COMPUTER COMMAND AND CONTROL COMPANY

DEVELOPMENT OF REAL TIME NAVAL STRATEGIC COMMAND and CONTROL SYSTEMS

ADVANCED WARFARE SYSTEMS DIVISION
NAVAL ANALYSIS GROUP
OFFICE OF NAVAL RESEARCH
DEPARTMENT OF NAVY
WASHINGTON, D.C.

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PREFACE

This document reports the results of a study of the essential operations that must be undertaken to develop a Real Time Strategic Command and Control for a Newly-Mechanized Naval Command.

The authors of the report are indebted to a great many military and civilian personnel of the Department of the Navy. Chief acknowledgement must go to the sponsoring agency, the Office of Naval Research, to the scientific officer, Mr. Ralph G. Tuttle, and to the Naval Command Systems Support Activity and Mr. R. Ksiazek. Without the aid and encouragement which was received from these sources it would have been very difficult to have made this start toward planning the implementation of real time command and control systems.

SUMMARY

The existence of the technological explosion makes it necessary to reexamine strategic command and control for possible application, and to find effective ways to implement the applications which are identified.

This report presents a plan for early achievement of real time in Naval strategic command and control; it includes provisions for a first step in the conversion to an integrated Navy-wide real time system.

In a previous task* in this study the concept for such an integrated system was developed and described, including the required existing technology. The concept, which is the end point of the phased development plan, included real time multiprogrammed computers at all major command sites and computer-to-computer interchange of queries and information for a world-wide Naval data base. The present report presents a development plan for newly mechanized commands, showing how they can develop their capability to participate in the Navy-wide system. It augments the previous task by presenting the technical and operational characteristics of the system with special attention to the all-important first step of development. The technical description includes equipment characteristics; system programs for control of job priority, execution, information retrieval, interrupt and recovery; functional programs for a variety of command responsibilities; a flexible file structure, a powerful query language and specific means for achieving flexibility and growth capacity. The operational description first reviews the requirements for such systems in detail and then describes the operational effects of implementing the Phase 1 technical plan.

The system will have a number of important advantages: rapid response, ease of use, more effective data management, high efficiency, and a number of new services which contribute significantly to a command's problem solving capability.

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* Computer Command and Control Company Report 21-102-4, "A Concept for a Real Time Naval Strategic Command and Control System", April 1965, portion of Office of Naval Research program of the Advanced Warfare Systems Division (Code 493), Contract NOnr 4366(00).

An approach based on existing USQ-20B computer configurations (at CINCUSNAVEUR and NAVDEFEASTPAC) is recommended. The implementation plan indicates that the system could be implemented with a software effort of about 21.5 man years (including 7 man years for a general file translator, which can be delayed) and an elapsed time of approximately fifteen months. Additional peripheral equipment is necessary at an approximate cost of $174,000.

CONCLUSIONS

1) The real time system will give the command a greater capability to carry out its responsibilities under wartime conditions and thus increase the effectiveness of the command.

2) The real time system can be developed now and serve as a follow-on system to the presently planned system at COMNAVDEFEASTPAC or CINCUSNAVEUR. The development of the new system will not interfere with presently planned operations. At the time of switch over, both systems can be operated alternately in the same computer during test operation. The enhancement of functions will continue thereafter.

3) The real system will utilize the entire computerized data base presently in existence.

4) An effective basic capability real time system can be placed in operation and replace the presently planned system in 12 to 15 months.

5) The basic cost of implementation of the programming effort is estimated as 21.5 man years (including 7 man years of general file translation, which may be delayed). This is exclusive of the additional peripheral hardware which would cost about $174,000 per installation, however the software will be useful in more than one installation.

RECOMMENDATION

1) Develop the real time system for COMNAVDEFEASTPAC and CINCUSNAVEUR, based on the USQ-20 and augmented by a small amount of peripheral hardware and a new software program package.

DEVELOPMENT OF REAL TIME
NAVAL STRATEGIC COMMAND AND CONTROL SYSTEMS

1. INTRODUCTION.

This report describes interim results of a study of real time Naval strategic command and control systems. A previously reported task in this study* described a system concept for an integrated, world-wide Naval command and control system which would substantially overcome many of the operational deficiencies of present systems. While this concept was described in great detail, the means for conversion from present practice to the integrated system was not described. Since the conversion process depends on the present practice and responsibilities of the subject command, and since each command is different, the technical planning for the conversion must be investigated separately for various classes of commands, and, ultimately, for each command.

The purpose of this report is to describe the results of studying a part of the conversion process for one class of commands, called newly mechanized commands here. Specifically, the report deals with the first major step of a phased conversion from essentially manual processes to the previously-described integrated system.

1.1 Characteristics of Real Time Strategic Command and Control.

For the reader's convenience, a number of the salient features of the integrated system are described below. For a more complete description the reader should consult the report of the previous task.*

1) Real time operation - The system operates in real time, that is, with the computers responding within the attention span of the users. Commanders, senior staff officers or other users are able to query the system and receive immediate responses (normally, complete responses). Similarly, input

* Computer Command and Control Company Report 21-102-4, "A Concept for a Real Time Naval Strategic Command and Control System", April 1965, portion of Office of Naval Research program of the Advanced Warfare Systems Division (Code 493), Contract NOnr 4366(00).

of information occurs at the time of its coding with all machine verification being performed as soon as the information is entered at a console. This feature leads to significant improvements in the management of the data base, with improvements in quality, timeliness and effort of assembly and maintenance.

2) World-wide Common Data Base and Access - All files, except certain privileged files, are available to any qualified user at any of the commands served. Each command holds a part of the system data base in its computers (with some overlap for survivability and ease of communication) and can query any of the files, either local or remote, in real time.

3) Direct User Access - The system is designed for use by Commanders, senior staff officers and others with operational responsibilities without the necessity for intervention by programmers, analysts or other intermediaries. The query language and associated programs will accommodate unfamiliarity with the system file structure and content. The query language uses English language terms and relations extensively.

The immediate response of the system and its ease of use make new uses for effective machine-aid possible. In particular, the user can turn over a much larger amount of detailed manipulation of information to the machine without losing control. He can make use of long series of dependent queries, using some queries to discover file structure and information availability and others for retrieval and manipulation. The system is thus able to act as a problem-solving tool rather than simply a processor of anticipated questions and programs without minimizing the usefulness of the latter function.

4) Structured Files - The information files of the system are held in random access mass memories accessible through a retrieval system held in common for all programs and all users. The file structure which facilitates this retrieval has several important properties:

a) Each major unit of information, called a record, is indexed (and therefore retrievable) by a variety of descriptive terms and relations.

b) The set of descriptive terms is open ended and may be expanded or contracted at any time.

c) The set of descriptive terms is rich enough to accommodate both routine processes and non-routine search); it includes both quantitative and symbolic terms.

d) For selected classes of descriptive terms, the indexing includes threaded lists of descriptors, so that the records having a particular descriptor can be searched selectively without examining irrelevant records which do not have that descriptor.

e) The file structure is general and common to all files. The file organization described in this report lends itself to the flexible, highly varied kind of processing expected with real time personal control by the user. The threaded lists give a high efficiency of search, and the rich descriptor structure allows the use of many easy, natural relations in the search and manipulation processes.

5) Multiprocessing and Multiprogramming - The changing responsibilities of Naval commands and changing stock of available technology require that systems be extremely flexible in order to avoid early obsolescence. Partly in response to this need, the portion of the system at each installation is a multiprocessor, with the capacity to accept or release computers as needed. The programming system is modular and relatively machine-independent, so that new computers can be added without rendering the older computers ineffective.

Command and control computing requirements characteristically include extensive reference to large files, so that the efficient use of computer time in conjunction with frequent use of mass storage input and output is a significant technical problem. A well-planned multiprogramming system can make effective use of input/output equipment and still keep the central processors busy nearly all the time with available computing.

The multiprocessing and multiprogramming described in this paragraph is applicable to the real time strategic concept for a world-wide system. In this task the applicability of USQ-20 at newly-mechanized commands was to be investigated.

1.2 Facilities and Requirements of Newly-Mechanized Commands.

In considering possible configurations of equipment, programs and methods for the newly-mechanized command, every item considered must contribute in some way to achievement of effective participation in the integrated system previously discussed. In order to choose facile combinations for the various stages of conversion, additional bases for justification are needed. The purpose of this section is to describe the basis for the selection of equipment programs and methods. This task considered only the problems of an individual newly-mechanized command and did not consider the real time interaction with other mechanized commands. For this purpose an outline description of the system under consideration follows.

The newly-mechanized command system is one which until recently has not used automatic data processing for the bulk of its work. It has limited experience and stock of computer programs to aid in prosecuting its responsibilities. It facilities and requirements are assumed initially to include the following.

A typical newly-mechanized command environment is one that is anticipated to prevail at COMNAVEASTPAC in the near future.

1.2.1 Facilities.

The restrictions on real time communications have been described in Technical Communications Corporation report, "An Analysis of the Impact of Naval Communications of ADP and Real Time Data Transmissions", Interim Report No. R65-100, prepared for the Office of Naval Research, Advanced Warfare Systems Division (Code 493).

1) Communication facilities adequate for carrying out its emergency and wartime responsibiltiies using manual methods.

2) A moderately powerful computer, such as the USQ-20, with a nominal set of input/output devices, (i.e., magnetic and paper tape facilities, card facilities and printers, but no mass memories or user consoles are assumed.)

3) An assembly language and program for the basic computer.

1.2.2 Requirements.

A representative set of responsibilities prevailing at COMNAVEASTPAC and to a lesser extent, those at CINCUSNAVEUR, have been used as guidelines. These responsibilities are such that they will make a contribution to the overall responsibilities of the Naval establishment by being served by an integrated command and control system. These responsibilities are listed in the first column in Fig. 1-1. These are translated in column 2 into the necessary data base, and in column 3 into specific functions. The necessary system features are listed in the fourth column in Fig. 1-1.

A major question posed during the study was whether the first step toward real time should involve a new family of computers, or may the existing equipment be utilized.

The study indicated that, a) mechanization is possible with the presently planned equipment, b) the additions that were indicated were of relatively small cost, c) the life of a system will be extended through the new programs and added peripherals. Therefore in this report, the implementation is envisaged in terms of utilization of the presently available computer, the USQ-20.

As a basic principle, emergency and wartime needs and functions are assumed to dominate the system. Peacetime processing rates and needs are therefore not paramount except as they are related to emergency and wartime processing rates and needs or in the unlikely event that they exceed emergency and wartime needs.

A number of pervasive difficulties with manual and automated methods in current Naval systems for dealing with information were identified in the first task of this study. Several of these apply particularly to the newly mechanized command, and should therefore be considered strongly in choosing a Phase 1 configuration. They include:

1) Input capacity - Manual command systems are typically unable to maintain an adequate, trained staff in peacetime to handle emergency information volumes when the need arises. The Phase 1 configuration should therefore provide for high-volume input with limited staff.

