formats for all elements of the system. Much of the data processing involves the transformation and plotting of data on vessel and aircraft movements (sea surveillance and the specialized displays). Processing of incoming force status data (forces/resources available versus deployed or committed) into useful formats is also required. Data processing also includes a machine computation to determine the time required for specific forces or resources to be in position and condition to support a specified operation.

2. Command and Control Tasks

It is convenient to catalogue the tasks performed in command and control so that the essential nature of each task is identified even though the system-specific names of the tasks may differ. There are seven classes of tasks--some of which have subclasses--described below. These tasks are referenced in the OSD which appears in the appendix.

a. Assimilation of Data

This is the process by which incoming data are sorted for pertinence to and incorporated into the system data base in a meaningful manner; it consists of three distinctly related subprocesses:

i. Data Identification

In order for incoming data to be processed and evaluated, it must be recognized as being of a certain class of file.

> Example: The report of a ship returning to Norfolk for repairs to one of her drive shafts is recognized as belonging to a "Force Status" file.

ii. Identification of Potentially Significant Data

From all the data entering a command and control system, the data of potential significance to the command must be identified and separated.

> Example: The identification of a need for action in the news that a friendly government has been overthrown or that a ship has not made required reports (and can be assumed "overdue").

iii. Data Storage

Sufficient details of incoming data must be retained in many cases, so that the alerting of system capabilities and further processing steps may be effected.

> Example. Command Post Watch Officer's retaining of the key facts of an incoming report to alert the Battle Staff.

b. Organization of Data

The data that are assimilated next undergo a process by which they are related to and integrated into the existing data base. This process is a non-evaluative function but requires judgment as to the relationship of incoming data to data on hand. Two subprocesses are identified.

i. Related Data Identification

Data that enter a command system must be related to other classes of data composing the data base. Incoming data may replace or update existing data, it may cause a change in the relative importance of the elements of the data base, or it may change (or add to) the categories of data in the data base. In any of these events, it is essential that all possible relationships of new data to the data base be identified, hence this class of activities. It is necessary also, in this activity, to translate incoming data to a language or format appropriate to the data base.

ii. Correlation and Comparison

This is the identification of trends in classes of data by comparing incoming reports with previously stored data. Again, this is not an evaluative function, but simply the identification of changes, trends, or discrepancies.

Example: Notation of depletion of resources, or correlating of air and ship contact reports.

c. Evaluation

This class of activities is concerned with the judgments as to the importance or value of data being received by the system, the assessments (qualitative and quantitative) of the incoming data, or the probabilities of uccess of various response alternatives. The evaluation process includes the development of a supporting rationale.

i. Qualitative Evaluation

This is the determination of the severity of an external situation or of the status of a capability in terms of its significance to the command. This determination is the initial step of any evaluation and establishes the direction of all of the subsequent data processing and evaluation. For example, a time constraint would be imposed if this initial step were to determine that a response to an incident was urgent.

Example: The report of a buzzing of a USN ship by foreign aircraft would be evaluated as significant and requiring a rapid response by the system.

ii. Quantitative Evaluation

Assignment of numerical values to data, the significance of data, probability of successful actions, etc., constitute quantitative evaluation. Most importantly this would be the assignment of probabilities of success to various alternative courses of action developed and proposed by the command system personnel. Quantitative evaluation can be a subjective assessment or it can be objective.

> Example: Quantitative evaluation can be made of: 1) parameter statuses such as present status of forces, weather conditions and physical factors in a potential operating area, and 2) decision alternatives, such as whether to deploy limited forces in a short amount of time, or a larger complement of forces in a longer time.

iii. Ranking of Alternative Actions

Alternative courses of action, once they have been evaluated in a qualitative and/or quantitative fashion, are ranked in terms of their probabilities of success and their associated tradeoffs. This ranking process produces an essential ingredient for any decision about implementation.

d. Synthesis

This is a semiroutine process involving basically the reformatting, paraphrasing, summing and integrating of relevant data into more meaningful blocks with respect to a particular problem or task facing the system. The product involves no derivation of new data, and the general nature of the data remains constant.

> Examples: Physical Factors + Weather = Environmental Conditions (EOC)
> or
> EOC + News Report + Intelligence = Situation Status

e. Deduction

One of the most important activities that occurs in the system is that of creating or deriving new classes of data, by logical inference from existing data. This is a deduction function in its classical sense.

Example:

- The formulation of the mission (response) from the current situation data, policy and other command directives.

- The derivation of general operating requirements (GOR) from the mission and current situation data.

Moreover, this deduction process is used to generate the decision rules and the action (response) alternatives that will be used by the decision maker in creating the output of the command system.

Example: Derivation of the unit performance criteria (decision rules) in the specific operating requirements which, in part, will determine which specific forces will be assigned to a mission.

f. Decision

This class of activities refers to the traditional decision making process wherein a system element selects one of two or more action or interpretation alternatives, according to a predefined set of decision rules.

i. Simple Decision

This type of decision is made in the decision-making situation where the alternatives are clearly identified and few in number, and the decision rules are available and explicit.

Example: Simple decisions relate to the following:

- Identification of file(s) into which data should be inserted.

- Correlation of contact.

ii. Complex Decision

This type of decision is made in a situation where the decision alternatives are developed by the decision maker(s), are many in number, and the decision rules are more complex and require, in many cases, sophisticated interpretation.

Example:

- Allocation of specific forces to an operation
- Development of SOR
- Formulation of mission

g. Action

The personnel of the system have occasion to engage in activities that are primarily psychomotor. These fall into two broad categories:

i. Routine

These activities are clerical in nature, such as typing, filing, writing, manual mathematical calculations, and operations of communication devices (telephone, intercoms, TTY, etc.).

ii. EDP

These activities relate specifically to the EDP equipments and file structure of the system, and are unique in this respect to this or any command system. Included in this category are such activities as data retrieval by means of input-output devices and file maintenance using card punches.

B. Applicability of Analytical, Quantitative Methods

It is only recently that serious attempts have been made to apply the cost-effectiveness discipline to the development of training requirements. Previously, standards of training were judged in terms of relating the man's knowledge and/or performance to some standard of what a "well-trained" man would do, and using training techniques to bridge the gap between the novice entrant and his well-trained counterpart who was a veteran of the system. For systems which are simple, or have evolved slowly enough for experience with operations to teach what is needed from each man, such naivete may have been satisfactory. However, when systems are so complex that the interrelationships between their parts and their output is not clear, internal, judgmental standards of how well each man in the system ought to do his job are inadequate. This is especially true when the system represents an order-of-magnitude departure from its predecessors, as computerized command-control systems do. In these cases, there is no substitute for an analytical approach to the setting of standards for task performance on the basis of maximizing system cost-effectiveness.

Strategic command-control systems, based on EDP, are not only new and complex, but they also contain a great variety of different sorts of task. Some of these are extremely high-level: for example, that of the commander himself. Others are very specialized: those tasks affecting the operation of the EDP equipment and its manipulation of the data. Some appear routine planning operations, much like those which most of his training teaches a Naval officer to do well: but just to do them in the way to which his career has hitherto accustomed him means to miss much of the help which the EDP equipment can offer. Some, again, are truly routine, and little different in a command-control system from what they would be elsewhere: typists, telephonists, electronic maintenance, etc., fall into this category. Thus, the development of requirements for training the staff of a command-control system runs a very large gamut of levels of personnel, skills, and novelty.

Finally, the output of the command-control system is hard or impossible to measure, and without measurement of output, a quantitative assessment of training required to maximize the value of system output is necessarily hard to achieve. Necessarily, the analyst will be forced to suboptimize and, by designing good parts, hope to achieve a good whole system.

The study, therefore, will have to deal with system performance criteria, though with no ability to avoid suboptimization altogether, and will have to deal separately with a set of very different sorts of personnel within the system.

Categories of Men and Tasks

It seems possible to divide up a command-control system into three subsystems, differing in their functions and their manning. They are:

- Decision-making subsystem
- Analysis subsystem
- Support and data processing subsystem

The duties of the support and data-processing subsystem are very straightforward: to give the most help possible, in terms of communications data and manipulations of data, to the analysts and the decision maker. Since the specific requirements of the analysts, at any time, are unpredictable, the functions of the support and data-processing subsystem may be defined as keeping available a complete and up-to-date data bank and facilitating its use.

The analysis subsystem takes (chooses) data from the data bank and manipulates it so as to show the feasibilities, costs, consequences, etc., of various alternative plans to deal with a situation. This has been the traditional duty of planners. It is different now only in execution; and this is because EDP both makes more information available for planning purposes, and also is able to relieve the human planner from the more routine elements of planning, such as performing standard calculations.

The decision-making subsystem accepts the analyzed alternative plans from the analysis subsystem, and chooses between them. The basis for choice is necessarily not fully logical or predictable. If it were (and when it is) there would be no need for the decision maker. He is the person charged by law with making decisions which are not obvious and which analysis cannot make obvious. He must judge, not analyze or compute, whether the prize offered by a plan is worth the risk involved, how much risk he is prepared to take, etc. The analyst can only tell him what is the biggest prize he can achieve for a particular risk, or the smallest risk he must accept to gain a particular prize. Prize and risk are incommensurable, and their relationship is not subject to analysis. Where large issues are involved, the decision-making subsystem consists of the commander himself, perhaps with a few advisors. When the issues are smaller, a man who is normally a member of the analysis subsystem may move into the decision maker's role.

Thus, the criteria of good performance for the three subsystems are:

- support subsystem -- provision of large amounts of data quickly and accurately

- analysis subsystem -- deduction of quantitative, logical consequences of alternate courses of action, to the extent, and with the precision, which their data and data processing equipment now makes possible

- decision-making subsystem -- making correct choices between incommensurables. The meaning of "correct" is nebulous and obscure.

From these categories, we see that there are good prospects for analytical determination of requirements for the support tasks. These are by nature repetitive, countable and measurable.

For the analysis subsystem it would be conceivable, though evidently foolish, to make some attempt to count or measure the number of "good analyses" made by the planner, and set up a standard of so many "good analyses" per fixed time period. But it is at least possible to conceive that an approach might come from watching and analyzing the performance of a planner, telling him where he was wrong or inadequate, where he failed to use his tools, and generally teach him to plan with the aid of a computer and a data bank. What he does is logical: and is therefore categorizable into "right" or "wrong". However, this is a long way from regarding a planner as a production line, with data entering at one end, and good plans coming out of the other.

For the decision maker, the situation is again worse. By their very nature -- the fact that they are judgments -- it is not possible to categorize them, except in rare cases, as right or wrong. Those charged by the Navy with major strategic decisions seldom if ever make decisions which are obviously wrong. Some are doubtless better than others and, over a period of years, some commanders have a better average performance than others. But to conceive of a mathematical, quantitative technique, which regards a senior Naval Commander as a production line for good decisions would be naive indeed.

Again, we may look at the need for determining training requirements. Support categories are often short-term enlistees, who are young, and in almost every sense untrained. They are doing a new kind of job, and they are vital to the performance of the system of which they are a part. Their training is technical and may take a long time unless sound requirements are set up for them.

Planning officers are veterans of many years in the Navy, all of which have been preparing them to see the consequences of actions taken with ships, aircraft and men· actions in bringing force to bear at the right time, in supporting forces with adequate logistics, in problems of time and distance, and so forth. If the command-control system were not computerized, no real training problem would exist. But these officers are taken from a ship or a desk, and placed in a new and highly complex environment of machines, and their associated language and procedures. How can their environment be so arranged that they will be able to take full advantage of their equipment and facilities? Since many of their facilities consist of machine programs, which can grow without limit, how can they be helped to assist in the useful growth of their systems? Evidently, there is a real problem here, but it is utterly different from that of the support group.

Finally, consider the senior decision makers. These are senior officers who are making the same sorts of decisions as they have been trained to make through many years of service. In every true sense of the word, these men are trained. To set requirements for them would be both unnecessary and without effect on what happened.

We may conclude that it is inherently possible and desirable to develop systematic methods of determining training requirements for the support personnel. It is desirable, and may be possible for the planning personnel. It is inherently impossible and undesirable to attempt to develop training requirements for senior Naval officers of the rank who are supported by strategic command-control systems.

C. Evaluation of Existing Techniques

The objective of this study was to assess the feasibility of applying available quantitative techniques to the evaluation of training requirements in strategic command-control systems. The necessary preliminary steps to this assessment were establishment of a system model that would serve to represent Navy strategic systems and examination of the quantitative aspects of training in a strategic command-control system. These preliminaries have been discussed above.

1. Training Analysis Procedure

So far as Dunlap and Associates is aware, only one quantitative technique has been developed which purports to determine task training requirements by reference to system output. This is TAP (Training Analysis Procedure), especially developed by Dunlap and Associates for USNTDC (ref. 5). A brief description of the principles of TAP is given in Appendix B. It was intended to be applied to weapon systems, which have inputs (in the form of data) and outputs in the form of targets engaged or destroyed. The worth of the system is measured by the number of targets it can destroy or engage in a fixed time. The number of targets is a function of many things, of which one is the training of men manning the system. TAP consists in a method for relating the performance increments which can be achieved by training the men to the number of targets which can be destroyed in unit time. It shows the effects of human performance on system performance, and allows effort to be expended first on training for the jobs where training has its biggest payoff, and then progressively through the tasks where training has less pay-off in system output.