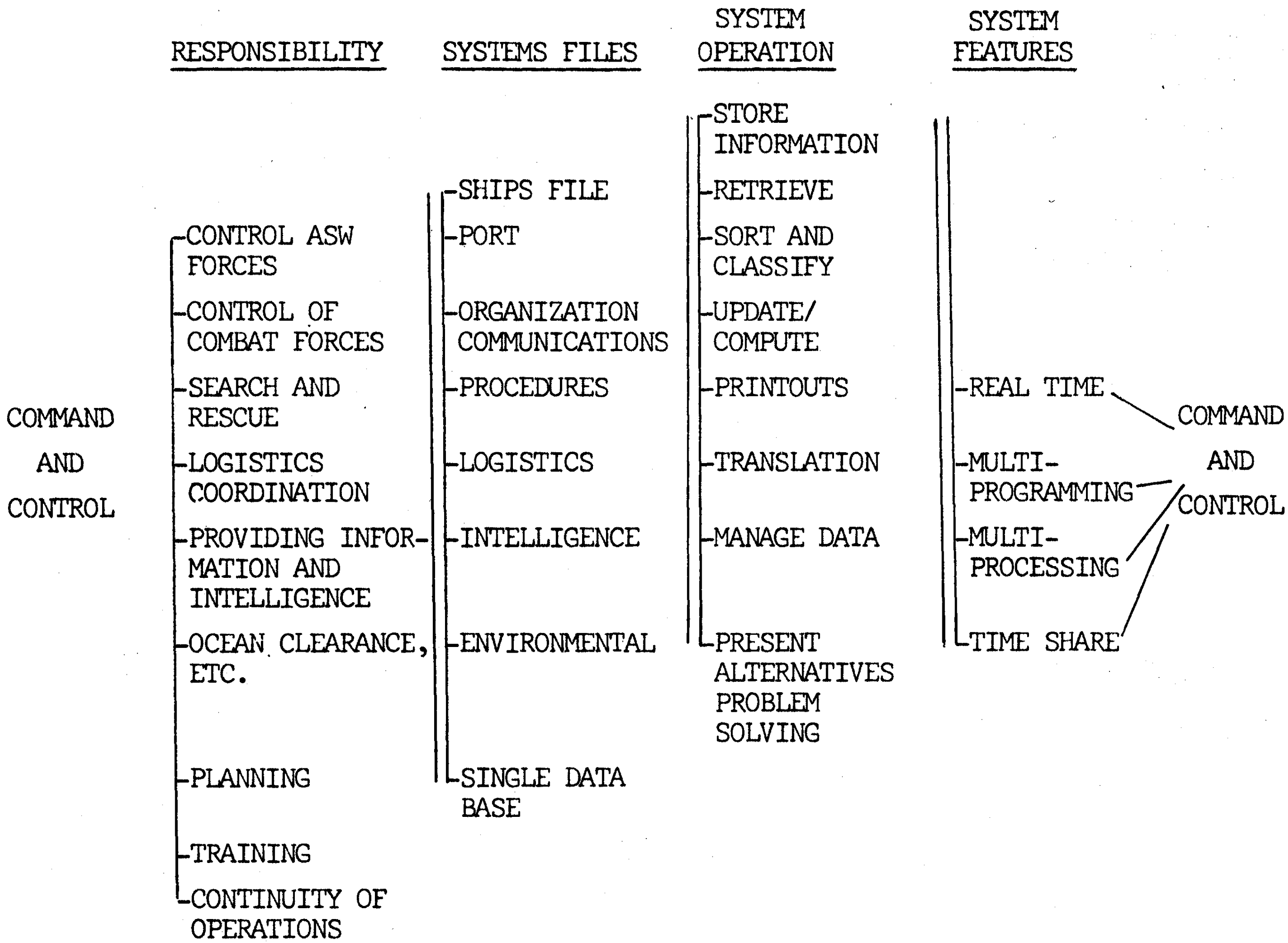

FIGURE 1-1 - TRANSFORMATION OF COMMAND RESPONSIBILITIES TO COMPUTER SYSTEM FEATURES.

2) Backup capacity - The acceptance of backup responsibilities involves major changes in the requirements of a command for information, including new requirements to accept major portions of the data base of the commands being backed up. Particularly if the commands being backed up are using computers, the manual command system is often unable to use the information effectively. Similar difficulties arise if the linked commands do not provide for compatibility between their computer systems by means of translation programs or adequate technical standards.

3) Untimely information - The process of manually digesting strategic information for the commander's use typically takes hours or days for all but the most urgent messages. The same processes at an external information source often make arriving information untimely. One of the major reasons for introducing computers is to improve the accessability and capacity to provide timely information for internal use and timely external reports.

4) Insufficient information base - The difficulties cited above prevent many kinds of information from ever being incorporated in a manual command's information base. The resulting base is often inadequate for informed decision making. The computerized system should therefore allow for an expanded data base.

1.3 General Development Plan.

This report presents a development of three phases (outlined in paragraph 1.3.1) leading toward an integrated world-wide system. This section outlines the development in terms of hardware configurations, programs required, operational functional improvement, and the implementation.

Table 1-1 shows the specific recommendation based on the use of the AN/USQ-20B computer.

The growth phases outlined below are presented in greater detail in later sections, first considering the equipment growth in Sect. 3 and then the related program growth in Sects. 4 and 5.

TABLE 1-1

EQUIPMENT, PROGRAMS, AND FUNCTIONS IN THE THREE PHASES

SYSTEM	DEVELOPMENT TIME AND USEFUL LIFE OF PHASE	EQUIPMENT ADDED TO INITIATE PHASE	PROGRAMS ADDED TO INITIATE PHASE	PROGRAMS ADDED DURING PHASE TO PERFORM COMMAND FUNCTIONS *	FUNCTIONS
INITIAL PHASE 1	DEVELOPMENT TIME: 12-15 MOS. USEFUL LIFE: TO PHASE 2	USQ-20B COMPUTER 2: 8 MILLION CHARACTERS (8M) DISCS 16 TELETYPE CONSOLES (LOCAL)	MULTIPROGRAMMING EXECUTIVE QUERY SYSTEM FILE SYSTEM GENERAL AND SEA SURVEILLANCE UPDATING	PROGRAMS FOR RESPECTIVE FUNCTIONS: OCEAN CLEARANCE PLANS GENERATOR, ETC. FILE TRANSLATION LAND AVOIDANCE UPDATE AIRCRAFT SCHEDULING	SEA SURVEILLANCE (SAR, OTA, ASW, NAVIGATION) LOGISTICS: CASREPS CONTINUITY OF OPERATIONS CONTROL OF COMBAT FORCES
INTERIM: PHASE 2	DEVELOPMENT TIME: 12-15 MOS. USEFUL LIFE: TO PHASE 3	UP TO 4: 8M DISCS 4: CRT DISPLAYS 8: TELETYPES (WITH LONG DISTANCE TELEPHONE LINES)	DISPLAY CONTROL PROGRAMS	MULTI-RESCUE FAST PLANNER ASW MULTI-CONTACT PROSECUTION PLANNING AIDS	OCEAN CLEARANCE PLANNING FUNCTION INTELLIGENCE TRAINING
FULL OPERATION: PHASE 3	DEVELOPMENT TIME: 18 MOS. USEFUL LIFE: 5 YRS. OR MORE	UP TO 4: 8M DISCS 4: CRT DISPLAYS 2: MAPPING DISPLAYS ON-LINE ACCESS TO OTHER COMMANDS	COMPUTER LANGUAGE TRANSLATION EXTERNAL QUERY LANGUAGE TRANSLATION	DATA BASE COMPARISON REMOTE REQUEST REPORT GENERATOR EXCEPTION REPORTING TESTS COMBINED PLANS CONSISTENCY TEST	ENHANCEMENT OF ALL OF ABOVE FUNCTIONS COORDINATION AIDS

* These may be added during Phase 1 or 2 as needed.

1.3.1 Equipment Growth Phases.

The phased growth of hardware accommodates, first, local real time activity, second extended consoles on long distance telephone lines for remote query and update and third, general on-line computer-to-computer comuunication.

Phase 1 consists of a real time, time-shared, integrated file local operations.

Growth of display capability is expected in Phase 2 in order to provide more convenient means for man-machine interaction in the input process, for on-line programming, for query and response and for computer-aided manipulation of situation and plan representations. The CRT displays in Phase 2 are able to provide more convenient and rapid input/output and editing than teletype printers greatly speeding up the input process and allowing the scanning of larger volumes of query output.

Also in Phase 2 an initial set of 8 distantly located consoles will be connected through telephone land lines for coordination between commands. They are tentatively allocated as follows:

Direct Superior Command	1
Other Commands Being Backed Up (2 each)	4
Parallel Command	3
	8

They would be used primarily for remote updating and querying rather than for other computer services.

The mapping displays in Phase 3 are for situation representation and for manipulating computer representations of combined plans.

In Phase 3 the computer-to-computer on-line communication would be used for a variety of services. It provides a basis for development of an integrated data base and shared data base maintenance out of the separate parts maintained by separate commands. In Phase 3 the integrated data base is integrated both intra- and inter-command. This provides a much firmer basis for long term continuity of operations and survivability of an effective, informed commander.

After Phase 3 capabilities are fully utilized, which we anticipate being five or more years away, further growth should incorporate a new generation of computers. Phase 3 capabilities will serve adequately until a new generation of computers is needed.

1.3.2 System Program Growth Phases.

The basic Phase 1 development produces an effective set of system programs which are useful for the remaining phases in their entirety. Specific additions to the system programs include I/O for the CRT display control programs in Phase 2 and for the map display in Phase 3.

1.3.3 Functional Program Growth Phases.

The functional programs added in the particular phases are not strictly identified with a specific phase, since the system's open-ended acceptance of programs allows it to incorporate them at any time after the system programs are complete. A wide variety of new services is made available during the usage periods of Phases 2 and 3 as shown in the 4th column of Table 1-1. A general purpose file translator may be included in Phase 1 or added at any time thereafter.

1.4 Phase 1 System Characteristics.

The Phase 1 configuration will be entirely local, extending no new services or operational requirements beyond the installation of the particular command which it serves. No other command will interact in real time with the subject command since in this phase the capability does not exist.

Specific characteristics which are chosen on the basis of these considerations are discussed below:

1) Capacity for real time activity.
2) Multiprogramming.
3) Provision for Random Access Mass Memory Devices and Information Displays.

1.4.1 Capacity for Real Time Activity.

Real time operation has a number of important advantages. Real time system operation is a mode of interaction between the system user and the machine which he uses. When the answers to queries are made available within the immediate attention span of the user the system is a real time system. While this subjective view of real time does not allow a precise statement of the maximum time intervals involved, a number of currently operating real time systems respond to request for computation in less than half a minute.* Real time operation also introduces significant improvements over the more common batch computing in the capability provided for the commander and his staff, in the information input process and in the efficiency of machine usage.

The most striking feature of a real time command and control system is its ease of use as an operational problem solving tool. The user normally deals with the system through a personal console by which he is able to make queries and request processing and display information which results from such requests. The immediate response of the system means that machine aid can be applied many times in succession on an individual problem. Alternative courses of action can be chosen. Their implications can be investigated. The results can be evaluated, and the problem can be reformulated if necessary. This facility in locating and manipulating information allows the commander or staff officer to concentrate his attention on the most relevant information and the most promising alternatives. When decisions are made, they are likely to be more knowledgeable, to be based on greater detail of information and on consideration of more alternatives than would in fact be considered without the aid of a real time tool.

The information input process is significantly aided by making it a real time process. Information to be filed is coded, verified, and entered into the data base piece by piece, with any necessary corrections being made

* A sample query analyzed in Sect. 6.3 for the recommended system gives its first useful output in 2.5 seconds or 18 seconds, depending on whether sorted, tabulated output is required.

immediately, before the next entry is processed.* This ability to do the entire input process at one place and at one time makes the input process more efficient than it would be otherwise. Particularly with a flexible set of semi-autonomous display consoles, the real time input system can speed up the rate of input significantly, thereby providing additional input capacity for wartime or emergency situations. The information in the data base is kept more timely since entry errors are corrected immediately and since it is not necessary to wait for an economic batch of inputs to build up.

Real time operation allows a drastic improvement in the efficiency of machine usage. The use of structured random access mass storage allows the computer to search selectively through the relevant filed information without processing large volumes of irrelevant information (as is normally necessary in tape-based systems.) It is this efficient search which makes real time machine response possible even when large diverse files are used, and which leads to the high relative efficiency of real time command and control systems.

The efficiency of updating processes is extremely high for similar reasons. Records to be updated can be located quickly and treated individually without waiting for economic batches and without relocating large numbers of records.

Real time operation makes on-line programming convenient and effective. This mode of programming allows the programmer to build and test parts of programs freely during the development process. It has proved to be a major improvement in programming technique for its present users, the chief improvements are in the speed and cost of program development.

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* Conventional filing of information in an electronic data base is essentially a batch process. Each piece of information to be filed is coded in a suitable format and incorporated into batches. Each batch is then checked in a number of ways, with the portions found erroneous being rejected or returned for correction. Finally the batch is used to produce a new file (typically on tape) from an old one, again with some rejection of errors. Each step is taken outside of the context of the others, and each time a person's attention is required, he must reassess and reidentify the action sought.

1.4.2 Multiprogramming.

The real time system activity requires a real time executive program for its control. The integrated system has as one of its basic features the simultaneous operations of programs (multiprogramming). The objective is to allow the USQ-20B to handle the largest number of simultaneous on-line users. Multiprogramming achieves this through 1) maximum utilization of I/O channels, 2) through overlapping processing and I/O and 3) through accommodating a number of user jobs simultaneously in the memory.

Conversion to a multiprogram executive at a later date would involve considerable duplication of effort in the construction of any non-multiprogram executive which would precede it. The reasonable point for orderly introduction of multiprogramming is at the beginning of the phased development, as part of the Phase 1 configuration.

1.4.3 Memory and Display Technology.

The recent development of computer related technology makes a number of significant new capabilities available for command and control. The provision for their inclusion in any significant new development is absolutely necessary. Briefly, the relevant technologies include:

1) Mass Memory Hardware and Software - The available information storage capacity for rapid, so-called "random access" has increased several orders of magnitude in the past few years, primarily through the development of magnetic disc and drum equipment, and more recently in certain developments using photographic memory or small flexible magnetic surfaces. Recent program control techniques for organizing, representing and gaining access to massed information in such media provide efficient ways to deal with large volumes of information which is of primary concern to improvements in command and control.

2) Information Display - A variety of new information input and display devices has demonstrated significant improvements in the volume of information which can successfully be presented to a person, and in the degree to which a person can be given effective control of a complicated information process. Particularly in real time systems, the new display consoles allow a

degree of man-machine interaction which has previously been impractical; furthermore they have demonstrated ways to work which make even the simple consoles into effective tools.

The existence of such technology makes it necessary to reexamine strategic command and control for possible application and to find effective ways to implement the applications which are identified. Such an overall examination was performed in a previous study period, and a system concept for a greatly improved Naval command and control capability was developed. The present study outlines steps by which the improvements can be achieved, with emphasis on the character of the all-important first step.

1.5 Expected Benefits.

The expected benefits which motivate the use of new technology include:

1) More effective data management - Storage of a given piece of information in one place in a common file rather than in the files of several users allows the effects of errors to be controlled. This form of storage and immediate access to storage assure the user that he has the latest information, that others on whom he depends have the latest information, and that their information agrees with his. Each of these three assurances can eliminate significant delays and uncertainties which are the basis for much communication in other kinds of systems. The availability of the final, filed information during the input process is expected to eliminate many of the errors which occur in changing information from form to form without feedback. In addition, real time updating will provide more timely information as a firm basis for coordinated action.

2) Efficiency - The efficiency of machine usage is expected to increase drastically through the use of recent technology. The savings of machine attention are available from two sources. First, conversion to mass memory files with effective internal structure allows the machine to deal with only those records which have a high probability of relevance rather than all records of a given file. Second, multiprogramming can substantially improve the usage of the processor by dividing its attention among several programs.

These efficiencies taken together are expected to increase the capacity of the system drastically, thus providing an opportunity for effective use of more computer aid and greater emergency capability.

3) New Services - New system programs with the capacity to accept programs in an open-ended fashion will permit new services to aid in meeting specific areas of command responsibility. For example, identification aid programs for ASW and logistics files of command importance could be added without disturbing the existing file organization or programs.

In addition, the ability to investigate files in depth with a dependent set of queries and programs is expected to be a particularly powerful new service.

4) Growth and Flexibility - The use of recent technology in the hardware and software of mass storage provides a capability for growth without the constraints inherent in older systems. Specifically, the provision of a rich, open-ended file structure and program set allows for free adaptation of files to new uses and easy programming with respect to the available files. The availability of an easy-to-use retrieval system will enhance both of these capabilities.

The remainder of this report presents a plan for implementing real time strategic command and control in the operating environment previously described. Section 6 demonstrates that these benefits can be obtained and gives some specific examples of possible performance of such a system.

2. REQUIREMENTS.

2.1 General.

The mission of a Naval command evolves from laws set forth by the Congress, directives issued by the Department of Defense and instructions set forth by the Secretary of the Navy and the Chief of Naval Operations. The mission statement indicates various functions which the Command must perform. These missions are derived from various functions papers and inter-service agreements which parcel out the responsibilities for defending the interests of the United States. In order to carry out its mission the Command has a number of requirements for authority, resources, and procedures necessary to fulfill the imposed responsibilities. Since the resources of the Navy are limited, an overabundance in one command will lead to deficiency in another. Likewise, if procedures are not adequate, efficient and simple, they will lead to requirements for additional resources.

The requirements of each command must be enumerated, analyzed and understood. Also, they must be reflected in the General Operational Requirements. There are a number of classification systems currently in existence which indicate the types of mission requirements in a mutually exclusive set of categories or classes. Each requirement presents considerable overlap with others. In general terms, the commander of a command and control organization must have detailed knowledge of several entities. First is environmental information, second is enemy force or potential enemy force information, third is friendly force and capability information, fourth is logistic information, and fifth is communications plans, techniques, liaison, and procedural information. It should be noted that these entities are included in the listing of requirements in Sect. 1.1

It is the purpose of this section to discuss missions responsibilities or requirements of the command and to explain in later sections how they could be performed more effectively and more efficiently with a real time Automatic Data Processing System. The assumption is made that the command is a Frontier Command and having approximately the same responsibilities as Commander Naval Defense Forces Eastern Pacific or Commander in Chief, U. S. Naval Forces, Europe.

When the responsibilities of the commander are analyzed it becomes apparent that the same tasks are elements of each of the responsibilities. The same information is required for performance of virtually all functions. Any arbitrary group of classification systems presents overlap and have considerable redundancy. A conclusion that must be drawn from the analysis is that file integration into a single data base is mandatory.

The analysis further reveals that many tasks not adequately performed now or performed manually could be performed economically and efficiently with the computer system. The system recommended in this report takes into consideration both of these conclusions providing for a single data base and for greatly expanded computer efforts.

2.2 Ocean Surveillance.

For the purpose of this study, Ocean Surveillance is defined as the capability to locate, track, identify, and report all surface and subsurface contacts which can activate a sensor. The sensor is based on visual, electromagnetic or sonic phenomena. An ocean surveillance system must be able to react to information prior to the activation of an applicable sensor. Information from sources such as MOVREPS, SUBNOTS, MEREPS, MSTSMR, and Ship Wx Reports and other sources must be acceptable. This information must be augmented by input information from the various sensors. In an ideal situation the commander having direct responsibility for a given ocean area requires information on all vessels, ships, boats and disturbances within that area. In the practical case, at least in peacetime it is necessary to arbitrarily limit the information to ships over a certain minimum size, for instance 1000 ton displacement. Otherwise, it is necessary to keep track of the multitude of fishing vessels, pleasure craft, junks, large fish and mammals. In wartime the movement of friendly fishing vessels and even larger vessels presents identification problems. The right of freedom of passage to neutral vessels on the high seas is well established in the body of international law and prohibition of their passage is generally politically unacceptable and more difficult than keeping them under surveillance.

It should be obvious that Ocean Surveillance is not an end objective in itself but is an extremely essential function to help the Department of the Navy control the high seas, and to make necessary secondary contributions in any conflicts either defensive or offensive in nature. Ocean surveillance provides crucial inputs to decision makers. The adequacy of these decisions will be proportional to the accuracy and completeness of ocean surveillance. In search and rescue operations, ocean surveillance is a dominating function. None of the various naval warfare functions, can be adequately performed without an adequate ocean surveillance system. The capability to perform this function is so important that a highly efficient, reliable and sophisticated ocean surveillance system is mandatory.

The ocean surveillance and reconnaissance system now being implemented in the Atlantic could have validity in the Pacific. In the Pacific this is a prime responsibility of CINCPACFLT and the designated successor to CINCPACFLT is COMFIRSTFLT. In the event of catastrophe, if it becomes necessary for the Defense Commander to assume this responsibility then he must have an adequate data processing system to undertake this responsibility.

Ocean traffic accounting is actually a subfunction of an ocean surveillance system. Within the area of responsibility of COMNAVEASTPAC* reference data must be maintained on Naval ships, Naval Units, Merchant Ships and ship routes. Active files must be maintained on Naval Ships underway, merchant ships, Bloc Merchant ships, Naval Ships in port and Merchant ships in port. In the event of emergency conditions this requirement further increases and in the event of general war conditions, and assuming currently designated successor command functions, it would be necessary to store reference data on more Naval ships, more Naval units, more Merchant ships and more ship routes. Ultimate purpose would be to minimize location data on all ships in the Pacific and adjacent areas.

As new and improved sensors are developed the capability to conduct ocean surveillance will increase. Additional contacts must be classified. Due

* COMNAVEASTPAC is used herein for illustrative purposes only and to indicate the scope of the task.

to multiple reporting, verification of reports will be necessary. Tolerable limits of accuracy within a sensor system can create problems of target classification.

The information available to the commander and to the forces which he must employ or coordinate is only as good as the input information which he receives. Erroneous or late information can cause the system to be overburdened, in a minimum of time. Timely reports and instructions must be issued to personnel or forces that will react. Table 2-1 indicates the tasks to be performed in ocean surveillance.

2.3 Continuity of Operations.

The Navy must have a positive capability to maintain continuous command and control in the event of disaster, or in the event it becomes desirous to transfer this function instantaneously to a new geographical location for any reason. Positive control must be continuous even with the destruction of a commander and his staff. The command and control capability must suffer minimum degradation in efficiency and effectiveness when geographical changes are made. Redundancy in command and control capability is a requisite to conduct of nuclear warfare.