The TAP makes two basic assumptions: that the system has some kind of definable and measurable output, which permits the second assumption that the quantitative relationship between parts of the system and the output can be defined. These assumptions are true of a great many purely logical systems. Certainly, in all man-made logical systems, the second assumption is true. The first assumption -- that output is measurable and definable -- is by no means always true, although it generally is. For example, the United States Senate is a man-made system, whose workings can be explicated and written down, at least for the most part. But only history is capable of judging the value of the output of this system. We cannot judge a Senate on the basis of the number of laws it makes alone: we must also consider the value (which may be negative) of each law. It is the fact that we cannot do this which makes TAP inapplicable to the Senate, and it is this which makes TAP inapplicable to the training of planners: the fact that we cannot assign some fixed value or merit to a plan.

Clearly, then, it is possible that TAP is applicable to the routine, support aspects of a strategic command-control system, but it cannot be applied to the plan-development functions therein, nor the plan selection function. It would be applied to two elements of the support subsystem: the communcations element and the data entry element. The outputs of these two elements could be described in such forms, respectively, as bits of information transmitted/received or entered per unit time. Chains of events can be described (in any specific system) which lead from the requirement to communicate, or to enter data, to the completed task. The amount of communication which takes place, and the amount of data entered, can be related to the performance of the human elements of these two chains, and standards set up which balance the capabilities of the men to the machines, so that the maximum usefulness of the system is achieved.

But a difficulty arises when errors must be considered. In many weapon systems, for which TAP was developed, it is only possible to do a job right or not do it at all. Not doing the job correctly is equivalent to not doing it at all, because the step must be repeated, and nothing is lost except time. There is either the positive utility of doing the job correctly, or there is no utility at all.

This is by no means always true of weapon systems, as consideration of any simple AAW system will show. If a mistake is made in identification, not only do we fail to shoot down the enemy, but we may shoot down our friend. Shooting down the enemy has positive utility, shooting down no-one has no utility at all, but shooting down a friend has negative utility. A failure to take this into account would cause us to under-rate the importance of training in identification procedures. The same difficulty may arise in connection with communications and data entry in command-control systems, according to the details of the procedures used. If there is always a check upon the correctness of data communicated or entered, so that a mistake on the part of an operator results in a "no-go, repeat" step, and not in false information being transmitted or entered, then TAP, unmodified, will give correct guidance to development of training standards. If, however, there is no error-detection step (or if it is very inefficient) then concepts of negative utility must be incorporated into TAP. This is not difficult, of course. Basically, it may be achieved by carrying positive and negative utilities separately throughout those analyses to which they are relevant (e. g., the analysis of AAW systems) and adding them algebraically.

An example is worked through, in Appendix C, to show where TAP can and cannot be applied to the model strategic command-control system.

2. Priority Analysis

So far, we have indicated that there are three broadly-definable subsystems within a strategic command-control system, which differ from one another as to whether they either can or should be analyzed by quantitative methods. They are:

- support subsystem, which both can and should be analyzed quantitatively with respect to training standards
- planning subsystem, which should be analyzed, if possible, but for which no quantitative method currently exists
- command subsystem, for which quantitative methods of analysis could not be applied, and for which training requirements determination would also be inappropriate.

Having dealt with the first subsystem, it only remains to deal with the second: the training of planners within strategic command-control systems. The following remarks will describe a semi-quantitative method which, it is believed, could be applied to the officers within a strategic command-control system who are responsible for the development of alternate plans, and whose application, we believe, would both increase the capability of current strategic command-control systems, and lead to their steady growth by evolution of their software.

It may be taken that the extra training required by a Naval officer to work on the planning staff within a computerized command-control system revolves around the computer. This is the only thing which is new to him. The presence of a computer, the benefits it can offer, and the dependence of the system upon it, raise several training problems.

a. <u>System Language</u>

All computerized command-control systems must necessarily possess a specialized language. For example, there must generally be displays, which are computer-driven and which use particular symbols to mean particular conditions or objects. There are also specialized ways of addressing the computer to obtain information from it, known as query languages. It is almost essential that planning staff in a computerized command-control know the language, so that they can use the computer, and never be misled by it.

b. <u>System Capability</u>

The system capability represented by its new element the computer resides not only in a data base, to which users knowing the "rules" have ready access, and the ability to generate up-to-date displays, for those who understand their symbolism, but can also perform a variety of arithmetical and logical tasks. This variety of logical and arithmetic tasks can grow throughout the life of the system, being limited only by the logical/arithmetical constructs (models) which are developed to describe certain aspects of the system's business and the time and resources taken to program them.

<u>In order to make use of this modeling capability</u>, the planning staff needs to be trained in several areas.

- They obviously must know what the computer has already been programmed to compute· what models it can solve at any time.

- Equally important, they must understand the models themselves well enough to trust them, when they are trustworthy, and must understand both the abstractions and the assumptions they imply so that they will treat them with enough respect not to be misled by them.

- Since many of the "models" are in fact submodels of operations (i.e., building blocks from which bigger models may be constructed) the planning staff must have experience and competence in using the models as building blocks.

- Since he will have to present alternative courses of action to a superior officer, who will generally have little training in operations analysis and modeling, the planner must have the capability to describe how he has built his plans, what assumptions they contain, and how the computer worked with him, in a clear and convincing manner, so that his senior officers will accept his estimates after intelligent and well-directed probing.

In order to be able to check this modeling capability against reality, which is essential if it is to be trusted just as much as it merits, some other things are important.

- The planning officer must have opportunities to check model predictions against actuality, and must have enough knowledge of statistics and probability to understand the meanings of the correspondences and differences he observes.

So as to increase the number, detail and scope of the models programmed into the system, so that its capabilities will continue to evolve in the software area, the planning officer

- should be trained and experienced in the field of operations analysis

- should have demonstrated both creativity and a critical capability in this area.

d. Priorities

Based on the foregoing analysis -- which should, of course, be extended into some detail, and made specific to the command-control system at issue -- it is possible to distinguish certain general priorities for system-specific training, as follows:

1) Before the new officer will be of any serious use in the command-control system, he must have a thorough understanding not only of its mission and organization (this would be essential to usefulness in any system at all), but must understand the language of the specific system. This will include both the query language and the symbolism of displays. Armed with this knowledge, the new officer will be able to make himself useful in a subordinate role, and to learn more.

2) Next in order of the things he must know to be really useful comes a familiarity with the data and the models stored in the computer. Armed with this knowledge, and the ability to understand the displays and retrieve data, he can play a truly useful role in operations, at any but the highest planning level.

3) The ability to explain the details of a plan, and to show why they are correct, both (1) and (2) are needed, together with one further set of skills: enough knowledge of models dealing with Naval operations to know what other analyses could be made (were there to be time to make them) and the briefing and expository skills necessary to present a fair picture of the situation to a highly experienced Naval officer who is unlikely to know much about analysis.

Finally, to make the system software grow, should come the group of skills concerned with the development and programming of new models. While these models can be produced within the system, and are probably better produced there, they can also be produced outside the system in many facilities to which the Navy has access. They therefore form lower priority training requirements for planning staff in command-control systems than those described above.

Within the above-mentioned sets of skills (Items 1, 2 and 3) it is possible, in some cases helpful, to develop further priorities.

(i) <u>Languages.</u> If it is reasonable to deal with priorities within such a fundamental class of knowledge as system languages, this can only be because of a serious personnel shortage, and this constitutes the kind of emergency which is specific not only to a particular system but to a particular time in its life. It cannot be dealt with on general terms.

(ii) <u>Stored Models and Data.</u> A full understanding of the models and data stored will take considerable time: perhaps months. Much of it can be learned outside the system, i.e., before the new officer is assigned to the operating staff of the system. Officers with these skills, or even with the capability of acquiring them, may be scarce. If they are, then partly-trained officers can work in the system if their part-training has been designed in a particular way. The design must be such that whole topics are taught. For example, all models and data relating to ship-movement times, rates and distances could be taught as a whole. Or all models and stored data relevant to air defense could be taught as a whole. This practice is contrasted with the opposite possibility: that of teaching models and data dealing with several different topics (for example, teaching some ASW models, followed by a survey of data banks on air defense, followed by more ASW "for variety", and some shipmovement models). The way recommended will ensure that the new planning officer will know enough about at least one subject to be its master, so that he can pull his weight in the system. Needless to say, the choice of what complete topic should be taught first ought to be dependent upon the specialties of existing command-control system staff and their expected tours of duty in the system: but the topic ought to be thoroughly covered before any other is commenced. When a planning officer knows one topic thoroughly, in terms of models and data bank, he may increase his versatility in the system by learning others. But this increase in his versatility will have far less effect on over-all system capability than his detailed knowledge of a single topic, such as ASW, with familiarity with all that the system can offer, in data and in models.