These requirements can be best met if each command and control center is an integral and integrated part of the overall Navy-wide command and control system. The development of functional compatibility and near-identical systems must be given highest priority in command and control research and development. Whenever economically feasible identical hardware equipment must be installed in all centers. This will reduce reprogramming expenditures and simplify procedures for maintaining continuity of operations. It is emphasized that a center must be capable of substituting for either a senior or subordinate command, or to take on responsibilities of a command at the level as itself, that is, one that is geographically contiguous or functionally similar. Table 2-2 indicates gross tasks in order to maintain continuity of operations.

TABLE 2-1

TASKS OF OCEAN SURVEILLANCE

Purpose: To locate, track, identify, and report all surface and subsurface contacts which can activate a sensor.

Task 1 - Developing the Data Base

Subtasks:

(a) Enter MOVREPS, SUBNOTS, MEREPS, MSTSMR, and Ships Wx RPTS into the file as soon as they are received, i.e., real time.

(b) Enter information reports concerning ship sailings into file. These reports come from sources such as Tug Pilots, port directors offices, newspapers, insurance companies and any other source including intelligence reports. Some of these entries are to be made in real time, others could be "batch" processed (if they are received in BATCHES.)

(c) Enter visual sightings reports from Naval surface ships and reconnaissance aircraft into the file when received, in real time.

(d) Enter sensor reports (SOSUS and others) into the computer as soon as they are received, in real time.

Task 2 - Evaluation and Classification

(e) "Note" all sensor reports which can be positively identified as known ships.

(f) Enter in computer all reports of sightings of unidentified or enemy ships. Entry to be made in real time.

(g) Use gross correlation techniques to determine identification of unidentified ships.

(h) Send search/reconnaissance units in order to identify all contacts which still remain unknown.

Task 3 - Track and Display

(i) Track all known contacts. This includes both identified and unidentified ships/SS.

(j) Continuously compare tracks of ships to sailing routes to determine destination and time of arrival at destination.

(k) Maintain a plot of all ships and tracks either in display form or available as a computer print out.

TABLE 2-1 (Cont.)

TASKS OF OCEAN SURVEILLANCE

Task 4 - Reports

(l) Report all enemy and those that are still unidentified to competent senior authority and to forces that will take action.

Task 5 - Statistical

(m) Gather statistical information regarding surveillance function. For instance, number of ships entering and leaving various ports. Types of cargo being transferred in a certain direction, number of ships in pipe line. This information can have strategic significance. (Did the line of merchant ships headed for Pearl Harbor on 1 December 1941 from Tokyo end at a certain point?)

TABLE 2-2

CONTINUITY OF OPERATIONS

Purpose: To have the capability to instantaneously substitute for a command and control center which is senior, subordinate or "horizontal" to the original command. The new command must be able to control remnant forces and effectively utilize these forces, with a minimum transfer of information.

Task 1 - The Data Base

Subtasks:

(a) Maintain a complete current organization chart of personnel, installations, logistics and forces assigned to designated commands.

(b) Maintain a capability file of forces designated in (a) above.

(c) Maintain a current list of geographical position of forces designated in (a) above.

(d) Maintain a current list of plans and op orders pertaining to utilization of forces in various contingency situations.

(e) Maintain a current status of communications networks available with alternate routes available to be used in the exercise of command control.

Task 2 - Implementation

(f) Upon receipt of notification that the command must assume responsibility for the function of another command use the information from Task 1 to conduct operations depending on the situation. This task alone justifies a real time system with a query capability which will assist the user in making the proper queries. When a command is notified that it is the successive command, the new commander and his staff will want to brief themselves in the minimum time as to the status and capability of the command they are relieving.

2.4 Antisubmarine Warfare (ASW).

Defending continental United States from missile launching submarines and protecting United States and friendly shipping from torpedo launching submarines are formidable tasks. The conduct of ASW is a paramount concern to the Navy. Any action a commander performs to reduce the threat is worthy of performance, yet a commander's resources can be squandered if he indiscriminantly tries to counter all unidentified contacts with military forces. As stated previously, one of the primary purposes for the ocean surveillance system is to be able to identify various contacts and to determine if they are friendly or enemy. By judicious use of an ocean surveillance system, including ocean accounting and other sources of information, a commander can greatly reduce the number of contacts which require at-the-scene investigation.

The ASW function can be illustrated by the specific duties of COMNAVDEFEASTPAC as a typical command and control center. The Ocean Traffic Accounting system (OTA) is charged with providing Oceanographic System Pacific (OSP) with the position, identification and, if possible, additional description of both friendly and unfriendly ships in the area where a contact may be suspected. The success of Oceanographic System Pacific would depend in many cases on the accuracy and completeness of the information provided to it by OTA. In prosecuting unidentified ship and unidentified submarine contacts, the cycle of updating of separate Navy, Merchant and Bloc files and retrieval from these files may approach two hours. This is inadequate since a submarine could change position by thirty to forty-five nautical miles in that period of time. In some cases the investigation may require reconnaissance flight. It is necessary to provide a reconnaissance flight with an accurate list, including description and position of all ships which it should encounter enroute to the area.

A requirement exists to be able to search files simultaneously and effect split-second information retrieval. These files should indicate the ASW forces available, the readiness and characteristics of these forces. The ocean surveillance files would indicate friendly ships that should be made aware of the possibility of an identified contact, and necessary changes in convoy routing or changes in tracks. Table 2-3 lists task requirements for ASW operations.

2.5 Ocean Clearance, Dispersal of Forces and Naval Control and Protection of Shipping.

An essential resource of the Navy is its mobility. By use of mobility, military force can be brought to bear on a single (or multiple) concentration. Conversely, forces can be dispersed to make them less vulnerable to enemy action. In particular it is prudent to disperse ships when the enemy is expected to strike a port. The administration of this function can be time consuming if performed manually but fortunately it is of a type which can be readily mechanized. The commander must know the present location of all forces and the current state of readiness. For ships in port he must know the repair status and time necessary to get a ship underway. The commander must have a dispersal plan for most contingencies and he must issue instructions to the various units indicating how they should proceed to the various dispersal areas. Additional instructions for rejoining and for command relationships are required. All these instructions are dynamic inputs to the overall functions which are continually changing. The location of ships, the status of repair and even relative seniority of commanding officers are never static. It is a never-ending task to keep this information current. It can be done with ease with a computer system.

It is of interest to note that no use is made of Automatic Data Processing equipment in this function by COMNAVDEFEASTPAC. Occasional practice is made by conducting exercises in which vessels clear ports. Plans for ocean clearance are only in the formative stage. Supporting ADP should be developed with files that include ship, cargo and fuel status. Routing plans must be performed which give realistic wartime considerations.

Under general wartime conditions the EASTPAC area will encompass up to 2200 ports and harbors and endeavor to keep track of 1400 merchant ships underway. The requirement here for ADP is obvious. Table 2-4 indicates the tasks to be performed in ocean clearance and dispersal of forces and protection of shipping.

TABLE 2-3

ANTISUBMARINE WARFARE

Purpose: To neutralize enemy or potentially enemy submarines.

Task 1 - Location - Detection

Subtask:

(a) Search ocean surveillance files by eliminating known contacts, locating positions of all unidentified contacts which may be enemy or potentially enemy submarines.

Task 2 - Classification

(b) Using correlation techniques, classify and as far as possible identify all unidentified contacts.

(c) Order appropriate suveillance - reconnaissance forces to scene to assist in classification.

Task 3 - Reporting

(d) Report to competent senior authority and to forces which will be used in utilization, and to forces which are to be dispersed location, identification, capability and probable intention of enemy or potentially enemy submarines.

Task 4 - Neutralization

(e) Search ocean surveillance files to determine forces in position which have capability of neutralizing submarines.

(f) Dispatch forces to area to neutralize submarines. Receive appropriate reports from tactical commander.

TABLE 2-4

OCEAN CLEARANCE, DISPERSAL OF FORCES AND NAVAL CONTROL AND PROTECTION OF SHIPPING (NCAP)

Purpose: To minimize the effect of enemy air and submarine strikes.

Task 1 - The Data Base

Subtasks:

(a) The location of all ships in port or in the command's area of responsibility is available on the ocean surveillance (ships) file.

(b) The current status of readiness of all ships in port and all naval ships in the area are available on the ocean surveillance (ships) file.

(c) Maintain location of enemy or unidentified contacts in the area.

(d) From search and reconnaissance reports and reports from other commands maintain a file of enemy aircraft and enemy missile launching sites.

Task 2 - Execution

(e) Disperse ships in port in accordance with current "dispersal" plan.

(f) Verify validity of re-grouping points and procedures.

Task 3 - Protection of Shipping (Planning)

(g) From ocean surveillance file, ships readiness file and loading plans form convoys for ships about to leave port.

(h) From readiness files determine escorts available to escort convoys.

(i) Determine convoy routes, and plans for evasion of enemy ships.

Task 4 - Protection of Shipping (Execution)

(j) Issue appropriate instructions to convoy commanders and appropriate reports to seniors.

2.6 Search and Rescue.

Search and rescue operations occur at irregular and unplanned intervals both in peace and in wartime. Experience indicates that they generally occur when least expected and to the detriment of other planned operations. They are generally performed in an environment of considerable confusion. They can be the source of embarrassment to the Navy Department due to the loss of life, and create considerable discomfort to individuals. On the other hand, if performed efficiently and successfully they can accrue good will and good publicity to the Navy and to the commander performing the search and rescue. In wartime search and rescue operations must be done in a routine manner, and if successfully accomplished extremely valuable resources can be conserved.

By providing accurate, timely and complete information the commander of a command control organization can set the stage and almost provide for a successful search and rescue, if it is within the realm of possibility. The information is, again, the same information required in the previously discussed functions. That is, information provided by the ocean surveillance files, and information provided by the readiness and capabilities files. These three types of information in reality can be integrated into a ships file. Regardless of the nature of the file this information must be available to the commander and his staff in real time. He must be able to assure himself with proper queries that he has the complete and accurate information.

It should be noted that in normal peacetime operations the Coast Guard has primary responsibility for search and rescue. In wartime this function will be performed by the Navy. Table 2-5 indicates the tasks to be performed in search and rescue operations.

2.7 Control of Combat Forces.

Except in unusual emergency situations or in very special isolated cases the commander of the command and control organization would not directly control tactical units. His control is exercised through subordinate staffs which have the responsibility of the actual application of military force.

TABLE 2-5

SEARCH AND RESCUE

Purpose: To seek out and provide assistance to ships, aircraft, and personnel in distress, and to coordinate the rescue.

Task 1 - Data Base

Subtasks:

(a) In ocean surveillance files maintain location and capability of all ships in the area.

(b) In readiness files maintain status of ships which can provide assistance.

Task 2 - Execution

(c) Dispatch vessels or aircraft to provide assistance.

(d) Keep abreast of situation and provide public information and logistic services as required.

However, the exceptions and the isolated cases are not trivial. During World War II the Chief of Naval Operations directly controlled units which were combating the German submarines in the Atlantic Ocean. It is very likely that other instances will arise wherein it will be necessary for the staff to actually control and direct tactical units. In the main it is necessary to have mechanisms, procedures, plans, and instructions so that subordinate staffs can be given appropriate but minimum instructions to meet various military situations that arise. The various functions to be performed are focused on maximizing the readiness and effectiveness of the tactical units subordinate to the intervening staff. These are concerned with planning, training, repair of major inoperative systems: morale and evaluation. Many of these functions are day-to-day routines of the staff officer which will necessarily be left undone during emergency or under wartime conditions.. Planning, administration of training, and evaluation requires considerable data and information. The data must be manipulated so that it is meaningful. In some cases many routine computations are required. Table 2-6 indicates the tasks involved in control of combat forces.

2.8 Logistics.

This function is one of coordinating planning of specific agencies involved in logistics. It is necessary to review and approve some logistic support plans prepared by these agencies. In actual practice the commander of a command and control center will only be directly involved in logistics in unusual circumstances. This will usually be in periods of high tension when adminstrative and operational personnel are extremely busy and their time is at a premium. The unusual circumstances will be in matters such as arranging to airlift men and materials during a crisis, or providing logistic support during a search and rescue operation. The staff need not know the many details such as quantities of supplies except in special cases. However, they must have a knowledge of the logistics system operation so that as a measure of expedience they can circumvent established procedures and provide logistic support in a minimum of time. They must have a detailed knowledge of the mission procedures, location, and capabilities of the various supply and logistic organizations in the area. Table 2-7 indicates the types of tasks involved in the logistic support function.

TABLE 2-6

CONTROL OF COMBAT FORCES

Purpose: To direct at a strategic staff level forces assigned in combatting an enemy. To provide them with necessary direction, instruction and other assistance so that they will be successful in their assigned mission.

Task 1 - Data Base

Subtasks:

(a) Maintain ocean surveillance file from which one can extract locations of ships both friendly, unidentified and enemy.

(b) Maintain readiness file from which one can extract readiness of own forces.

(c) Maintain intelligence file which indicates best known capabilities of enemy.

(d) Maintain weather - meteorlogical data file.

(e) Maintain contingency plans files as best advice for a given situation.

Task 2 - Execution

(e) Assign forces in accordance with situation and in accordance with best information from contingency plan. (The query language should be designed to help user in evaluating the information and comparing the actual situation with the situation in the contingency plan.)

(f) Receive plans from subordinate commanders. Check plans with information in the data base. This is a semi-manual operation. The reports from the subordinate should indicate questions to be verified and checked.

Task 3 - Reports

(g) Report to senior commands and to parallel commands action taken or to be taken might affect them or influence their continuity of operating plans.

TABLE 2-7

LOGISTICS

Purpose: To render assistance to ships and aircraft requiring spare parts or services on an emergency basis, and to render administrative assistance to ships filing casualty reports.

Task 1 - Data Base

Subtasks:

(a) Maintain file of capabilities of all repair and supply facilities.

(b) Maintain listing of ships having filed casualty reports (in conjunction with the ships readiness file).

Task 2 - Execution

(c) Provide liaison information for various logistic agencies as required to assistance in emergencies of increasing the effectiveness of the fleet.

(d) Provide accounting support for special items such as petroleum, certain weapons, aircraft and other designated commodities.

(e) Provide special transportation for high priority items.

2.9 Planning for Current and Contingency Operations.

The day-to-day work of the staff officer centers around planning. The effectiveness and efficiency of the command is directly related to the ability of the staff to do completed staff work, that is, perform fully their planning function. Yet there are many distractions to this central function. Accounting must be made of equipment and publications, reports must be made to seniors, training exercises must be evaluated, personnel must be administered. Planning is done in a piecemeal fashion amidst all the distractions. It becomes a laborious, drawn out task with many loose threads. Much of the information is not available at a central location and long delays ensue while the information is being gathered.

Planning consists of 1) searching publications and instructions promulgated by seniors, 2) gathering statistical information from various documents promulgated by technical organizations such as the Naval Oceanographic Office, and 3) applying this information to data gathered from staff publications. After these three steps it is necessary to analyze the planning data to select all possible alternatives, solve problems to make compromises and then to present it in a meaningful fashion. Planning is a difficult operation even without distractions. With routine distractions the efficiency of planning is reduced and the effectiveness of the command is degraded.

The quality of planning depends on the ability to foresee, predict and get an overall picture; normally the planner has either too little or too much detailed information which is not properly classified or digested. It is difficult to get adequate detail with effective summarization and explicit internal relationships. In general a planner needs both simplified and highly abstracted data and an abundance of detailed data. The minimum figure permits easy manipulation and ease of arriving at a decision. The abundance of data permits verification of results and gives the planner a higher degree of confidence in his work.

If the primary function of the staff is to plan, it is essential that the proper tools be provided. In this case it is a large data base with a query capability which permits the user to interrogate the base until he has a maximum confidence in his decision. Real time operation insures that he has a minimum of distractions from the beginning of a query until he is satisfied with the results. This, in turn, means that he can work more effectively under pressure.

The above is a highly idealized solution to the staff planner's problem. However at the beginning it is planned to have in the system as a minimum, information pertinent to the command; information such as ships files, readiness capabilities, port files, intelligence files, a static search and rescue file, and a weather file. Table 2-8 describes the tasks in the planning function.

2.10 Summary of Requirements.

Sections 2.2 to 2.9 consist of a listing of tasks and subtasks to be performed by the operational personnel of a command and control center. It can be argued that the listing is not all inclusive; that the summation of a large number of relatively minor unlisted tasks might affect the mode of operation of the command and control center. The listed tasks comprise the bulk of important tasks for which the command center has responsibility. Additional tasks only make automation in real time more necessary.

In the review of Tables 2-1 to 2-8 it should be noted that there is considerable redundancy of tasks to be performed. The same tasks are listed again and again. Different names--those that are more conventional--are used to describe the files. Table 2-9 emphasizes this redundancy.

For each responsibility the same information is used to provide the commander and his staff with the necessary information to meet requirements. The information can be listed as follows:

1) Ships file
2) Port file
3) Organization/Communication file
4) Search and Rescue Procedures file

TABLE 2-8

PLANNING FOR CURRENT AND CONTINGENCY OPERATIONS

Purpose: To prepare plans for current and contingency operations which will, (1) give the commander and his staff a point of departure to cope with future occurrences, (2) train the staff so that it will be prepared for future occurrences, and (3) to provide a data base that will describe the environment in which unusual occurrences might occur.

Task 1 - Data Base

Subtask:

(a) Maintain an ocean surveillance file which will describe the location and readiness of ships in the area.

(b) Maintain a port file which will describe the port facilities in the area.

(c) Maintain an organization chart which will indicate command-control-communications relationships between the various commands.

(d) Maintain a static search and rescue file which will indicate S&R procedures, principles and relationships.

(e) Maintain an intelligence file which will indicate the current intelligence picture.

(f) Maintain a listing of plans available for coping with current and contingency situations.

Task 2 - Execution

(g) Study contingency plans promulgated by seniors and determine when it is necessary to augment them, that is, define the problem.

(h) Augment the plans as necessary using data from the data base, listed above.

TABLE 2-9

INFORMATION TO SUPPORT OPERATIONAL FUNCTIONS

	Ships File/ Readiness	Port File	Communications/ Organization File/Op orders	Search and Rescue File	Logistics File	Plans and Intelligence File	Weather File
Ocean Surveillance	X	X				X	X
Continuity of Operations	X	X	X		X	X	
Antisubmarine Warfare	X		X		X	X	X
Ocean Clearance, etc.	X	X			X	X	X
Search and Rescue	X	X	X	X	X	X	X
Control of Combat Forces	X	X	X		X	X	X
Planning for Ops	X	X	X	X	X	X	
Logistics	X	X			X		
Providing Information*	X	X	X		X	X	X
Training*	X	X	X	X	X	X	

* Not discussed in text.

5) Logistics file
6) Intelligence file
7) Weather file

Figure 1-1 shows the conversion of command responsibilities to computer functions. Section 1.4 described the general need to maintain and query these files in real time.

It will be shown in Sect. 4 that these files can be reduced to a single data base. Section 6 will indicate some specific instances of the general utility of being able to query these files in real time.

3. HARDWARE DEVELOPMENT BY STAGES FOR A REAL TIME COMMAND AND CONTROL PROCESSING CENTER.

3.1 Devices for a Real Time System.

This section discusses the growth in the number and kinds of hardware devices in the computer complex during the three phases shown in Table 1-7. In brief, this growth occurs

1) by the addition of greater numbers of simple consoles, i.e., teletypes,
2) by the addition of the faster and more flexible cathode ray tube consoles,
3) by the addition of more mass storage to hold the file,
4) by the addition of on-line communications to distant commands,
5) by the addition of programs for new services and functions.

The primary distinction between a real time and a non-real time or batch processing system, insofar as the hardware is concerned, is that a mass storage medium is used for the files which permits individual and rapid (quasi-random) access to items desired either for retrieval or update. The effect, as far as the user is concerned, is the immediate (within a few seconds) response to his transaction (i.e., retrieval or update). Generally, real time systems emphasize the aspect of immediate retrieval of information, however, the real time update function which is often the greater bottleneck in non-real time systems, is potentially of equal or greater benefit. As discussed in later sections, the real time system can effectively eliminate the most severe updating bottlenecks.

It is important to have many points of real time access to the system in order to take full advantage of the real time features. The participation of a large number of people in the formation and use of the data base helps keep the data base consistent and up-to-date. If consoles were provided only for the senior commander and his staff, this essential care of the data base would not be nearly as effective. Since a large number of expensive consoles is impractical, the relatively inexpensive teletypes are recommended as the basic console. For all uses except top command and high volume information input, they are adequate.

The memory device generally associated with the real time system is the magnetic disc file. The model recommended in this report provides an access to any record in an average time of 85 milliseconds and has modular capacities of 8, 28, 56 and 112 million characters depending upon the exact model selected. Alternatively, a magnetic drum with similar characteristics may be used, and under certain circumstances, a magnetic card or strip system such as the Magnacard, Data cell, CRAM or RACE.

The memory device universally used by batch processing systems is the magnetic tape file. Storage requires the serial passage of the tape in order to select specific items. Consequently the retrieval time per query, even for highly efficient batched systems is on the order of minutes to tens of minutes. Furthermore, updating requires the rewriting of entire tapes because the update data cannot be inserted in the middle of the tape.

3.2 Initial and Eventual Families of Computers.

Several families of computers produced by different manufacturers could be considered for real time command and control application. A phased plan is presented in this study starting with the AN/USQ-20B. The AN/USQ-20B is a militarized processor with which Naval personnel have considerable familiarity and which can be adapted to the required peripheral devices, including the magnetic disc files, teletype, CRT displays and other standard peripherals. This processor has 32,000 words of 4 microsecond memory. It is estimated that 8,000 words are sufficient for the executive routine and the buffers for teletypes, leaving 24,000 words for functional programs in a multiprogramming environment. The use of this 24,000 words of core is divided among the various functional programs which are active concurrently. A separate functional program is normally used for each statement of a query; for queries of more than one statement, only part of the required program is in core at one time. The mass storage will also provide back-up storage, as will be described more fully in Sect. 3.9. A follow-on phase (after Phase 3) would consider the eventual transition to a newer generation, time-sharing, multiprocessing system such as the IBM 360, CDC 6000 series, GE 600 series and others. Each of these new systems is characterized as having real time capability through the provision of mass random access memories and fully multiplexed I/O telecommunications facilities. Within each line there is a series of models which enable modular equipment growth with upward and downward software compatibility.