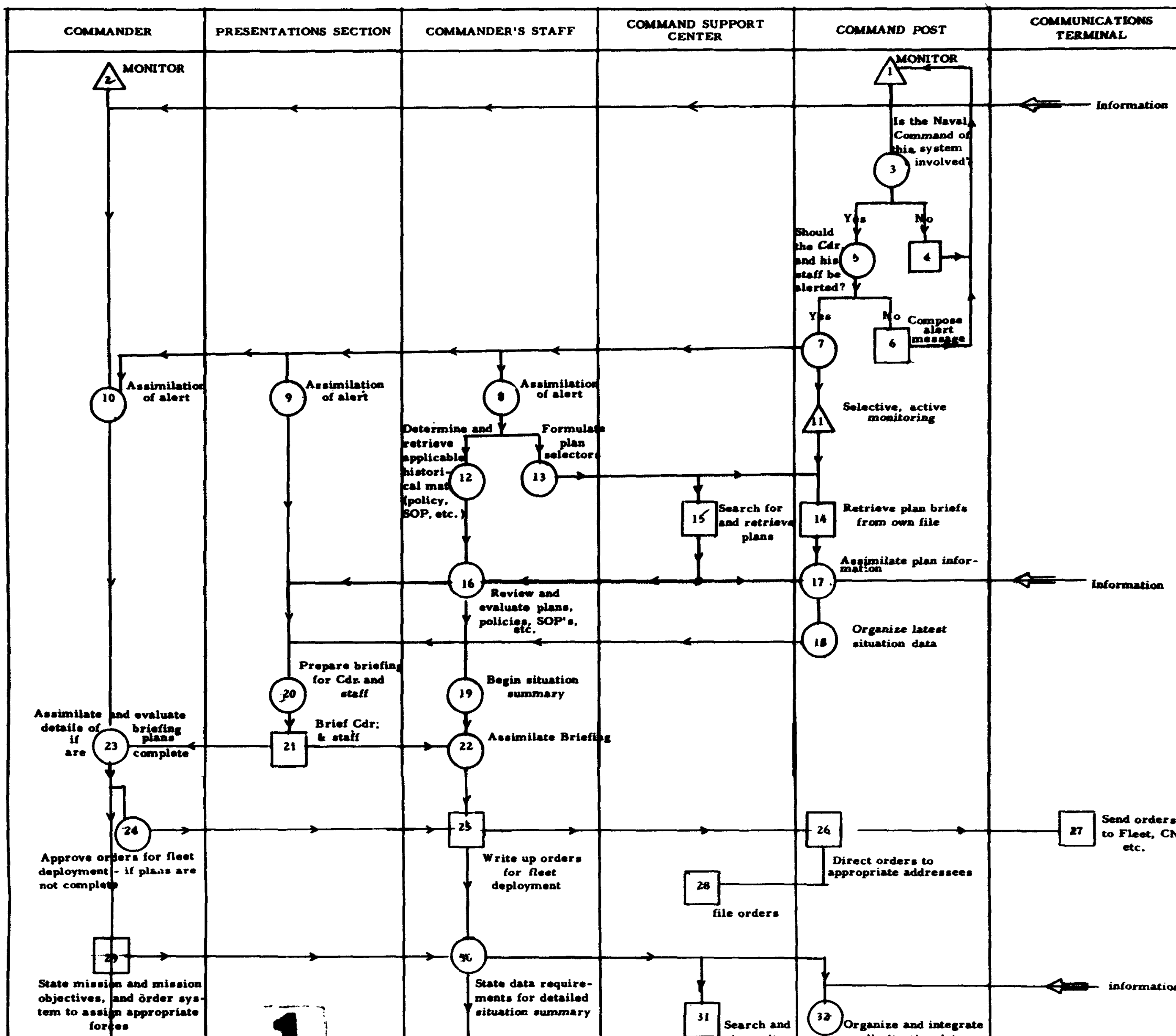
IV. CONCLUSIONS

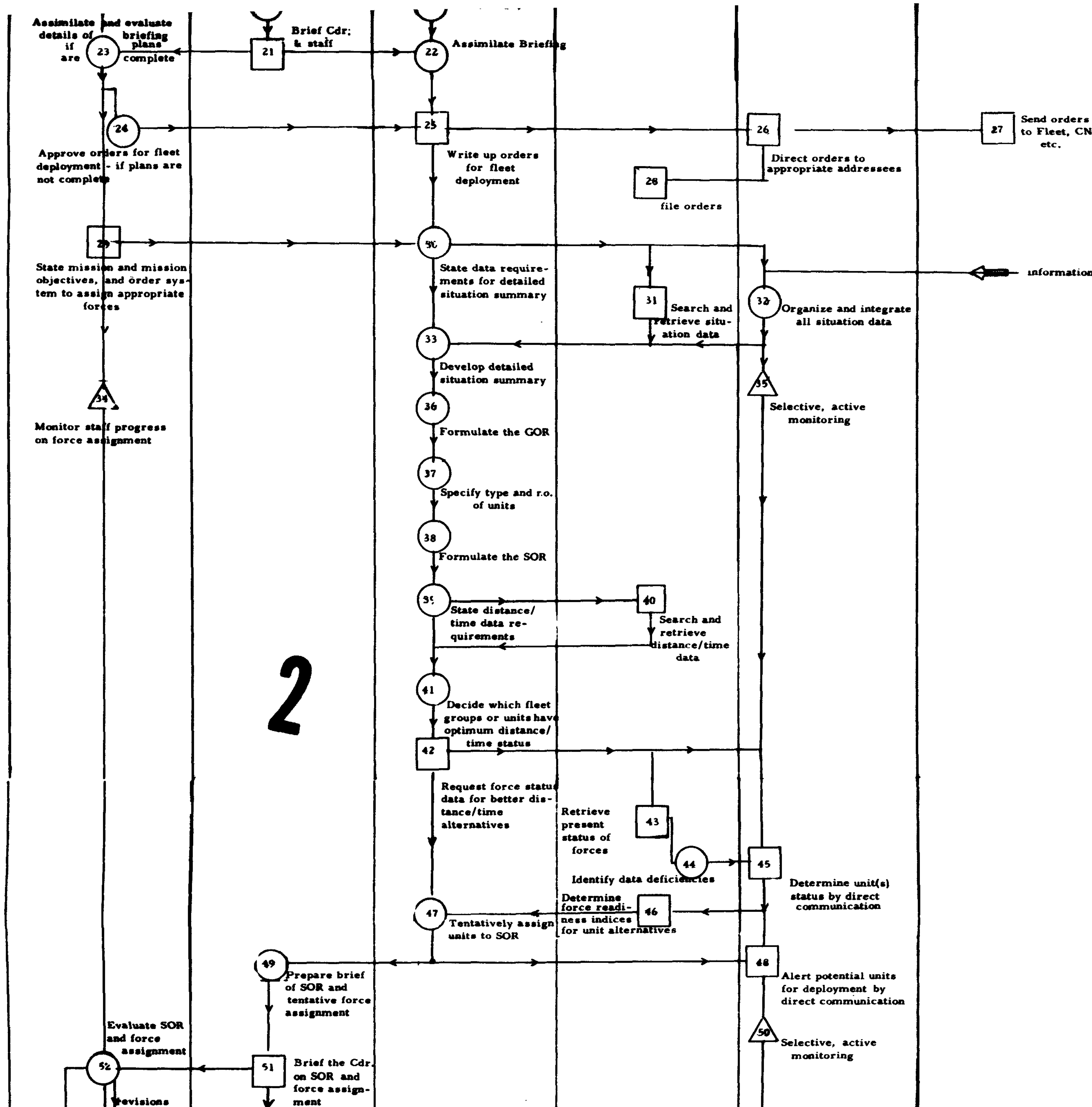
The following conclusions may be drawn from this study of the applicability of quantitative methods to determination of training needs for personnel in strategic command-control systems in the Navy.

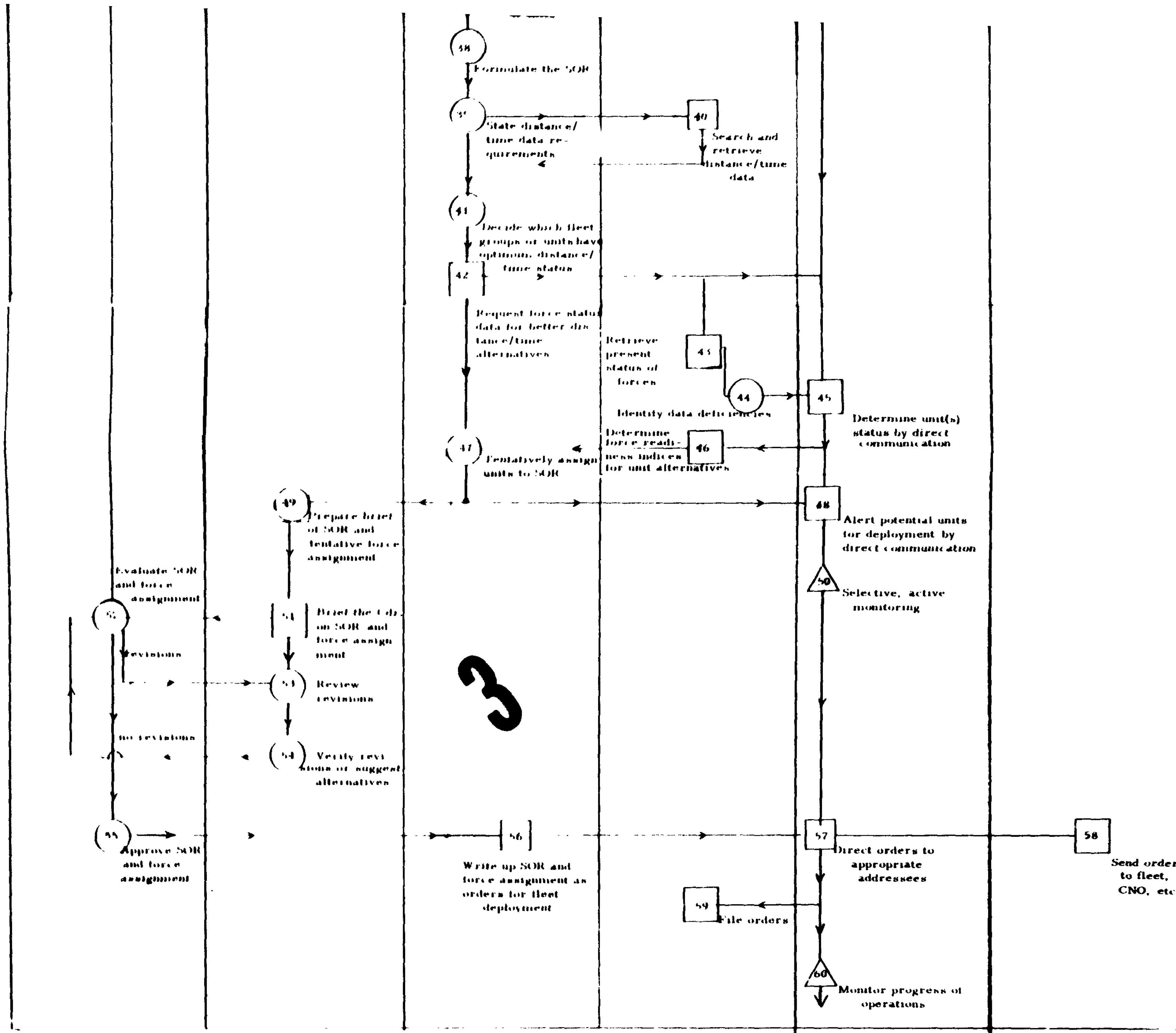
1. TAP (Training Analysis Procedure) may be used to determine the training requirements for all of the lower-level personnel in the system, up to, but not including, officers who develop plans for evaluation by higher echelons. In its unmodified form, TAP is suitable only for use with systems which contain adequate checks against the insertion or retrieval of erroneous data.

2. A modification of TAP could readily be developed which would free it from the restrictions stated above. It would do this by specifically considering the negative utility associated with the entry or retrieval of incorrect information.

3. Quantitative methods are inapplicable to the determination of training requirements for the planning staffs in strategic command-control systems, since the activities of these men cannot be meaningfully considered in "production-line" terms, of the form "rate of generating adequate plans". However, a fully logical system is available, and is described in the body of the report. It is based upon the extra requirements which the data processing system in modern command-control systems places upon the skills of planners, and the extra opportunity which it presents to them in terms of development of detailed plans which more fully represent the physical operations which would result from them.


COMMANDER
PRESENTATIONS SECTION
COMMANDER'S STAFF
COMMAND SUPPORT CENTER
COMMAND POST
COMMUNICATIONS TERMINAL
MONITOR
MONITOR
Information
Is the Naval Command of this system involved?
Yes
No
Should the Cdr and his staff be alerted?
Yes
No
Compose alert message
Assimilation of alert
Assimilation of alert
Assimilation of alert
Selective, active monitoring
Determine and retrieve applicable histori-cal mat (policy, SOP, etc.)
Formulate plan selector
Search for and retrieve plans
Retrieve plan briefs from own file
Assimilate plan infor-mation
Information
Review and evaluate plans, policies, SOP's, etc.
Organize latest situation data
Prepare briefing for Cdr. and staff
Begin situation summary
Assimilate and evaluate details of briefing plans if are complete
Brief Cdr; & staff
Assimilate Briefing
Send orders to Fleet, CNO etc.
Approve orders for fleet deployment - if plans are not complete
Write up orders for fleet deployment
Direct orders to appropriate addressees
file orders
State mission and mission objectives, and order sys-tem to assign appropriate forces
State data require-ments for detailed situation summary
information
Search and retrieve situ-
Organize and integrate all situation data


21 Brief Cdr; & staff
22 Assimilate Briefing
23 Assimilate and evaluate details of briefing plans if are complete
24 Approve orders for fleet deployment - if plans are not complete
25 Write up orders for fleet deployment
26 Direct orders to appropriate addressees
27 Send orders to Fleet, CNO etc.
28 file orders
29 State mission and mission objectives, and order system to assign appropriate forces
30 State data requirements for detailed situation summary
31 Search and retrieve situation data
32 Organize and integrate all situation data
information
33 Develop detailed situation summary
34 Monitor staff progress on force assignment
35 Selective, active monitoring
36 Formulate the GOR
37 Specify type and r.o. of units
38 Formulate the SOR
39 State distance/time data requirements
40 Search and retrieve distance/time data
41 Decide which fleet groups or units have optimum distance/time status
42 Request force status data for better distance/time alternatives
43 Retrieve present status of forces
44 Identify data deficiencies
45 Determine unit(s) status by direct communication
46 Determine force readiness indices for unit alternatives
47 Tentatively assign units to SOR
48 Alert potential units for deployment by direct communication
49 Prepare brief of SOR and tentative force assignment
50 Selective, active monitoring
51 Brief the Cdr. on SOR and force assignment
52 Evaluate SOR and force assignment
revisions
2



OPERATIONAL SEQUENCE DIAGRAM FOR NAVY COMMAND SYSTEM "ASSIGNMENT OF FORCES" PROCESS

APPENDIX A

AN APPROACH TO THE CONSIDERATION OF TRAINING REQUIREMENTS IN STRATEGIC COMMAND AND CONTROL SYSTEMS

1.0 Introduction

To establish a requirement for training requires two things to be placed in evidence. First, a reasonably definite description of the set of tasks to be carried out, and second, descriptions of the set of agents available to carry out this set of tasks. More than this the terms in which the tasks are described must be the same set of terms in which the capabilities of the agents are described. If the set of tasks coincides with the set of tasks performable by the available agents, no training problem exists. If there is a set of tasks required that falls outside the set of tasks performable by the agents, a requirement for training will have been established.

The method to be described here is therefore directed toward the earliest possible definition of the set of tasks required to be performed by human agents. Although this study is not concerned primarily with system design, it will be necessary to refer to the fundamental concepts in the design of the command and control system in order to describe the logical steps in the identification and description of the set of tasks. These steps are as follows:

Step 1

Formal description of a command and control system is a fundamental step in system design. The formal description is the basis upon which all the subsequent analysis of the particular system is carried out. The basis for the formal description is contained in a number of official documents. These documents deal with such functions as planning and plans, the format of directives and other communications, and the supervision of operations. These documents generally describe a set of relationships established between the elements of commands by Naval law and custom. Every Naval command system must conform to this basic set of constraints. The formal description generally will place in evidence the following fundamental relationships. The given command will have a direct superior. The part of the higher command structure immediately superior to the given command will usually be relevant to the activities of the given command. The given command will have one or more subordinate commands. The specific nature of the relationships among this complex of commands must be put in evidence as data for the design of the system.

Step 2

The formal description relates the given command to the relevant part of the over-all command structure. In order to proceed further with the system design the command must be still further characterized and identified by the particulars that distinguish this given command from others. These particulars are the nature of the forces under the direction of the command, and the degree of closeness of control or supervision to be exercised. Step 2 then consists in the design of the system (or the preliminary design) in such a way that the formal requirements put in evidence at Step 1 are satisfied. In Step 2, the activities of the command are identified and described in detail. This detail is necessary in order that all of the necessary programs can be written out. These programs should effectively describe each of the activities of the proposed system.

Step 3

At this stage, all of the programs describing the activities of the system are presumed to be in evidence. These programs are now assigned to agents. Some of the agents will be machines, some will be human. Obviously this assignment of man and machine function was anticipated at an earlier stage in the system design, but at this particular step the assignment is presumed to be definite.

Step 4

The activities of the human agents as assigned in Step 3 are now developed in detail, including the man-machine relationships. These details amount to programs which are related to specific human functions, such as symbol recognition (understanding of the command and control languages, as entailed in the ability to read the required symbol list), complexity of associative behavior, and motor skills, if applicable.

Step 5

The requirements on the human agents are translated into the same terms as are used for descriptors of the available set of human agents.

The completion of this step results in the validation of a requirement for training if such a requirement can be shown to exist, otherwise the available agents are competent to perform the required functions without training.

Each of the above steps is discussed in detail in the following paragraphs.

2.0 Formal Description of Command and Control

Fundamentally, Command and Control Systems exist to support the process of military decision and the execution of the directives necessary to the implementation of these decisions.

Initiation of the Process - For practically all commands the process is initiated by a directive from the immediately superior command. The directive assigns a mission and in addition furnishes certain information that serves to clarify the intentions of the higher command. For example, the higher command can provide a statement of the mission assigned to it by its immediate superior. Statements of this last kind make it possible for a command receiving a directive to be aware of the missions of any number of superior echelons in the chain of command. This information is useful to the commander in clarifying the intent of the directive. It forms a part of the directive and it tends to eliminate any ambiguity concerning the primary military utility associated with the accomplishment of the mission. If the mission assigned to the command is a part of an over-all plan of operation which involves other commands, the directive will be accompanied by the details of such over-all plans as are necessary for the given command in formulating its own plan of operation.

Nature of Plans - Plans are conceived as detailed descriptions of definite coordinated missions. The planning command assigns these missions to the forces under his command. A primary device for achieving coordination consists in setting forth the assumptions upon which a given plan is based. If P is a plan based on an assumption (A) we can denote this fact by referring to such a plan as $P_1(A)$. The assumption A is essential only if the realization of the condition stated by A is required for the validity of the plan. In other words, A is an assumption only if P_1(not A) is not a valid plan. Two plans might be provided for either of the two contingencies, "A", "not A", that is a pair of plans $P_1(A)$, P_2(not A), the plan having validity now depending on the resolution of the outcome of the trial which determines which of the two contingencies will be realized. This outcome must be determined before it is known which of the two plans is valid. In distinction from contingencies, an assumption in a plan $P_1(A)$ which represents a directive from a superior, the condition A is regarded as being factual. It is provided to the subordinate command for the purpose of planning information at the lower level. The responsibility for the assumption rests with the superior command, or with some command still higher.

Estimate of the Situation - The first step upon the receipt of the initiating directive is to provide the local staff with the commander's estimate of the situation. The commander's estimate is provided by a complex process. Obviously such processes cannot be programmed in the ordinary sense of the word, but the following sequence of activities gives valuable insight into the nature of the process of arriving at the estimate, and in particular gives a good indication of the general character of the support that ought to be furnished by the supporting system.

1. The analysis of the mission is a fundamental responsibility of the commander. In this analysis the commander takes account of all of the information provided in the directive, the particular mission for which he is responsible, the missions of his superiors, the mission of other commanders participating in the operation, the assumptions of the plans transmitted with the directive, and his own position in a structure of command as assigned for the operation.

2. The commander summarizes the situation as presented in the directive, and provides a statement to his staff in which he gives the necessary guidance and performs the essential interpretations of the directive that will be required for the staff to carry out the necessary planning for the command.

3. The staff correlates the existing information concerning the enemy strength.

4. The commander now integrates his analysis of the mission with a preliminary estimate of the enemy capabilities, and decides on a tentative course of action.

5. The tentative course of action is similar to a working hypothesis which is communicated to the staff by the commander, together with such other general information as he deems necessary for the effective development of staff estimates.

6. The staff estimates result in certain conclusions which specify the relative strengths of friendly and enemy forces.

7. The commander then estimates the enemy capabilities relative to the staff estimates and the provisional course of action.

8. At this point, the available courses of action for both friendly and enemy forces are analyzed and compared.

9. This last comparison forms the basis for the decision.

It is apparent from this sequence of events that the command is supported by a system that effectively analyzes certain kinds of military operations. The essential point about the analysis is that it allows for good predictions to be made as to the outcome of events resulting from a given allocation of missions to forces.

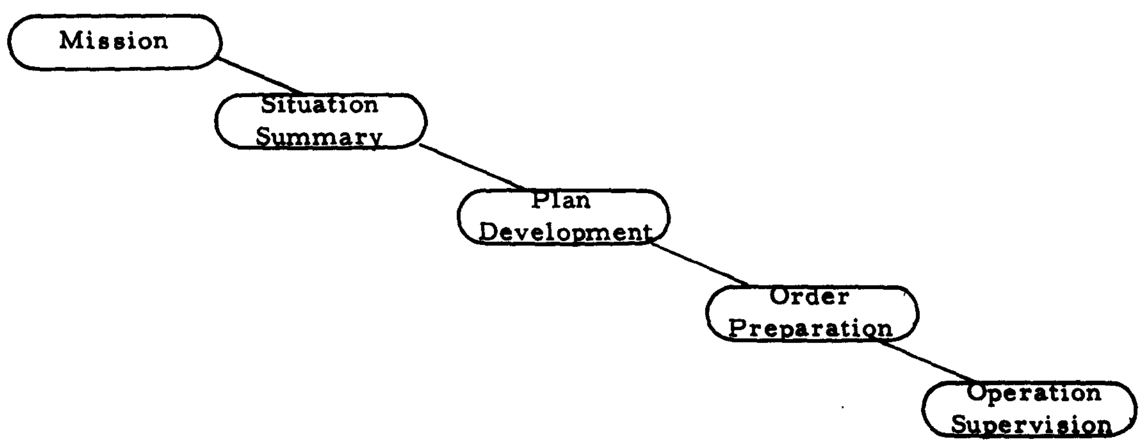
In order for these predictions to be made, the system requires certain analogs of command and operational behavior. A commander must be able to predict the reaction of his subordinate commanders to his directives and to the operational environment. The supporting system is concerned mainly with the analogs that permit an analysis of operations to be made. An analog of this kind is generally known as an operational model. The model is a device for determining the logical consequences of certain postulates, assumptions, or other data supporting a chain of reasoning. The initial reaction of the commander to a directive in analyzing the mission results in a selection of the proper operational model. The preliminary estimate of enemy capabilities furnishes one of the primary data to the model. Similarly, the provisional course of action identifies the forces and their mode of employment in the performance of the mission. The operational model in effect then allows the staff to infer the probability of success from the given set of data. By successive refinements of the course of action, an estimate of the probability of success is arrived at that warrants a decision in favor of the corresponding course of action.

The command system thus contains analogs of each of the kinds of operations or activities that can be carried out by the forces under the command. It is essential that the command be able to estimate the probability of success of the forces under the command even though the commander may not detail the actual plan of operation. Economy of force considerations require this for any planning activity. If the commander cannot estimate the probability of success for the missions assigned to his forces, these forces will be either overburdened or underburdened depending on uncontrolled situations.

As an example of this, suppose that CINCLANT under JCS is directed by CNO to initiate a tight blockade of Cuba. CINCLANT has certain forces under its command. Physically, these forces consist of Naval, Air Force, and Army units. Organizationally, these forces have a certain command structure. While CINCLANT may or may not elect to detail the operation in terms of assigning specific forces to specific areas, it is required that CINCLANT be able to estimate the effectiveness of blockade available to the forces under his command. The detailed disposition of forces may be left to the task force commander once this individual is designated by CINCLANT.

To look a little more into this requirement for operational models, blockade is probably not a model of itself, but is made up of a number of submodels, such as air search, sea search, antisubmarine patrol activities, and similar related models. The integration of these models into a single model relating to the mission is basic to the Estimate of the Situation. It is through the exercise of these models, that the diverse technical factors affecting a complex military operation are integrated in a systematic way to provide the commander with an estimate of the probability of success of mission attending the available choices open to the commander.

The complete chain of events in the system is as follows:



3.0 Command Structure

The highest echelon of command is necessarily the most remote from the actual conduct of operations, and the tactical level of command actually conducting operation is most remote from the source of decision. The number of intermediate command elements is determined rationally by the limitations on availability of information. At one end of the scale we can envisage a system in which the supreme political ruler of a country is furnished with a command system that consists merely of a set of buttons each labeled with the name of a city in the world. Pressing the appropriate button would fire a nuclear rocket at the city. At the other end of the scale we can think of a political leader bound by custom to consultation before military action is undertaken and with a command and control system and forces such that the detailed locations of his own and enemy forces are only known many hours or even days after these locations have been arrived at. Within proper limitations as to the sphere of activity, modern air-defense systems tend to be simple, with very direct and immediate tactical control. However, the majority of command systems require several intermediate elements between the highest echelon of decision and the lowest tactical level. In a Naval strategic command system, the scope of operations and the limitations on information rates relative to the rate of reactions of weapons requires that only a relatively remote and indirect form of tactical supervision be exercised.

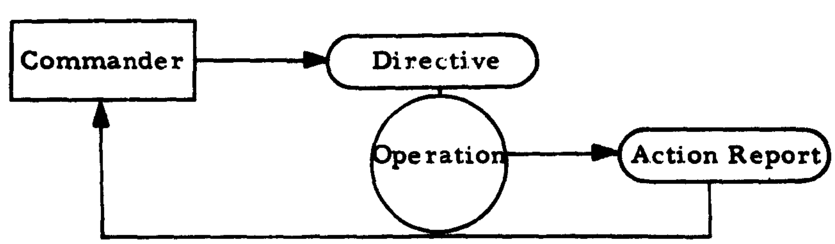
From the preceding formal description the second step in system design is to organize the particular command and control system according to the principles of systems analysis. It has already been established that a command system has two primary channels of input-output information. The input to the system can be regarded as the directive. The output of the system is its own directive to a lower echelon. Each of these directives follows a format and is essentially reducible to a set of numbers or a list of numbers and specific instructions. These two input-output elements are primary in the command chain function. There are, however, a number of auxiliary inputs to the system and a number of auxiliary outputs from it. These auxiliary inputs and outputs are essentially sensing elements whose purpose it is to provide certain data to the system. Such auxiliary inputs are those of intelligence, meteorological reports, hydrographic information, ephemeral information, climatological information, physiological, biological, and medical information, and special geopolitical and geophysical information that may relate to the mission.

The design can then begin by laying down the format and the connections of all of these information channels, both primary and secondary. The next step is to look at the internal structure of the supporting activities of the staff. The commander filters and interprets the initial input to the system for the staff. The staff filters and organizes the secondary information sources for presentation to the commander. The staff activities can be organized around the operational models. Models are relatable to plans by the Commander and Battle Staff. The commander's interpretation of a directive is essentially in terms of the operational model or group of sub-models. The model implies a certain call or request for data from the auxiliary sources.

Models of the above kind must be in existence for each of the possible kinds of basic operations going into the performance of missions. Each model is called up when appropriate, furnished with the corresponding needed auxiliary data, and utilized to furnish estimates of the probabilities of success, consumption of resources, and other factors entering into the commander's decision.

The commander's decision is translated and expressed in the form of the directive. The format of the directive determines the information requirements. The plan corresponds to the integrated set of operational models. The assumptions correspond to the facts relating the various models or the conditions of the operations. These are part of the commander's decisions. He transmits these together with the mission assignment as part of the directive.

The remaining function of the command is supervisory. As already pointed out, the close supervision of operations is only possible at a level at which the necessary information for close supervision is available. Inappropriate levels of close supervision are not customary in modern commands. The attempt to exercise this kind of supervision is immediately evident at the command level in the proliferation of plans corresponding to the need for covering many contingencies. It also becomes evident at the tactical level in that situations tend to arise that are not covered by the contingent plans, and these situations result in confusion and indecision. The supervisory chain runs as follows:



In order to exercise supervisory control in such a situation some predictive device is needed. The device available and probably the only usable one is the use of the same operational model as was used in planning updated by the action reports from the tactical commands. This device removes the predictable part of the response and leaves the fundamental uncertainty of a magnitude roughly equal to the unpredictable rate of activity by the time lag in the reporting process. This is the fundamental level of uncertainty that must be accounted for by the decisions at the lower echelon.

The following programs must then be spelled out in detail.

1. The program for handling the directive to the command. This program consists of analysis of the directive and mission, together with the plan and other information contained in the directive. In effect, this program identifies the model or models to be used in planning the mission at the local level and provides certain inputs to these models in the form of the commander's interpretation of the directive.

2. The auxiliary information inputs consist of those inputs not furnished by the commander's interpretation of the directive. This set of inputs comes from a number of different technical sources and will in general require preliminary processing for use in the operational model. For each such source, the nature of the preliminary process must be clearly stated in terms of a program for producing the proper inputs.

3. The technical models of the operations themselves are essentially programs. They may be either simple or complex but they ought to be complete. In this connection, it should be pointed out that auxiliary programs may be required for the coordination of separate operational models. In general, a facility for performing this programming will be required. At the higher command levels the complexity of the process may require that mechanical data handling be used so that this ability to provide necessary improvised programs may be critical.

4. The program for preparing the directive to the subordinate commands should specify all of the inputs, and the sources of these inputs for each element covered by the format of the directive.

5. The supervisory program must be provided. This is the program that relates the reports of compliance and other action reports from the subordinate command to the operational models. In effect, any supervisory program contains the same set of models as the set being supervised and in addition contains a supervisory program or model in terms of which the supervisory decisions are generated.

4.0 The Assignment of Activities to Agents

This very complicated process begins with a categorization of activities. It is very difficult to provide a complete and unambiguous categorization of this kind. It is, however, useful to make the following kinds of distinctions.

Command decision is a critical activity, and is not a programmable activity in the ordinary meaning of the term. The fact that there are systems in which the reaction is virtually determined by the stimulus, such as in quick reaction air-defense systems, and that in these cases, the system is virtually automatic ought not to be interpreted to mean that command decisions are made automatically. The proper interpretation is that in systems of this kind although the problem of data handling is extremely complex, there is no essential set of alternative actions that require evaluation as a basis for decision. Thus, the so-called decision is nothing more than a program. Few command decisions are of this kind.

There is a second set of activities that are less critical but still of great importance. Some of these activities could be programmed but are not. There are a variety of reasons for this. For example, one activity of a meteorological specialist is the drawing of isobars. This is a programmable activity. Whether or not to assign such an activity to a program for a machine is a matter of judgment on the part of a system designer. This is not a judgment that can be made in the absence of information as to the competing activities that require machine processing. The first step in allocating agents to the activities is to decide whether or not the activities are programmable. For example, we have already decided that the essential command activities are not programmable. This set is then set aside and the remainder of the set is considered.