3.3 A Phase Development Plan.

The following three subsections describe the phased growth of the AN/USQ-20B equipment configuration.

The first phase stresses the real time querying and updating of local files. Typical queries are answered in seconds unless there is a backlog of higher priority queries and/or processes that pre-empt the system. All files are local to the computer. Sixteen local stations for entering queries and receiving responses are required in this phase. These 16 consoles could be used as shown in Table 3-1. Completely multiplexed operation of all sixteen is needed so that a single console cannot lock out any of the others. A mass-storage capability of 30 to 60 million bits with an average access time of less than 0.3 seconds is required.

TABLE 3-1

CONSOLE USAGE

USE	NUMBER OF CONSOLES
Commander	1
Staff of the Commander	3
Transaction Updating	4
System Programmers	3
Logistics	2
Intelligence - access	1
Intelligence - input	1
Training and Maintenance	1
	16

Figures 3-1a and 3-1b show the three phases growth of the AN/USQ-20B system configuration suggested for the implementation of the real time command and control computer system.

Peripheral communication to the USQ-20B is via the 16 data channels. Shown in Fig. 3-1a are the various attachments that would be needed. The configuration is compatible with the programming system currently planned for EASTPAC in its use of peripheral devices and channels.

Channels 2, 3, 4, 5, 6, 10, 11 and 12 service the standard on-site peripherals - line printers, paper tape read/punch, card readers and punches and console teletypewriter.

Channels 7, 8, and 9 service the 3 MARS Magnetic tape banks of 4 tapes each. (12 tapes total). All of these would be attached under Phase 1. Tapes are used (1) as scratch utilities, (2) for back-up copies of the master files which can physically be removed from the machine and brought to another machine, and (3) to provide batch processing capabilities so that tape files or massive amount of input from other computer centers may be utilized.

Channel 16 services a large screen CRT with light pen input. One of the functions of this device would be for mapping and other pictorial displays. Hard copy output is provided by a typewriter printer. The light pen (as well as key board) are used to input information in either graphic or alphanumeric form. The attachment of this device is envisioned for Phase 3.

There are two major conversion problems to be faced with the USQ-20B configuration. First, that of interfacing, in a fully multiplexed mode of operation, to the 16 remote teletype consoles recommended under Phase 1 and to remote CRT's as developed in Phase 2. Second is the operations with disc storage. The USQ-20B does not have the multiplexed communication capability and hence must be augmented by means of an I/O processor.

This adaption could be done in two ways. The user consoles could be multiplexed through a specially built adaptor for the USQ-20B or any of a number of available small computers (typified by the Univac 1218 and the PDP-8) could be used for the purpose. The dominant criteria in choice of an

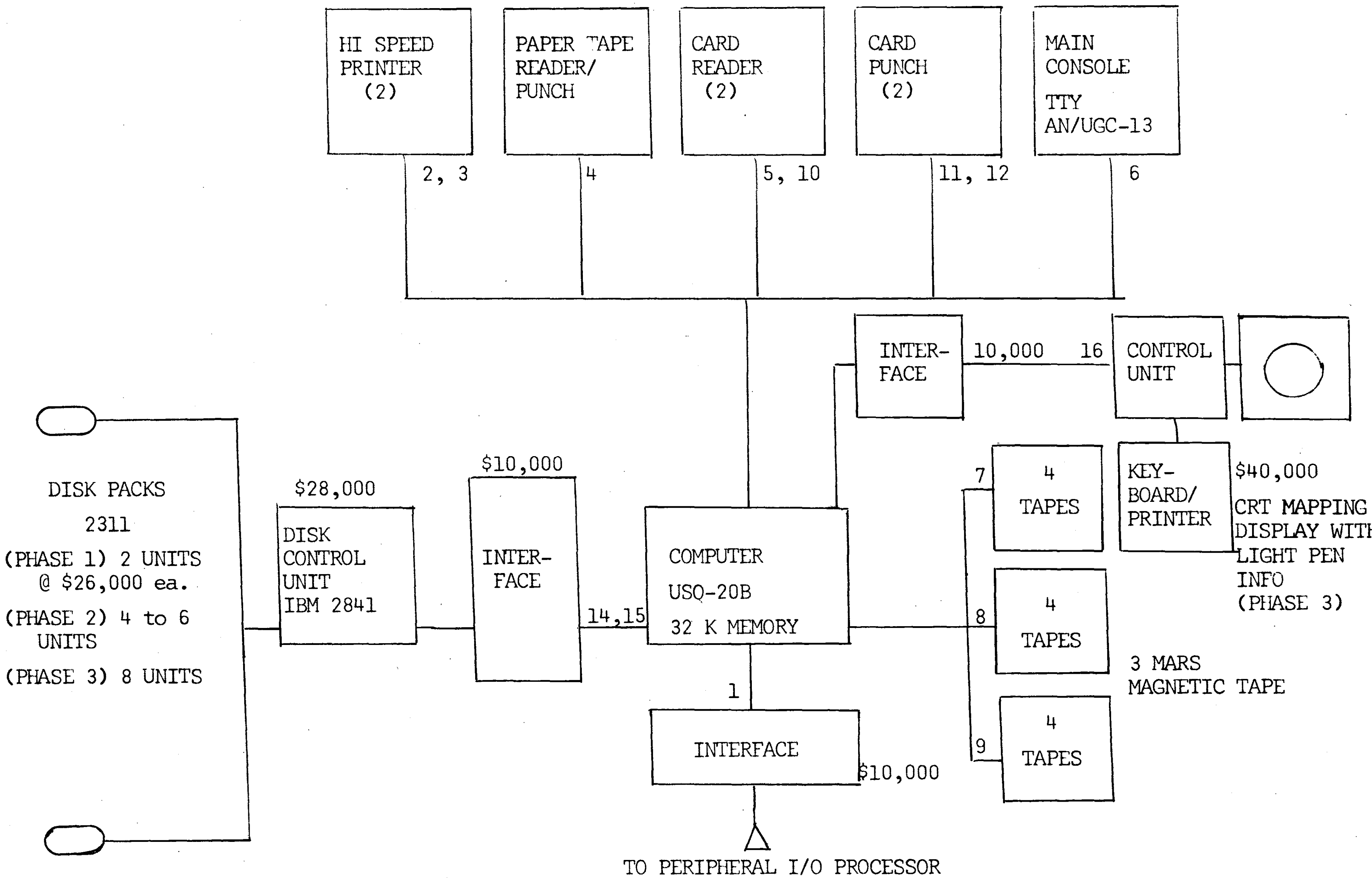

FIGURE 3-1(a) - PHASED HARDWARE DEVELOPMENT.

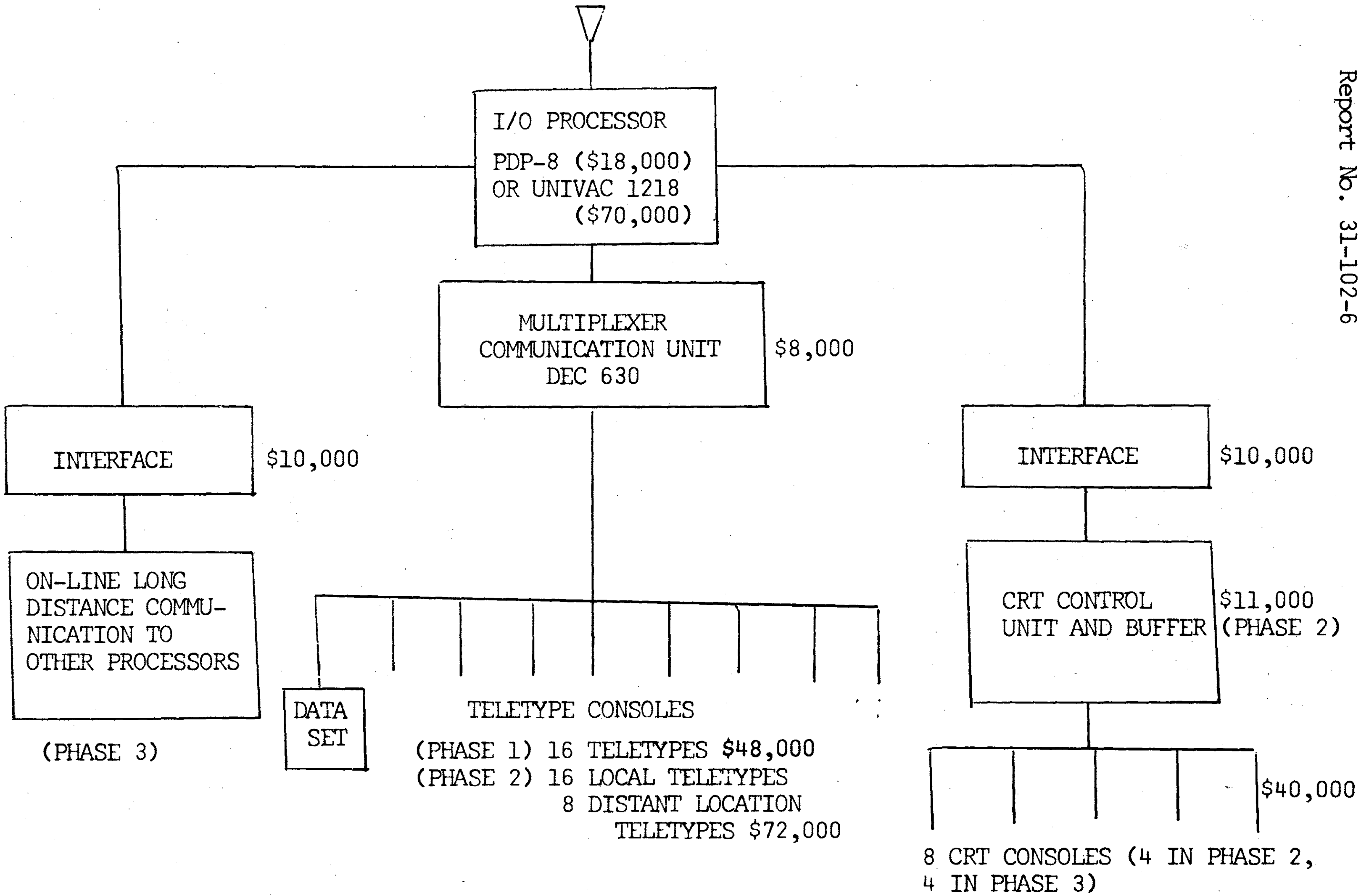

FIGURE 3-1(b) - PHASED HARDWARE DEVELOPMENT.

I/O computer for this application are capacity to multiplex a large number of channels (with appropriate attachments), cost, memory capacity for comfortably large buffers and program space, and proven in-service reliability and maintainability. Table 3-2 compares the salient features of the alternatives and presents the recommended configuration including the PDP-8 computer. The recommended alternative is chosen because it does not increase system cost, because the interface computer can significantly improve the system capacity and speed of response under load and because the PDP-8 has been successfully employed in this capacity in other systems. The final decision on which alternative to choose would depend on intangibles beyond the scope of this study. The configuration for the USQ-20B which follows the recommended adaption is shown in Fig. 3-1 attached to Channel 1.