Certain activities are partly programmable or more efficiently carried out using a machine program with a certain degree of associated decision making by human agents. Complex tracking problems are sometimes carried out by such a combination of agents.

Finally, there are activities that are programmable and carried out most efficiently by machines. These are activities that, while relatively simple, occur with such frequency or in such a volume as to form bottlenecks in the flow of data to other programs. Generally speaking, activities of this kind tend to be assigned to machines.

For commands at the higher echelons, for example, CINCLANT, it is unlikely that the major problem is so much in the devising of efficient means for handling a large mass of relatively homogeneous data, such as tracking data. The complexity of the problem of the higher commands is not so much in the volume of similar recurring activities but in the fact that a very large number of separate and different actions must be accomplished. This is the difference between two systems one having few input types each with a large input data rate, and another having a large number of input types, each having either one or only a few pieces of data to present.

This last mentioned fact is recognized in the way in which Naval staffs are actually organized and by the way in which the activities are allocated.

The command activities, interpretation, direction, and decision are the sole prerogative and duty of the commander.

The supervision of the staff is generally carried out by a Chief of Staff, who may be the deputy.

The technical evaluations of operations are under the Operations Officer.

Auxiliary inputs to the staff are provided by a number of specialists, Meteorological, Engineering, Ordnance or Weapons, Hydrographic.

Intelligence Officers provide the commander with data on enemy activities (e.g., photo-reconnaissance).

Each of these activities can be expected to encompass many hundreds of different detailed pieces of information. Since the activities are in general not machine programmable, the simplest way of organizing the overall activity is by providing a program in terms of human agents where the activity is not machine programmable. The result of such a program is a complete specification of the set of jobs required by the system.

5.0 The Requirements on the Human Agents

The simplest model in terms of which the requirements on human agents can be stated is the Turing-Post characterization of algorithmic agents. The programs for agents of this kind can be completely specified.

Essentially, these algorithmic agents can perform all ordinary arithmetical operations and such other operations as are reducible to ordinary arithmetic, such as geometrical operations. Agents of this kind differ in complexity and efficiency relative to various tasks. Generally, the efficiency of the agent tends to improve as the program is more specialized. The complexity of the agent depends on the following characteristics. First, the complexity of the input set. This is the set of symbols read by the agent or the set of stimuli to which the agent responds. Second, there is the complexity of the set of responses. The responses may be symbol production or motor activities. Finally, there is the complexity of the internal organization of the agent through which the stimuli and the responses are related. A very simple agent of the Turing-Post variety can be programmed to follow out any arbitrary program whatsoever. Such an agent is a universal agent. Agents of this kind are generally encountered in the form of more or less complex machines. There are a number of important ways in which human agents differ in their method of carrying out a set of programmable activities.

First of all, human agents generally are provided with a large number of programs for meeting a large number of different situations efficiently. It would be difficult, if not impossible to either enumerate the programs or to determine the specific content of such programs. Second, even when human operators are engaged in tasks that are reducible to known machine programs, they tend to do so with a greater degree of self supervision than attends the activities of most machines. While to a certain extent comparisons of human and strictly mechanical capabilities in the area of computation and data processing are speculative, it is literally true that we do not at present know how to write the programs for many human activities, and we have in addition, no clear idea as to the economy or lack of it attending the mechanization of these programs if we knew what they were.

This fact means that many of the job descriptions are essentially circular. That is to say, the job is described in terms of certain programs or generalized capabilities of human agents, these same capabilities being used to describe the agent himself. There is no help for this at the present state of development of systems analysis. The circularity does not detract from the essential practicality of the system in fitting people to jobs; the net effect is mainly in the possibilities that the system of categorization results in inefficient utilization. This last effect is the subject of research that continues, and does not really bear on the immediate problem of the present study.

What is essential is that for many of the activities, we do not define these activities in an algorithmic way and do not apply any ultimate criterion to identify the agents capable of performing the activities. This is obviously true in the activities of the commander, at least the ones that are apparently the most essential ones. Here we appeal to a reference group from which commanders are selected by custom and according to law. Many reference groups other than the reference group of officers qualified for command are used, for example, meteorological officers, EDP specialists, and the other groups of specialized experts. The essential job of the system designer is to assign tasks to reference groups in an appropriate way.

The foregoing considerations as to the ways in which tasks and people must be related by the system designer gives a number of clues as to the kind of training that will generally be necessary, and moreover provides this kind of training well in advance.

Some of the more important kinds of training for which there is some degree of a prima facie case for a requirement are given as follows:

1. Training in communication between reference groups.

   Each reference group is familiar with a set of symbols or stimuli which serve as inputs to the group. When reference groups that are essentially different are to operate in a system, a degree of familiarity of each with the symbols and stimuli of the other is a necessity. This is particularly true for all forms of technical expertise. Here the output symbols must be understandable to the reference group to which these symbols are being furnished. In other words, the output of one group must fall within the set of stimuli to which the recipient group can respond.

2. Training in man-machine communication.

   The problem is similar to the problem of communication between different reference groups. Machines generally are restricted to a rigid format for accepting inputs, and produce outputs selected from a specific set of symbols. The output symbolism must be intelligible to the set of users.

3. The need for redundancy.

Algorithmic mathematics suffers from an important and well-known drawback. This drawback is essentially the sensitivity of the outcome of a computational program to errors at various stages of the program. This circumstance requires that extreme accuracy in the individual steps must be achieved in order that very moderate standards of accuracy can be assured in the final results. To a certain extent, all organized human affairs suffer from this same defect. The chain of events from the wanted nail, the lost horseshoe, horse, battle, and kingdom lost expresses this anxiety over the effect of the minute on the over-all scheme of things. The general method used to minimize effects of this kind is in the application of various tests of consistency, or in the use of sampling procedures that tend to reduce the possibility of propagation of the effects of small errors. From an organizational point of view, a good deal of useful redundancy can be injected into the system if the individual reference groups are at least formally indoctrinated into the nature of the activities of the remaining groups. This kind of indoctrination is a virtual necessity in complicated systems.

4. Training for supervision.

Supervision introduces a special kind of redundancy into the system. A supervisor in effect understands the programs of the agents he is to supervise, and in addition, follows a program of his own, an executive or supervisory program. Typically, the supervisor does not monitor all of the input symbols acted upon by the agents under his supervision but relies upon sampling or tests of consistency. Supervision in the sense in which it is understood here is an executive function designed to insure conformity to directives and quality of results. As such supervision refers to two different levels of activity, internal and external. Supervision of external activities is a function of the command itself that has already been discussed. Internal supervision is required to assure quality of the work of the staff.

In setting up the relationships between men and tasks in the system, we are able to distinguish a number of classes of agents. The first class is that of the commanders in the system. Clearly, this class is a given reference group. This group defines its own activities and generates it own criteria.

The second class is a closely related one, that of operations officers. This group is also a given reference group. It is possible to apply ultimate criteria within the class, at least for some of its functions. These functions are essentially the technical ones that deal with individual algorithms or models, at a given level. It is more difficult to provide ultimate criteria for these individuals at the next higher level of activity, namely the integration of the algorithms or models, into more inclusive systems, and in the notion of grasping the significance of the basic directive and missions. These latter abilities are usually simply implied by membership in the reference group.

The third class consists of technical specialists. These individuals are generally members of well-described reference groups; they are, in fact, subgroups of the group of scientists or technicians. In common with the previous group, there are certain criteria applicable to the members for a certain part of their activities but substantial and significant portions of their competence is inferred from the fact of membership in the group.

A fourth class is the class of technicians. This class is distinguished from the previous class in being drawn from different reference groups. In terms of any given ultimate criteria, individuals from different groups may be classed together. However, the unprogrammable portion of the activities of a given reference group generally bars the use of individuals in more than one category. The technicians are distinguished in another way. Their activities in a command and control center are generally highly specialized, and sometimes even unique. A good part of their activities are programmable and are, whenever possible, reduced to algorithmic behavior. The technical activities at this level are generally in the nature of support, such as the operation of communications equipment, the operation of plotting centers, and operation of data reduction centers.

The demands for supervision essentially require training at all levels, even the highest. Effective supervision requires a knowledge of the activities being supervised, and in addition requires an inspectional procedure together with some rule of executive action based on the outcome of the inspection. The symbols used in communication must be intelligible to all significant members of the group if a proper level of redundancy is to be obtained. At least each individual having a supervisory or monitoring function must understand the significance of the symbols produced by the group under his supervision.

When complex data reduction is contemplated in any system or when the basic data consists of many different individual items, special executive or supervisory routines will generally be devised. These routines are essentially in the nature of special reports for executive purposes. When dealing with machines, such a system amounts to having a limited set of questions that can be asked at appropriate stages of the data reduction. It is essential that the nature of these questions and the nature of the machine response be clear to the supervisory personnel, in order that they understand the means available for supervision of the process. This will generally require a particular kind of training.

These remarks apply to all classes of agents in the system who are charged with any supervisory or monitoring function.

Technicians generally have additional problems. The symbols used in communication in the system are generally highly specialized, and in addition, sufficiently numerous as to provide a problem in training for symbol recognition. Morse code is a commonplace example of the need for training in symbol recognition. The symbols used in representing air battle situations provide a second example, and the symbols used in synopsizing the weather reports provide a third. Examples of this kind are numerous and commonplace. Command language as commonly used tends to be highly compressed from a semantic point of view, this compression being achieved by the introduction of numerous special symbols. The net effect of this compression is the reduction of redundancy from the level commonly present in the language. This does not mean that the command language is less efficient. On the contrary, it is more so since much of the redundancy required for the general kind of communication for which the common language is adapted is not usable in an effective way in the more specialized military context. The expansion of the ordinary language by the introduction of numerous symbols does create a learning problem to which the previous examples relate.

The second problem in the training of technicians in data reduction, communication, and computational activities is in symbol production. The input and output languages of the technician are not always the same thing. For example, a technician can be taught to draw isobars and isotherms from messages containing strings of coordinates (x_1, x_2, x_3, x_4), the first two coordinates representing position and the second and third representing temperature and pressure. Here the input symbols are strings of numbers, and the output symbols are lines on a chart.

A closely related example occurs in plotting in which direction finding is being done. The inputs to the plotter are pairs of symbols in which angles and observer stations are given. The plotter draws the bearings on a chart to which the observers are properly related and marks the intersections.

The third problem in training technicians is in establishing the desired associative behavior between input and output. This is not a simple problem, even conceptually. The Turing-Post model of algorithmic behavior applies here. The gist of the problem is in the fact that practical agents usually do not exhibit the same associative behavior for all occurrences of a given input symbol as a stimulus. Turing's model is particularly clear on this point. He observes that not only is the agent capable of shifting from one rule of associative behavior to another, but he is able to apply a rule for shifting his attention from one class of symbols to a second class, in other words, to shift attention to different portions of his environment. A program in this sense is a set of rules depending only on the particular state of the agent and the symbol last operating as a stimulus that establishes the type of associative behavior both with reference to the output behavior, but with reference to the next type of internal state of the agent.

This rather abstract notion is set forth clearly in Reference 4, and will not be elaborated on here. However, the significance for the problem at hand will be expanded upon. In the example given above, it is evident that numbers do not result in an invariable response. The first pair of numbers results in a plot of position. This association of a number pair with a position on a chart is one type of associative behavior. Having located all positions on a chart, the agent shifts to a new type of associative behavior relative to the set of numbers (representing say, temperatures, on the chart). This new rule is one by which the agent is able to construct the contours approximating to the locus of points of constant temperature. Presumably, the agent is even more complex and having completed this task, shifts his attention to symbols representing pressures and provides a chart of isobars.

In well established training situations in which old material of a general nature is being taught, such as for example in instruction in arithmetic, this course of events is quite obvious. We begin with symbol recognition, the symbols being usually the ten symbols of the decimal system. The next step is to establish certain kinds of associative behavior. Addition is one such form of behavior. This is a rule relating pairs of integers to a single integer. In this case, the input symbol can be regarded as the pair and the output symbol as the single associate. Arithmetic behavior is built up out of simple associations of this kind. A fundamental problem in training of this kind deals with the question that must invariably occur when one teaches arithmetic. Suppose that an individual has been taught the algorithm for multiplication. The idea of algorithm is captured in the notion that although the individual was tested by his ability to work particular examples, i. e., by a sampling of the possible situations, we somehow believe after a certain number of such samples have been taken, that the individual has finally learned to multiply or that he has not. At some state we infer from observing the behavior of the agent in response to stimuli, that the individual is correctly programmed. The complete chain whereby an algorithm such as multiplication is established as a program and essentially verified by a supervisor, is quite a long and difficult process. When new algorithms of any degree of complexity are being set up and established in human agents, a second problem occurs that compounds the mere problem of establishing the algorithm. This second problem arises from the fact that new systems quite often contain flaws not intended and not apparent until a particular situation is realized. Agents are programmed completely if their behavior is to be algorithmic. If situations are presented to the agent for which he has not been programmed, he will either stop, or proceed in some irrelevant manner. The training of agents or operators, therefore, must often proceed under adverse circumstances in which significant alterations of the system program are being made.

6.0 Training Requirements and Training Emphasis

The preceding paragraphs have given indications of the types of agents that will be utilized in the system and the types of activities in which these agents will be engaged. In addition, the point in the system design at which human job requirements are first subject to identification has been pointed out. While it should be recognized that a command and control system is not necessarily a static unchanging system, and may in fact go through many evolutionary modifications, it is still true that when a new system or a new component to such a system is introduced, there is a first point in time at which the supervisors of the system can be satisfied that the system or component is in complete operation as intended. A primary training goal ought to be established to bring about this state of completely effective operation, if possible, at the same time as the actual construction of the physical portions of the system and their installation is complete, or as soon after this point in time as possible. This means that all of the participants in the operation of the system including the supervisors should be provided with the necessary prior training as outlined above in order that they can at least begin to function in such a way as to allow for the ultimate acceptance of the system. The users and supervisors must, therefore, accept at least that part of the training burden that allows them to judge the degree of operational effectiveness of the system. This requirement means that everyone in the system must initially be trained up to some point, that point in fact at which the system becomes operational, and can be so judged by the supervisory process. Prior to this point, the system cannot be meaningfully described as operational.

Beyond this point at which the system becomes operational, it will in general become evident that further training may be useful. Training of the kind understood here is that which would go to the increasing of the efficiency of the system, in terms of rate of operation or other measures of utility peculiar to the particular command the system is to support. Of these two training situations, the first, that of bringing the system into operation at a given acceptable level of effectiveness is probably the most severe of the two, and is clearly the more immediate of the problems. First of all, the system cannot be monitored without the existence of sufficiently well trained operators, to operate the system at a level at which monitoring is meaningful. Second, monitors must be trained to a point that they can make a decision that the system and its operators are actually operating effectively. These requirements raise a number of problems that while not the primary concern of the present study, still ought to be mentioned. Operators should be trained in the system component operation sufficiently early. If the portions of the system cannot be directly connected as required, simulation techniques can be resorted to. Some supervisory training ought to be undertaken concurrently with the training of the operators. This supervision of the training of operators is invaluable for establishing the validity of the supervisory programs that will be designed into the system.

APPENDIX B

OPERATIONAL SYSTEM DESCRIPTION

This description is in the form of an operational sequence diagram (OSD). In this format, each of the major components of the system is identified and the tasks performed by each in carrying out the specified function are shown in temporal and functional relationship.

What is described here is the sequence of activities that would follow the receipt by a command and control system of an order from a higher command or of information about an event that requires (or potentially could require) the use of forces under the command and control system. The sequence of activities has as its goal the assignment of those forces that are adequate to the requirements but whose use will not impair the command's capacity to fulfill its mission in other areas. This has been titled, "Assignment of Forces."

In using this description, it is necessary to refer to both the OSD and the narrative. The OSD contains brief titles for each activity which are described in detail in the narrative. The narrative is keyed to the OSD by numbers appearing at the beginning of each paragraph in the narrative. The OSD is organized on an unscaled time line which starts at the top of the diagram as time-zero and proceeds downward. The OSD shows the functional relationship among activities by means of the information flow lines connecting them. Certain conventions are followed in the construction of the OSD:

- Each activity is shown on the OSD as being in one of three categories. The category symbols are numbered in the diagram and refer directly to the numbered paragraphs in the following section.

  △ Monitoring - which is a state of readiness to receive information, either from outside or within the system. A triangle is used to denote this on the OSD.

  ○ Processing - a generic title for all of the tasks described in the classification. The narrative specifically identifies these. A circle denotes processing on the OSD.

☐ Action - the transfer of data within the system and control activities. Some actions are implied by the flow lines, others are indicated by squares on the OSD.

- Each process depends on input either from outside the system or from a preceding process. This has been shown by means of flow lines between processes and the external sources (communication terminals) and flow lines within a series of processes.

- Machine (EDP) activities are identified as such in the narrative.

The following is the narrative portion of the description and should be read only in conjunction with the OSD that is illustrated in this report.

1. Monitoring. This is the initiating activity in system operation. At this point the system is in a state of readiness to receive information input into the command (or planning) activity. The activity represented is an ongoing, active, perceptual process, whereby the various channels of data coming into the system are scrutinized for items of potential significance. During this activity an external situation is perceived as warranting special attention.

Tasks:

- Correlation and comparison--incoming reports are compared with previously stored data to identify trends or deviations.

- Identification of potentially significant data.

- Data Storage--sufficient details of the reports regarding the situation are retained to facilitate later processing of this data.

2. Monitoring. This symbol indicates a state of readiness for informational input, but in a more passive sense than the Command Post. The commander is constantly involved in command activities not related directly to the processing of all incoming data to the Command Post. However, he must be ready to receive information of any significant development from within the Command Post or from sources external to the Command System.

3. Processing. A review and evaluation of the potentially significant data with regard to its severity is made by the Command Post. A situation is considered severe or significant if it requires further processing by command elements to identify or develop a responsive posture.

Tasks:

- Qualitative evaluation--the severity of the situation is ascertained.

- Simple decision--the decision is made as to whether the command elements of the system should be concerned with the situation.

4. Action. If the decision made in No. 3 is "No," then the Command Post resumes the monitoring state indicated in No. 1.

5. Processing. If the decision made in No. 3 is "Yes," then the following decision is made:

Task:

- Simple decision--the decision is made whether to alert higher order command elements of the system to the nature and development of the situation.

6. Action. If the decision in No. 5 is "No," then the Command Post resumes its monitoring state as in No. 1.

7. Processing. If the decision in No. 5 is "Yes," then an alert message is composed by the Command Post Staff and transmitted to the Commander's Staff (Operations, Plans, Intelligence, Logistics), the Presentations Section, and the Commander himself.

Tasks:

- Synthesis--all the data of immediate access to Command Post personnel regarding the situation are collated, paraphrased and integrated into a concise alerting message.

- Routine Action--a brief synopsis of the written message is transmitted by telephone to the appropriate addressees.

- Routine Action--the above data is formatted and written up into a written message and sent to the addressees.

8. Processing. The Commander's Staff receives the alert and assimilates the details.

Task:

- Data Storage--the significant factors of the alerting message are retained for later processing.

9. Processing. The Presentations Section receives the alert and assimilates the details.

Task:

- Data Storage--the significant factors of the alerting message are retained for later processing.

10. Processing. The Commander receives the alert and assimilates the details.

Task:

- Data Storage--the significant factors of the alerting message are retained for later processing.

11. Monitoring. The Command Post returns to a monitoring state following the dispatch of the alerting message. This state is a more focused monitoring of the data parameters concerning the situation, rather than the general monitoring of all data parameters as in No. 1. From this point on until the successful completion of the ordered naval action, most of the monitoring effort of the Command Post becomes successively more focused on parameters of the situation at hand.

12. Processing. The Commander's Staff, upon receiving the alert, conducts an internal study to identify any SOP or naval policy that would apply to this situation and be useful in determining a naval response.

Task:

- Related Data Identification--using the details of the alert to serve as selectors, any available stored policy or SOP data are identified. This is not a retrieval from the Command Support Center, as such, but directly from the various members of the Commander's Staff.

13. Processing. Using the situation information contained in the alert message as a basis, information is generated for use in retrieving any stored plans. This "plan selector" information takes two forms. One form is tailored for transmission to the Command Post and the other for transmission to the Command Support Center.

Tasks:

- Synthesis--the plan selector information is synthesized from the information contained in the alert message. For the Command Support Center this plan selector information must be worded in terms of the data base file structure to facilitate retrieval of plans by automated means. For the Command Post, the plan selectors can be worded in concise manner without regard to any structure of data files. In general, plan selector information contains data regarding the nature of the situation (i.e., landing of enemy arms in a neutral country, attack on the United States, etc.), and the location of the situation.

14. Action. Using the plan selector information generated by the Commander's Staff, the Command Post searches and retrieves any plan brief information they may have as backup to the automated Command Support Center. The plan information retrieved by the Command Post remains in the Command Post to serve as a guideline for any later organization and assessment of the incoming data regarding the situation.

Task:

- Routine Action--a manual retrieval is effected for available abstracts of plans.

15. Action. The request for plans is received by the Command Support Center and is implemented into a retrieval for stored plans.

Tasks:

- EDP Action--the plan selector information is used in the retrieval of plan data from the data base.

- Routine Action--the retrievedplan data is transmitted to the Commander's Staff and the Command Post.

16. Processing. All applicable plans, policy and SOP and previous orders are now evaluated for eventual input to the preparation of a briefing for the Commander. At this time, the staff makes initial recommendations for naval action on the basis of the evaluation of the above material.

Tasks:

- Correlation and Comparison--the data regarding the situation is correlated and compared with the plan, policy and SOP data to determine whether the Navy presently has a valid responsive posture.

- Qualitative Evaluation--the merits and demerits of the existing body of responsive data are evaluated, resulting in recommendations for fleet action and/or system planning activity to correct any inadequacies in the responsive posture.

- Ranking of Alternative Actions--if alternative courses of action for the fleet and/or system are determined, then a ranking of these may take place as to their estimated payoff.

- Synthesis--the results of the above activity are integrated, paraphrased and formatted into a concise report for use by the Presentations Section in the preparation of the briefing for the Commander.

17. Processing. The plan information, retrieved by the Command Post from their own files and received from Command Support Center, is assimilated by the appropriate Command Post personnel.

Task:

- Data Storage--the significant aspects of the plan information are retained.

18. Processing. All the plan information in the hands of the Command Post personnel is used as a structuring concept for developing a synopsis of the available situation data. This is not an evaluation of the data as much as a compilation. This report is forwarded to the Briefing Section for presentation to the Commander.

Task:

- Synthesis--the available data regarding the situation are integrated, paraphrased and formatted into a concise situation summary. The summary would include data from such sources as news reports, sightings, intelligence, movement reports, etc.

19. Processing. Following the transmission of their review of plans, policies and SOP's, the Staff now begins to develop a detailed and comprehensive situation summary. This summary includes not only current news and intelligence data regarding the situation, but the following:

- Pertinent historical news and intelligence data regarding political, economic and psychological factors.

- Data regarding physical factors of the potential operating environment (hydrography, sea lanes, proximity to enemy territory or forces, weather, terrain features, geography, etc.).

- Forecasted statuses of situation data parameters.

The initial summary of the situation generated by the Command Post serves as direct input to this larger scale effort of the Commander's Staff.

Task:

- This activity initiates the tasks that are described completely under No. 33.

20. Processing. The identification and review of plans, policies, and SOP's by the Commander's Staff and the initial situation summary by the Command Post are used as source material for preparing a briefing for the Commander and his Staff.

Tasks:

- Synthesis--the above information is integrated, paraphrased, and formatted into an audio-visual briefing for the Commander and high level staff members.

- Routine Action--various clerical tasks are performed in writing up the text and graphic aids for the presentation.

21. Action

Task:

- Routine Action--the briefing material generated in No. 20 is presented to the Commander and his Staff.

22. Processing.

Task:

- Data Storage--the key facts of the briefing are assimilated and retained by the Staff.

23. Processing. The Commander now assimilates and evaluates the material of the briefing. He is particularly concerned with evaluating the Staff recommendations for implementation of any available plan details, in view of the available situation factors regarding the incident under consideration. The Commander thus evaluates any Staff recommendations for action.

Tasks:

- Data Storage--the key facts of the briefing are retained by the Commander for further processing.

- Correlation and Comparison--the Commander correlates this incident, if possible, to any applicable SOP's or previous orders, to retrace the Staff's process for making any initial recommendations for action.

- Identification of potentially significant data--the Commander identifies the data categories which need further processing, e.g., aspects of the situation which may require more data to increase the validity of the responsive posture.

- Qualitative Evaluation--the Commander evaluates the Staff's recommendations for fleet action and/or system planning activity based on available plan details. Basically, this is an evaluation as to current command responsive posture and the need for further planning.

- Complex Decision--the Commander must now decide whether the plan details are sufficiently complete to result in immediate issuance of orders to the fleet, or further planning activity by his Staff.

24. Processing. If the available plan details are determined valid and in sufficient detail, the Commander gives his approval for writing them up as orders for transmission to the specified fleet units. He may make small changes in wording and inflection at this time.

Task:

- Deduction--the Commander deduces from the available data any changes in wording of the impending orders to increase their effectiveness by making them specific to the current situation.

25. Action. The staff begins to write up the plan details and suggestions from the Commander as orders for the fleet. This activity includes the insertion of such facts as location of the incident, description and location of the operating areas, dates and time for the various phases of deployment, etc.

Task:

- Routine Action--such activities as formatting and typing of the orders take place at this time.

26. Action. The Command Post directs the written-up orders to the predetermined addressees both within the system (Command Support Center for filing) and external to the system (the fleet, CNO, the President, etc.).

Task:

- Routine Action--the Command Post addresses the orders to the appropriate destinations and orders the Communications Section to transmit them.

27. Action.

Task:

- Routine Action--the Communications Section transmits the orders by standard communication devices to the destinations stipulated by the Command Post.

28. Action.

Task:

. Routine Action--the Command Support Center selects the appropriate file and enters the orders into the data base.

29. Processing. Following the evaluation of the available plan details and a resulting decision that they are either not valid and/or in sufficient detail. the Commander then directs the system in planning activity. Here, the Commander utilizes a previously stated mission concept and objective of such a mission. This may be the result of a previous directive by CNO regarding a contingency of the type at hand, or a consultation with CNO shortly after the occurrence of the incident. The Commander now states the mission (or action to be taken by the fleet) and objectives of the mission (what is accomplished by the mission) and orders the Staff to develop the operating requirements and assign the appropriate fleet forces.

30. Processing. Using the Commander's statement of the mission and the mission's objectives, the Staff now identifies all the data parameters involved in developing a detailed situation summary. The contents of a detailed situation summary are specified in general terms. Areas included are the following:

1. Characteristics of the potential operating area

   a. military geography

      1) topography
      2) hydrography
      3) climate and weather

   b. transportation
   c. telecommunications
   d. politics
   e. economics
   f. sociology
   g. science and technology

2. Relative combat power

   a. enemy

1) strength
2) composition
3) location and disposition
4) reinforcements
5) logistics
6) time and space factors
7) combat efficiency

b. friendly

1) strength
2) composition
3) location and disposition
4) reinforcements
5) logistics
6) time and space factors
7) combat efficiency
8) friendly force assistance

However, these general areas must be defined in detail and placed in the context of the particular situation at hand.