In order to demonstrate full feasibility for the other alternative (use of a special multiplexer) all of the succeeding discussion of programs relies upon the USQ-20B alone. However, if an interface computer were used, the tasks indicated in Table 3-2 or any portion of them could be profitably shifted to the interface computer. The total effort of implementation would not be significantly affected.

In the recommended configuration the USQ-20B is connected through the interface to a PDP-8 computer, which serves as the I/O processor-buffer, and through a DEC 630 Multiplexer, it can be connected to any number from 1 to 64 communication lines modules with up to three different data transmission speeds. (Fig. 3-1b). The interface must be specifically designed for the purpose of receiving (or transmitting) 30 bits (1 USQ-20B word) parallel from (to) the USQ-20B and transmitting (or receiving) 12 bits (1 PDP-8 word) parallel to (from) the PDP-8. Such a device costs about $10,000. The PDP-8 is a general purpose computer with a 4K, 1.5 μsec memory, which is expandable to 32K. The word length is small (12 bits), but this is adequate for the purposes of an I/O processor. The cost of a PDP-8 with 4K memory is $18,000 and it may be leased for $900. per month. The 630 Multiplexor consists of a master control unit and sub-control units for each set of 8 communication modules. Eight sub-control units can be attached to the master control unit,

TABLE 3-2

ALTERNATIVE INTERFACE IMPLEMENTATION FOR THE USQ-20B

Description	Specially Built Interface Multiplexer	Interface Computer*
Hardware Designation	(Special)	Univac 1218 PDP-8*
Capacity	Fully Adequate	Higher
Cost Estimate	$25,000 - $100,000	$36,000* - $88,000
Tasks of the Interface Device	Multiplex Many Consoles into One Computer Channel	Multiplex Many Consoles into One Computer Channel Input Checking and Assembly of Messages ___ Output Formatting Query Language Interpreter General Message Interpreter

*Recommended

providing a maximum capacity of 64 modules for communication lines, each of these lines may be independently multiplexed into and out of the system. The cost of the 630 master control plus one sub-control unit is approximately $6,300., renting at around $200. per month. Each line module costs $550. and rents for around $20. per month. The PDP-8 can buffer small portions of each message, both for input and output, and then have them read into or out of appropriate working areas in the USQ-20B by the normal I/O commands (as would be used for tape, disc, printer, etc.) of the USQ-20B. If the number of multiplexed lines were to increase toward the limit of 64, then the PDP-8 would have to increase its internal core storage.

Inasmuch as the PDP-8 is a relatively high speed (15 μsec core memory) digital computer, it should not only be used as a buffer, but as a message pre- and post-processor; thus, freeing the USQ-20B exclusively for the execution of functional programs. Preprocessing includes syntactic error checking and formatting of the input message. It may even assume part of the role of the executive. This might include the formatting portions of the General Message Interpreter and the Query Language Interpreter. These are discussed in the next section.

Attached to the I/O Processor (Fig. 3-1b) would be three channels. One feeds the DEC 630 Multiplexing Communication Unit, which in turn feeds the teletypes. The second feeds, through an interface, a CRT control unit which in turn controls up to 8 CRT displays, and the third channel feeds, through an interface, a high speed communication line to another processor at a distant location.

Under Phase 1, 16 local teletypes are to be used, increasing to 24, under Phase 2, with the 8 additional teletypes being located at distant points, and connected over long distance telecommunication lines.

The CRT displays are introduced under Phases 2 and 3. The console consists of a keyboard for entering queries and a cathode ray tube (CRT) for display of both the query and the computer's response. These displays will be clustered for both cost and operational reasons. Most of them will be dedicated to the entry of real-time information and will be manned on a production basis. Their advantages over the teletype lay in speed, in the flexibility with which character errors can be corrected, and in the ease with which the operator may spot more subtle kinds of file errors or data errors and initiate corrections. These units rent for about $60. per station plus about $300. for the controls and buffers for the 8 unit cluster. Stations must be within about a thousand feet of their control. A single, half duplex data phone line is sufficient for an entire cluster. By the use of a polling option at nominal cost, the computer can talk to each man in the cluster independently of the actions of other men in the cluster. All the men in the cluster can work simultaneously with negligible interference caused by the single data line.

Hard copies of the displays could be provided by teletypewriters under the control of the local buffers or they could be provided by means of dedicated teletypes that were directly connected to the computer, i.e., some of the aforesaid 16 teletype stations.

Typical updating will consist of a display of the desired item from the file for manual verification of the proper item, followed by addition or changes of the item by the man at the keyboard, and then transmission back to the computer for checking and refiling and for various summarizations. More efficient updating of the files should result from this process because: 1) the console is more amenable to correction and editing, and 2) computer checking of the input produces an immediate verification response to the operator. The timeliness of this response, while the transaction is still in the operator's mind, will save time and eliminate errors.

On-line, long distance communication to another mechanized command center is scheduled under Phase 3. This would enable the users of one system to have on-line access to the files in another system.

Attached to channels 14 and 15 are the Magnetic Disc Files. Here again an interfacing requirements is met since the contemplated disc file is the IBM 2311 Disc Pack, which is currently being produced in a militarized version. As indicated in Fig. 3-1a an increasing schedule of disc capacity is required through the 3 phase development in order to accommodate the more inclusive and expanding file systems.

The critical nature of the information in a command and control system requires that a second disc copy of the working files be maintained at all times for use by suitable restart procedures in the event of an equipment failure.*

Thus, the AN/USQ-20B could be adapted for the purposes of a real time command and control system. Section 4 will develop the multiprogramming aspects of this system through the System Executive, and utilizing this equipment configuration.

Table 3-3 summarizes the cost and quantity by phase of the additional peripheral equipment required for this application beyond the USQ-20B processor and the standard peripherals attached to channel 1. As noted in the total columns, $174,000 is required under Phase 1, an additional $169,000 is required under Phase 2 and an additional $122,000 under Phase 3. The grand total for the 3 phased implementation is $465,000, which may be interpreted as the effective hardware cost of converting the USQ-20B batch processing system to a real time, multiprogrammed system.

* The need for such copies is recognized in current practice; the present study did not consider whether they were actually necessary.

TABLE 3-3

SUMMARY COST AND QUANTITY CHART FOR ADDITIONAL PERIPHERAL EQUIPMENT

DEVICE	PHASE 1		PHASE 2		PHASE 3	
	QUANTITY	PURCHASE PRICE	QUANTITY*	PURCHASE PRICE*	QUANTITY**	PURCHASE PRICE**
Disc Pack IBM 2311	1	$52,000	4	$104,000	2	$52,000
Disc Control Unit	1	28,000				
USQ-20B/Disc Control Interface	1	10,000				
Teletype Consoles	16	48,000	8	24,000		
USQ-20/PDP-8 Interface	1	10,000				
PDP-8 I/O Processor	1	18,000				
DEC 630 Communication Unit	1	8,000				
CRT Control Unit and Buffer (for 8 CRT Display)			1	11,000		
PDP-8/CRT Control Unit Interface			1	10,000		
CRT Display Consoles			4	20,000	4	20,000
CRT Mapping Display with Light Pen and Printer/ Keyboard					1	40,000
USQ-20/Mapping Display Interface					1	10,000
PDP-8/Hi Speed Telecom Line Interface					1	10,000
TOTAL BY PHASES		$174,000		$169,000		$132,000
Grand Total						$475,000

* Beyond that of Phase 1 ** Beyond that of Phase 1 and 2

4. SYSTEM PROGRAMS.

The system programs are composed of four functions, information storage and retrieval, multiprogramming executive, a General Message Interpreter, and Input/Output. These programs have been described in the previous report.* The approach described there is generally independent of the configuration of the equipment. It is envisioned that it can be adopted in its entirety. Also, it is similar (with some additions) to the system for real time, time-sharing, for Atlantic Sea Surveillance at FOCCLANT. Considerable experience exists with this approach. It is also documented, including flow charts of the various routines.

For completeness and continuity, some features of the system are reviewed in the following. For additional information, the reader is referred to the report* and to NAVCOSSACT documentation on the Atlantic Sea Surveillance System.

4.1 Storage and Retrieval of Information.

4.1.1 File System.

The Command and Control real time file system would necessarily have to integrate a number of currently utilized files, most of which are either semi-automated, automated or on magnetic tapes operating in a batch processing mode. Among these files are those for surveillance. Each of these file systems must be incorporated into the command and control system only to the extent necessary to enable the appropriate command and control functions to be carried out at the required operational levels. Hence, for example, extracts from the inventory files for the purposes of real time command and control would not contain the various quantities on hand for bits and pieces or components or even most subsystems, but rather the inventory status of critical or high priority subsystems, assemblies or larger systems. Similarly, the CASREP, which is concerned with the malfunction of critical components, would be stored in the system.

In summary, all necessary abstracts or extracts from other operational systems and data inputs, such as the CASREP, position reports,

*Computer Command and Control Company Report 21-102-4, "A Concept for a Real Time Naval Strategic Command and Control System", dated April 1965.

sailing plans, etc., will be collected under a unit record for each ship. Similarly unit records would be created for other items of central interest, such as ports, sailing routes, prime contractors, etc. Each such record is characterized by (1) a unique record identification such as an accession number, (2) a set of information retrieval keys which associate records and (3) other data elements.

4.1.2 File Organization.

The file organization scheme is described in the following. It uses list techniques to simulate an associative memory in which each record is stored with an arbitrary number of keys and any record may be retrieved by any of its keys. The technique uses a set of index tables referred to collectively as a tree, which contains an ordered set of all the keys in the system, each key with an address of a record indexed by that key. In each record is the address of the next record indexed by the key, if any exists. A record appears only once in the file but is linked to as many lists as there are keys in the record.

The retrieval keys are characterized as having an attribute and a value. For example, if the "ship's displacement" were a key attribute, then the values would be 1000 tons, 1500 tons, etc. In a sea surveillance file the Task Group might serve as a key which establishes a list in memory by which all ships in a task force may be readily retrieved. Each ship's record is stored only once, rather than multiply in as many inverted files as required. The lists, as they are called here, are formed by linking, via an address, each ship's record with identical key values. Hence, all ships of Task Force "A" are linked by addresses. Table 4-1 illustrates a number of key types.

Figure 4-1 illustrates the linkage for a set of 5 fictitious records containing keys from the set (A,B,C,D). The records are numbered in order of their supposed entry into the file. (Solid lines only).