Due to the nature of the situation, other specialized categories of data may be appropriate and are identified. The Staff must translate its needs (general and specific) for situation data into terms of the file structure of the data bases. This translation is necessary for efficient retrieval of the data by the Command Support Center.

Tasks:

- Related Data Identification--the data parameters composing the situation summary are related to categories of stored information in the data base, and the needs for data are specified and requests for this information are worded in terms of the file structure and content of the data base.

- Deduction--any specialized data parameters pertinent to the development of a detailed situation summary are deduced from the available situation data and mission statements.

- Routine Action--requests for all situation data from the Command Support Center and the Command Post are generated, being worded in terms of the data base content and file structure.

31. Action.

Tasks:

- EDP Action--the Staff request for situation data is translated into a retrieval of the specified information from the data base.
- Routine Action--the retrieval situation data are organized and packaged for transmission to the Staff.

32. Action.

Task:

- Routine Action--as per the request from the Staff, all currently received situation data are collated and sent to the Staff (i.e., TTY report, intelligence).

33. Processing. The situation data received from the Command Support Center and the Command Post are now worked up into a detailed situation. It should be noted that this process of developing a detailed situation summary is not a one-shot process, but an ongoing activity that continues throughout the planning process. Changes in the quality and vector of dynamic situation data parameters (i.e., weather, enemy activity, political factors) may cause a change in the direction of the planning process (i.e., reformulation of the mission). Thus, the situation summary must be continually updated in varying degrees of detail until the mission has been completed, and the Commander informed of any new developments.

Tasks:

- Qualitative Evaluation--the situation data are evaluated and significant factors are isolated and emphasized in the write-up. The term "significance" refers to any situation factors that appear to affect the reaction time and/or magnitude of naval response. If any such factors are isolated, the Commander is notified.
- Quantitative Evaluation--the status of some situation parameters may be evaluated in a quantitative fashion by assigning a numerical value to some predetermined scale. Examples are assignment of a threat value to enemy activity and potential strike power, or a numerical representation of weather conditions as they affect the capability for conducting operations.

- Correlation and Comparison--significant factors of the current incoming dynamic situation data are correlated with the stored historic data to note changes and trends.

- Deduction--where appropriate, the future status of dynamic situation parameters is deduced from the preceding processing.

- Synthesis--the evaluated and correlated data are paraphrased, integrated and formatted into a comprehensive situation summary report in such a manner as to allow rapid update of the material.

- Complex Decision--the decision is made as to when the development of the situation summary is sufficiently adequate to proceed to develop a set of general operating requirements (GOR).

34. Processing. After stating the mission and objectives, the Commander actively monitors the progress of the Staff in the assignment of forces in the mission. In particular, he attends to any significant developments in the situation (actual or derived by the Staff). If any significant developments occur, the Commander is prepared to consult with the Staff and CNO regarding a reformulation of the mission and/or objectives.

35. Processing. The Command Post, as a function of its review of plan briefs and synopsis of current situation parameters, narrows and focuses most of its attention on the dynamic situation data parameters previously judged of greatest importance by the Staff. The Command Post (C. P.) then continues this state of monitoring and acts as a filter for incoming information, feeding it continuously to the Staff as it becomes available.

Task:

- Identification of potentially significant data--the C. P. continuously must isolate potentially significant items of incoming information and be prepared to notify the Staff regarding these items.

36. Processing. The Staff begins deducing the operating requirements for forces. The first step is to formulate the general operating requirements, i.e., the gross kinds of operations that are to be performed by fleet units. The contributing data to this process are the previous analysis of the situation and statement of the mission and mission objective.

Task:

- Deduction--statements regarding the types of actions to be performed by fleet units are deduced that, in the estimation of the Staff, will fulfill the missions. These general operating requirements are action statements specific to types of fleet units such as:

  - Reconnaissance by aircraft
  - Underwater surveillance by sonar-equipped ships
  - Surveillance of the surface of the sea and air by radar-equipped ships
  - Specific strike operations by aircraft and ships
  - Landing of special forces by submarines
  - Etc.

37. Processing. Another intermediate step in developing the complete set of operating requirements is the specification of the type and number of fleet units to perform the operations in step No. 36.

Task:

- Deduction--the type and number of units necessary to perform successfully the general operating requirements are deduced. To perform this process, reference to documentation stating the operating characteristics or capabilities of various classes of weapons systems may be necessary. This documentation would be in the hands of the Commander's Staff.

38. Processing. The set of specific operating requirements is generated. These specific operating requirements are composed of statements specifically defining the following:

- The location of operations (latitude/longitude)
- The time of onset and offset of particular operations
- The degree to which the specified operation will be carried out, or the frequency of performance

Task:

- Deduction--the specific operating requirements are deduced on the basis of the situation summary, missions, general operating requirements, type and number of units, and operating characteristics of types of units.

39. Processing. It becomes necessary at this time to determine the disposition of potential units with respect to the operating area. Thus, the staff formulates a request, worded in terms of the file structure and content of the data base, for the following information:

- The name and location of all types of units stated in No. 37, within a specified radius from the potential operating areas stated in No. 38.
- The distance of these units from the operating areas.
- The estimated time for these units to reach the operating areas.

Tasks:

- Deduction--the radius must be deduced within which to conduct the search for the name/location/distance/time information about units.
- Routine Action--the request for the above information must be formulated for transmission to the Command Support Center.

40. Action. The request for name/location/distance/time data is received by the Command Support Center and a retrieval of this information from the data base is initiated. The retrieval process of this information is expected to be an automated one, attributed to a computational capability of the EDP portion of the Command Support Center.

Tasks:

- EDP Action--the retrieval for location/distance/time information is effected as per the request of the Staff.
- Routine Action--the retrieved data are organized and sent to the Commander's Staff.

41. Processing. On the basis of the name/location/distance/time data received from the Command Support Center, the Staff must identify specific units (by name) which appear to be capable of reaching the operating areas within the time frames specified in the SOR. For each type of unit there may be several acceptable alternatives.

Tasks:

- Simple Decision--the decision must be made as to the units which are capable of reaching the potential operating areas within the time frame(s) specified by the SOR and/or mission.

- Ranking of Alternatives--the possible type alternatives are ranked in terms of their operating capability to reach the potential operating errors.

42. Action. Once the better distance/time type alternatives have been identified, then an estimate of the status of these forces becomes necessary in the decision-making process of force assignment. The term "status of forces" refers to information relating to:

- Present commitments (if any) of these forces and any plans for their future deployment.

- Fighting status or operational capability of units:

  - Weapon systems operational
  - Crew readiness
  - Food stores
  - Fuel supply
  - Ammunition reserve

With regard to the fighting status or operational capability of ships, the Staff is interested primarily in an estimate of fighting status or "readiness" projected to arrival at the operating area.

Tasks:

- Routine Action--the request for all relevant projected force status data for the better distance/time alternative must be generated for transmission to the Command Support Center and the Command Post (a standard format exists for the request).

43. Action. It is assumed that there exists an automated capability for determining the "readiness" of units at the time they reach the area of deployment. This capability includes a program whereby such selectors as present status, operating requirements/rates of consumption, distance, time, underway replenishment are inserted and an operational readiness index or capability to perform (percentage) is automatically generated.

A prerequisite to this process is the determination of the present status of units for which the readiness estimates were requested by the Commander's Staff.

Tasks:

- EDP Action--the request for force status data (present and future commitments, present fighting status/operational capability) is translated into a retrieval of force status data.

- Routine Action--the retrieved data are organized and formatted for later processing.

44. Processing. The Command Support Center, after querying the data base, identifies any data suspected as not being current, and requests the Command Post to contact individual units to secure the current information.

Tasks:

- Quantitative Evaluation--the Command Support Center evaluates the retrieved force status data with respect to its currency.

- Deduction--the Command Support Center deduces what required data are not stored, or what stored data are inadequate (i.e., unstored operation orders, or non-current unit force status reports).

- Routine Action--the Command Support Center requests this information from the Command Post.

45. Action. The Command Post receives the request from the Staff for force status data and sets about retrieving any data they may have. At the time the Command Post may receive a request from the Command Support Center to contact any units and ascertain their status, where the required information is evaluated as unstored or non-current.

Tasks:

. Routine Actions

  - Retrieve any current force status data such as applicable Orders to the Fleet that may be in the possession of the Command Post.

  - Directly contact any units requested by the Staff and/or Command Support Center and procure the required status data.

  - Collate and organize all Force Status data for transmission to the Command Support Center.

46. Action. The Command Support Center now receives all available required force status data and determines the projected readiness indices for the distance/time alternatives requested by the Commander's Staff.

Tasks:

. Identification of Related Data--any selector information not presently available, such as consumption rates for units and underway replenishment figures, is obtained.

. EDP Action--the selectors for retrieving projected readiness estimates are inserted.

. Routine Action--the retrieved force readiness data are collated and organized for transmission to the Staff.

47. Processing. The staff now has in its hands the following information:

. The latest available data regarding the situation
. The SOR
. Force Commitment Data
. Projected force readiness data for the "reasonable" alternative units supporting the requirements for type and number

The above data are processed and decisions are reached about the assignment of forces to the mission and SOR. As a result of the process and any new developments in the situation, portions of the SOR may be revised.

Tasks:

- Data Storage--the significant features of the above data are assimilated and retained for data processing.
- Qualitative Evaluation/Complex Decision--the force commitment data must be evaluated and the decision must be made as to what units are or can be made available for this mission with respect to the criticality of their present and planned deployment.
- Qualitative Evaluation--the estimated force readiness data and the SOR are analyzed and evaluated with respect to each other. At this time the readiness data are analyzed with respect to time to reach the operating area and a reference is made to the SOR to determine the stringency of the time requirements to reach the operating area.
- Complex Decision--after determining the criticality of the time parameters, decisions are made as to the importance of units having complete operational capability at the time of arrival in the operating area.
- Qualitative Evaluation--the situation data are evaluated and any significant developments are noted that may require a revision of the SOR.
- Complex Decision--specific units by name and type and alternatives are assigned to the SOR, with the decisions reached being a logical outgrowth of the preceding activity. The SOR and latest situation summary and forecast form in part the decision rules for making the decision.
- Quantitative Evaluation/Ranking of Alternatives--alternative configurations of force assignments are assigned probabilities of success and ranked in order of preference.

48. Action.

Task:

- Routine Action--the Command Post receives the recommendations for force assignment from the Staff, and sends an alert to the units involved to prepare themselves for possible deployment.

49. Processing. The recommended force assignment, SOR, and latest summary of the situation are received from the Staff and are organized into a briefing for the Commander.

Tasks:

- Synthesis--all of the above material is collated and integrated into a briefing format for the Commander. Any presentations such as maps, charts, or alphanumerics are identified at this time.

- Routine Action--all briefing material is prepared for presentation to the Commander.

50. Monitoring. The Command Post continues its focused monitoring of the situation for any new developments.

51. Action.

Task:

- Routine Action--the briefing on the force assignment recommended by the Staff is delivered to the Commander.

52. Processing. The Commander evaluates the force assignment and SOR and either approves them as they stand or makes recommendations for revision.

Tasks:

- Qualitative Evaluation/Deduction

  - The Commander evaluates the details of the briefing and deduces any revision in the force assignment or SOR.

53. Processing.

Task:

- Qualitative Evaluation--the Staff evaluates any revisions of the force assignment or SOR made by the Commander.

54. Processing.

Task:

. Deduction--after reviewing the recommendations for change made by the Commander, the Staff verifies the Commander's revisions or deduces alternative suggestions.

55. Processing. If the Commander has no recommendations for changing the force assignment and SOR recommended by the Staff, he approves them and orders the Staff to write them up as Orders to the Fleet.

56. Action.

Task:

. Routine Action--the Staff writes up the current summary of the situation, the approved SOR and force assignment into a prescribed format as orders for transmission to the appropriate fleet units. The units intended for deployment are specified by name.

57. Action.

Task:

. Routine Action--the Command Post directs the orders to the prescribed list of addressees.

58. Action.

Task:

. Routine Action--the Communications Section sends out the orders over the appropriate communication modes to the fleet units involved and other external addressees such as CNO and the President.

59. Action.

Task:

. EDP Action--the Command Support Center enters the orders into the data base.

60. Monitoring. The Command Post selectively monitors both the situation and the implementation of the orders and progress of operations. Any significant developments in any of the aforementioned areas must be identified and passed on to appropriate command elements of the system. This could result in a recycling of all or segments of the foregoing force assignment process.

Note: It is assumed that steps number 1-21 would proceed rather rapidly in any real situation, with the ensuing steps consuming a greater amount of time due to their greater degree of complexity.

APPENDIX C

APPLICATION OF TAP

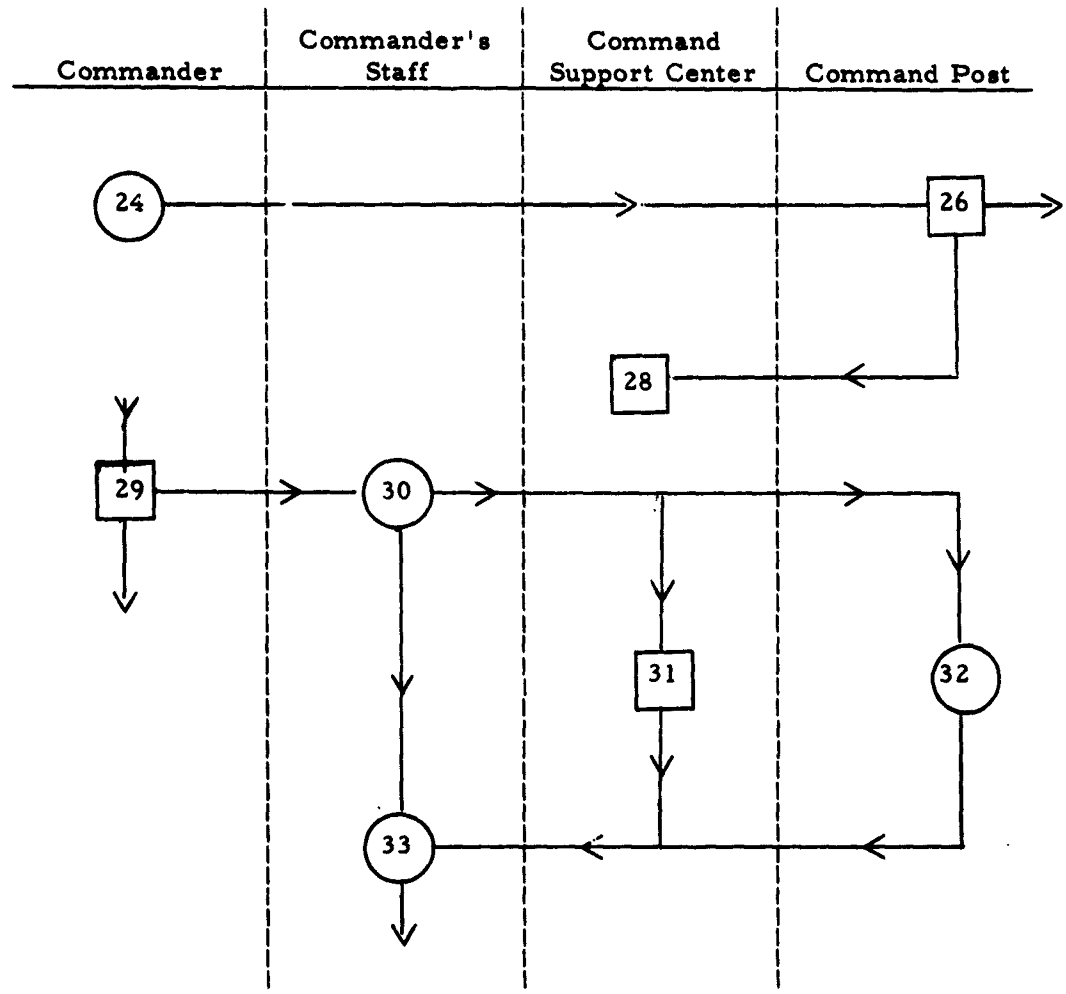
The following example illustrates the difference between the data processing-handling tasks that can be accommodated by quantitative techniques and the command tasks that cannot. Figure 1 is the basis of this example which is taken from the strategic command system model presented earlier in this report. What is shown in Figure 1 is a sequence of activities concerned with the retrieval of data for a situation summary and the development of the summary. Items 29, 30, and 33 on this sample sequence are items of command decision. They are complex activities and include evaluative and complex decision-making tasks as described in the classification presented earlier. The descriptions of these three items are presented below to illustrate the nature of the activities that make them up. (These descriptions have been shortened slightly from their original form.)

Item 29. Processing. Following the evaluation of the available plan details and a resulting decision that they are either not valid and/or in sufficient detail, the commander then directs the system in planning activity. Here, the commander utilizes a previously stated mission concept and objective of such a mission. This may be the result of a previous directive by CNO regarding a contingency of the type at hand, or a consultation with CNO shortly after the occurrence of the incident. The commander now states the mission (or action to be taken by the fleet) and objectives of the mission (what is accomplished by the mission) and orders the staff to develop the operating requirements and assign the appropriate fleet forces.

Item 30. Processing. Using the commander's statement of the mission and the mission's objectives, the staff now identifies all the data parameters involved in developing a detailed situation summary. The contents of a detailed situation summary are stated in general terms. Areas included are the following:

1. Characteristics of the potential operating area

   a. military geography
   b. transportation



Item

24	Approve orders
26	Direct orders to addressee
28	File orders
29	State mission and objectives
30	State data requirements to direct retrieval
31	Search and retrieve situation data from files
32	Organize situation data from external sources
33	Develop detailed situation summary

Figure 1. Sample Sequence of Activities (adapted from the OSD).

c. telecommunications
d. politics
e. economics
f. sociology
g. science and technology

2. Relative combat power

a. enemy
b. friendly

Due to the nature of the situation, other specialized categories of data may be appropriate and are identified. The staff must translate its needs (general and specific) for situation data into terms of the file structure of the data bases. This translation is necessary for efficient retrieval of the data by the Command Support Center.

Tasks:

. Related Data Identification--the data parameters composing the situation summary are related to categories of stored information in the data base, and the needs for data are specified and requests for this information are worded in terms of the file structure and content of the data base.

. Deduction--any specialized data parameters pertinent to the development of a detailed situation summary are deduced from the available situation data and mission statements.

. Routine Action--requests for all situation data from the Command Support Center and the Command Post are generated, being worded in terms of the data base content and file structure.

Item 33. Processing. The situation data received from the Command Support Center and the Command Post are now worked up into a detailed situation. It should be noted that this process of developing a detailed situation summary is not a one-shot process, but an ongoing activity that continues throughout the planning process. Changes in the quality and vector of dynamic situation data parameters (i. e., weather, enemy activity, political factors) may cause a change in the direction of the planning process (i.e., reformulation of the mission). Thus, the situation summary must be continually updated in varying degrees of detail until the mission has been completed, and the commander informed of any new developments.

Tasks:

. Qualitative Evaluation--the situation data are evaluated and significant factors are isolated and emphasized in the write-up. The term "significance" refers to any situation factors that appear to affect the reaction time and/or magnitude of Naval response. If any such factors are isolated, the commander is notified.

. Quantitative Evaluation--the status of some situation parameters may be evaluated in a quantitative fashion by assigning a numerical value to some predetermined scale. Examples are assignment of a threat value to enemy activity and potential strike power, or a numerical representation of weather conditions as they affect the capability for conducting operations.

. Correlation and Comparison--significant factors of the current incoming dynamic situation data are correlated with the stored historic data to note changes and trends.

. Deduction--where appropriate, the future status of dynamic situation parameters is deduced from the preceding processing.

. Synthesis--the evaluated and correlated data are paraphrased, integrated and formatted into a comprehensive situation summary report in such a manner as to allow rapid update of the material.

. Complex Decision--the decision is made as to when the development of the situation summary is sufficiently adequate to proceed to develop a set of general operating requirements (GOR).

By contrast, the routine nature of Items 31 and 32 is illustrated in their descriptions:

<u>Item 31. Action</u>

Tasks:

. EDP Action--the staff request for situation data is translated into a retrieval of the specified information from the data base.

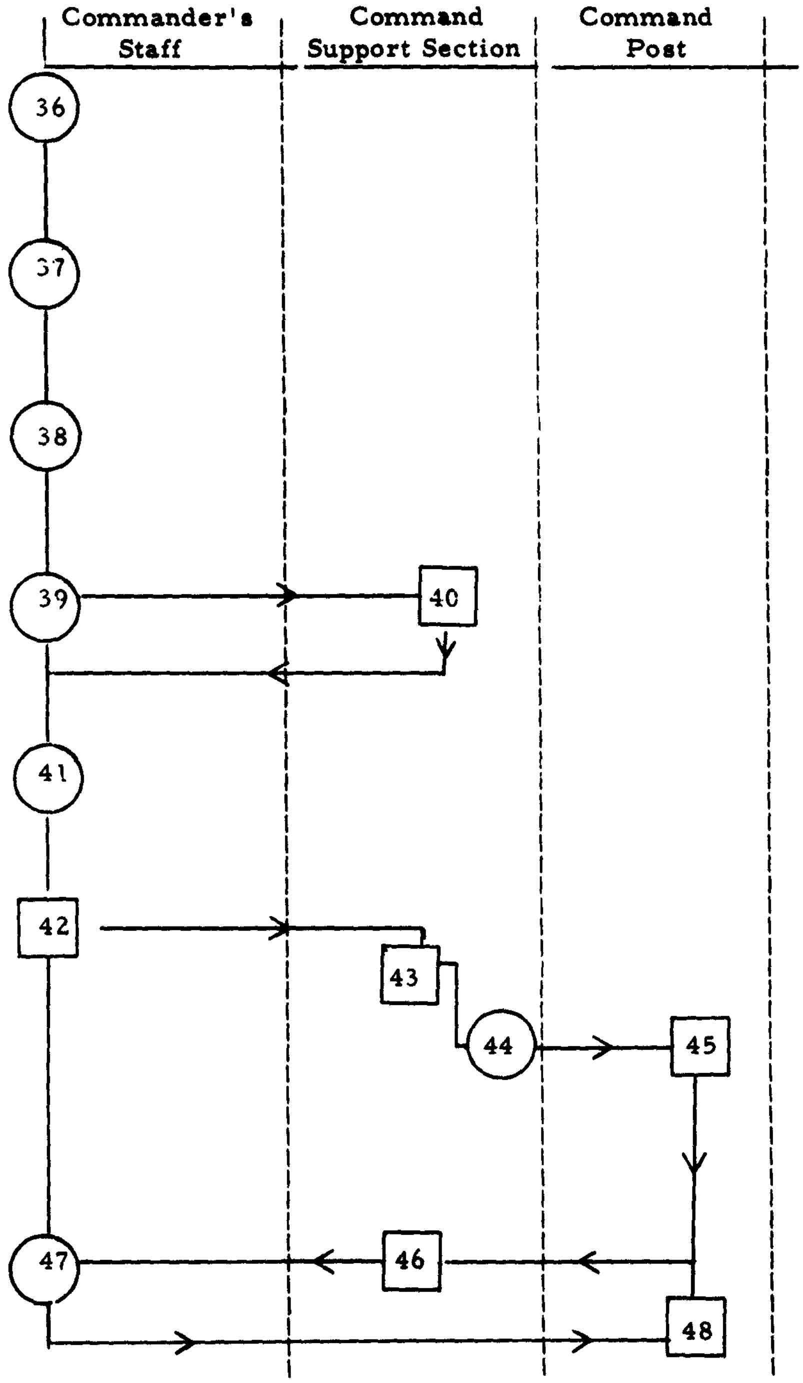
- Routine Action--the retrieval situation data are organized and packaged for transmission to the staff.

Item 32. Action

Task:

- Routine Action--as per the request from the staff, all currently received situation data are collated and sent to the staff (i. e., TTY report, intelligence).

The activities in Items 24, 26, and 28 are likewise routine activities concerning the issuance and filing of orders. The important features of these tasks (and the class they represent) are that criteria can be established for speed and accuracy of performance and can be meaningfully applied. In the more complex tasks, such criteria are difficult to establish. A qualitative statement such as "it is desired that the best job be done in the least time" might be made for these tasks, but it would not permit quantitative analysis. For the other tasks, the data to be retrieved can be identified and accuracy would imply that all data correctly stated were retrieved. Time measurement would be of the elapsed time from request of data to delivery to the requesting agency. Another example is presented in Figure 2 to further illustrate the difference between kinds of activities. The sequence shown in this figure relates to the development of specific operating requirements and the tentative selection of forces for assignment. The requirements reflect the needs of the situation, the environment and the status of forces available to assign to the situation. In this sequence, two activities are of the complex type: 36 and 38, both of which involve the evaluation and organization of data in operating requirements. All of the other activities are routine data-handling and processing that are required to support the complex activities.



Item

36 Formulate general operating requirements

37 Specify type and number of units to be used

38 Formulate specific operating requirements

39 State data requirements

40 Search and retrieve data

41 Select units on basis of time/distance relative to area of deployment

42 Request force status data

43 Retrieve force status data

44 Identify data deficiencies

45 Obtain force status data from units

46 Compute readiness of units

47 Tentatively assign units

48 Alert units

(Note: "Units" refer to operating elements of the fleet.)

Figure 2. Sample Sequence of Activities (Adapted from the OSD).

BIBLIOGRAPHY

The following constitute the main sources of data for this study. The information obtained from 1, 2, and 3, is obvious from their titles and is reflected mainly in the description of the projected system and in the conclusions about command and control processes generally. The fourth citation contains the description of the algorithmic models that are referred to in the discussion of the nature of training. In that report the paper by Tennenbaum dealing with the Turing-Post model is the specific source. The fifth reference describes the original development of TAP that was examined for application to command and control.

1. Facilities Manual for Fleet Operations Control Center U.S. Atlantic Fleet (U). Cooke Engineering Co., Alexandria, Virginia, May 1961. CONFIDENTIAL

2. Naval Operational Planning (U). NWP-11, 1953. CONFIDENTIAL

3. Organization Manual (Rev 1-63) (U). Fleet Operations Control Center, U.S. Atlantic Fleet, March 1963. CONFIDENTIAL

4. Mehlburg, J., et al. Fundamental Concepts in the Theory of Systems. Wright Air Development Center, Wright-Patterson Air Force Base, Ohio, WADC Technical Report No. 57-624, November 1957.

5. Tech Report: NAVTRADEVCEN 1169-1. Training Analysis Procedure (TAP) Vol. I: Theoretical Development. Van Albert, C.E., et al. Dunlap and Associates, Inc., Stamford, October 1963.