The records containing Key A are 5, 3, 21, while those with Key C are 5,4, and 2. Since retrievals follow along lists, in order to retrieve those items with both A and C Keys, it is necessary, either to follow the A list and

TABLE 4-1

EXAMPLES OF KEYS AND FORMATS

KEY	NO. OF CHARACTERS OF BITS
Position (to a precision of .1°)	Port or Not Port: 1 bit; Lat.: 11 bits; Long.: 12 bits
International Radio Call Sign (IRCS)	Call Sign: 6 characters
Name and Nationality	Name: 6 characters; Nationality: 2 characters
Ship Type and Sequence of Uprights	Symbol: 2 bits; Ship Type: 6 bits; Sequence of Uprights: 40 bits
Pendant/Hull Number	4 characters
Activity Processing Code	4 characters

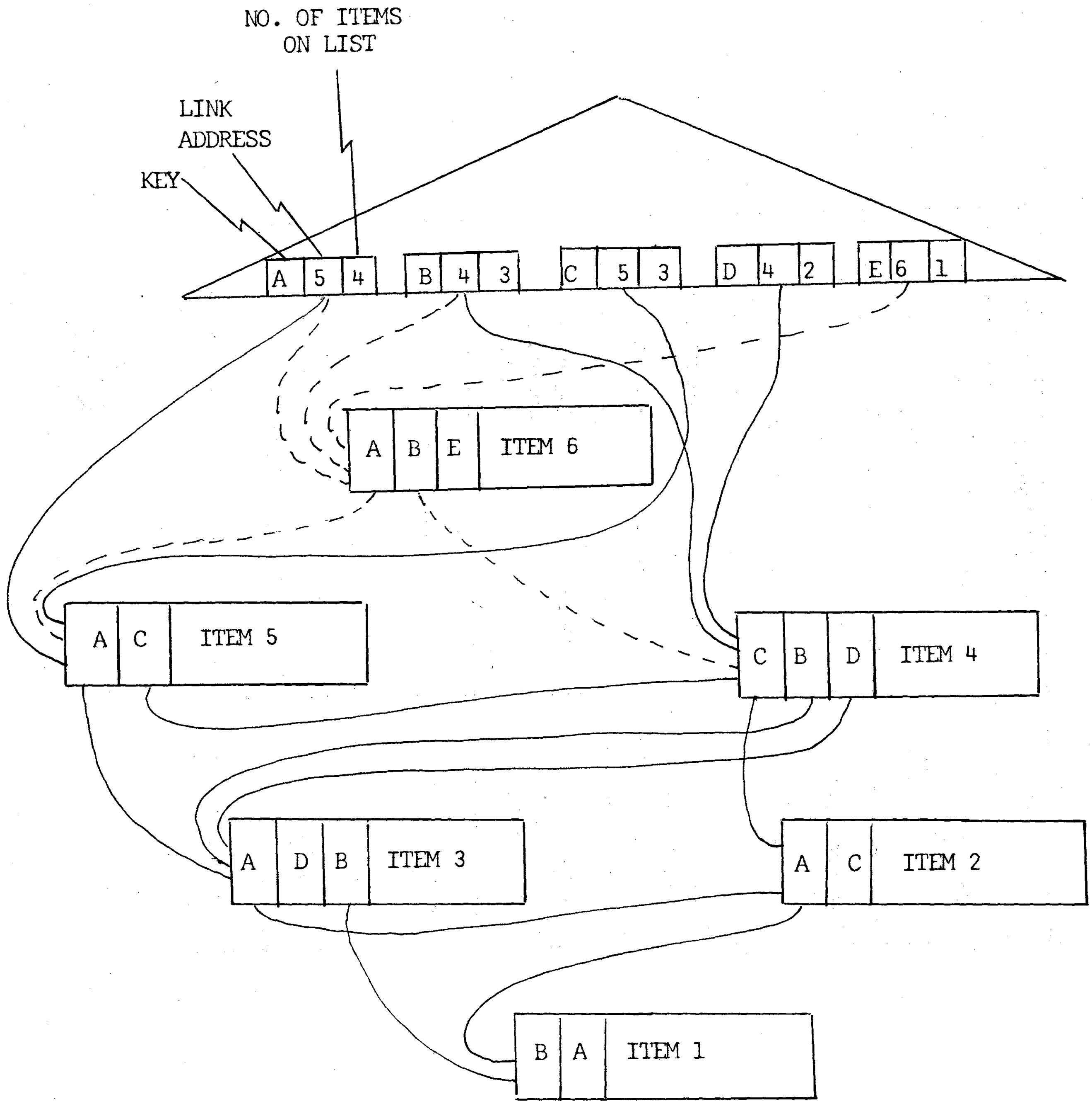

FIGURE 4-1 - SAMPLE MULTILIST FILE.

then look for the presence of key C or else to follow the C list and seek the presence of key A. In this case the latter would be selected since the C list is the shorter, as indicated by the list length accompanying the key linkage at the bottom of the tree.

When a new record is added to the file, it is added at the top of the list corresponding to each of its keys. For example, if record 6 contains keys A,B and E then, as shown in the broken lines the address of record 6 replaces the link address in the tree for keys A and B, and the former link addresses (to records 5 and 4, respectively) would be inserted in record 6. The linkage from the tree to records 5 and 4 is thus broken, and the configuration in memory would appear as shown by the broken lines. Key E is new and therefore would comprise a new list. The program that constructs the tree initially is also capable of real time updating as shown here both with respect to modification of linkages and creation of new lists. Note that by the "push-down" list technique, the new record is added to the list without affecting any of the other records on the list and without necessitating reading of the list. The next subsection treats the subject of real time updating in greater detail.

4.1.3 Retrieval of Items from the List Structured File.

In order to retrieve records from the file in response to query, the best strategy is to find the shortest list length. The query search argument is called a description, and consists of a logical conjunction the terms of which are logical expressions containing a) keys, b) other data element values and c) logical and algebraic relocations such as, 'OR', 'AND', 'NOT', =, >, <, etc. The searching of lists is concerned only with those terms that contain key values and, in particular, non-negated key values (i.e., where 'NOT' precedes the key), since the list of records not in the file is generally rather large. Hence, the retrieval program expects to find at least one term in the description which contains a non-negated key value (or values). If this is not found, a message is returned to the Remote Inquiry Console, indicating that at least one key value must be specified. Three types of logical terms may be encountered in the descriptions, which may be used to determine the list or lists to be scanned. These are:

1) A single key value as: A 'AND' B 'AND' C
2) A disjunction of key values as:
   A 'AND' (B 'OR' C) 'AND' (D 'OR' E)
3) A range of key values as:
   (A 'TO' F) 'AND' (X 'TO' Z)

Any combination of the three may occur. In case 1, the retrieval program will decode each of A, B and C on the tree, find the length of each list and search the shortest.

In case 2, the retrieval program would find the list lengths of A, B plus C (since both lists B and C must be searched) and D plus E. The smallest sum among A, B plus C and D plus E is searched. Each item retrieved is, of course, accepted only if it meets all of the other conditions of the description, including those on data element values.

In case 3, all lists lengths between A and F on the tree are summed, and similarly X to Z, and the smallest of the two sums is selected. All lists in the term with shortest list length sum are then searched. Intuitively it would appear that the overhead sustained in making so many retrievals from the tree in order to determine it would in general be worthwhile, since the disparity in list lengths among the conjuncted terms may run as high as several hundreds to one, whereas the average description would not contain more than a few tens of keys within a single conjunct. The list length (or aggregate list length) for each term in the description that contains a key value must generally be calculated if the shortest is to be found. If, however, a list length of 1 is found for a particular term, then the calculations terminate and the list of length 1 is scanned (i.e., a single record is retrieved.)

4.1.4 Real Time Updating of the List Structured File.

One of the most powerful features of the real time, list structured file system is its ability to update the file system on individual or batched transactions in real time by eliminating the necessity for passing any significant portion of the file through the processor. The processor accesses the required unique records from the random access disc storage. This occasion requires an average of 50 milliseconds from the time the processor command is issued. The processing of the update is likewise quite rapid. The entire process would be completed within approximately 1 second from its initiation in the processor.

The update programs maintain information in each record on the permissable age of that record so that obsolete records can be deleted automatically.

4.1.5 File Protection, Rearrangement and Purging.

Provision must be made for the following:

1) File Protection - The privacy of records must be protected for users who desire such privacy. The means for ensuring such privacy, for update and retrieval are described later in Sect. 6.2.1 and 5.2.2.

2) File Rearrangement - Whenever the reserve area tends to fill up, the space of deleted is collected, by shifting the position of records. This is described in Sect. 5.2.1.

3) Memory Purging - Means must be provided for scanning the memory on a regular basis and deleting records not relevant or records left due to faults in operations of certain programs. The implementation of this feature is described in Sect. 5.2.2.

4.2 The System Executive.

4.2.1 Functions of the Executive.

The function of the executive is to supervise the execution of all programs in the central processor. These functions may be enumerated as follows:

1) The input and interpretation of queries or console originated (system operator) commands, and placing of the query on a queue. Since the system operates in real time, the user may interrupt operation at any time to enter a query. The teletype (or CRT consoles) are connected to the I/O computer as indicated in Fig. 2-1 of Sect. 2, hence the part of the executive that responds to (or accepts input from) the remote consoles resides in the I/O computer. It buffers the entire message, formats it and detects syntactic

errors. When a message is completed the I/O computer interrupts the central processor and transmits the message. The remainder of the input executive resides in the central processor, where the message is interpreted by a programming module called the message preprocessor. In the event that an I/O computer is not used, all of these functions are performed by the central processor.

2) The scheduling of query execution based upon arrival time, priority and current processor load. The central processor puts the queries on an execution queue, which is maintained in the disc. The executive transfers jobs (queries) from this queue with an execution area in core depending upon a) availability of space in core, b) the relative priority of the jobs on the queue, c) the order of arrival (on the queue).

3) The loading of functional (service) programs from the disc to core as required for the execution of a query. Each query may, in general, consist of a sequence of statements, where each statement calls for the execution of some functional or service program upon a particular set of data, called operands. The functional programs are stored on disc in relocatable binary code (i.e., may be brought into core and located anywhere). When a particular statement from a query is scheduled to be executed, its functional program is transferred from disc to core and located in available space by the executive. The executive maintains both a list of available space for this purpose as well as a schedule, called the Job Schedule Table, indicating the current (operational) status of each job (query).

4) The interruption of a job in execution as required under time sharing and multiprogramming, or in response to a console command. Under the principles of time sharing, each job is given a specific time to be in execution in accordance with its priority, the number of times it was previously in core, and the current processing load. When this time expires, if other jobs are waiting in the disc queue, the job in core is dumped back into the disc along with status data which will enable subsequent restart when the job again comes back into core. Termination or temporary suspension of a job may also be initiated from the remote console.

In the event of a detected error, the program (and only that program) would be dumped from core along with an entire dump of all core locations and non-addressable registers (relevant to the execution of that program). An error message is also put out to the appropriate console.

5) The storage and retrieval of operands in the (list structured) disc file in response to requests from functional programs. All storage and retrieval of records in the disc is performed by a program of the executive system called the Storage and Retrieval (S&R) Module. Functional programs communicate operands to the S&R Module, which then retrieves them one at a time from their appropriate lists in the disc file. The S&R Module also checks all retrieval conditions before transmitting a retrieved record back to the functional program.

Three types of retrieval conditions exist. The first type are logical and relational conditions placed upon the keys or data elements and relate to the data or information content of the record. (See Sect. 4.3). The second type of condition is a protection feature which inhibits retrieval or update of a record unless a (user) protection key in the record is matched against the identification key in the query. This enables the establishment of protected files. The third condition is a temporary inhibit on updating of a record. If a record is in the process of being updated by a functional program, a temporary update inhibit is placed on the record (by setting a bit in the record). Another functional program which subsequently attempts to update this record, before the previous functional program has released the inhibit, will not be able to do so. This type of interaction is possible in a time-shared, multiprogrammed system and the system must therefore incorporate this protection feature.

The S&R Module also performs all list and decoding tree construction when records are modified, added to or deleted from the file (see Sect. 4.1).

4.2.2 Block Diagram of the Executive System.

Figure 4-2 illustrates in a block diagram the general flow of program control among the various routines in the executive. The diagram is

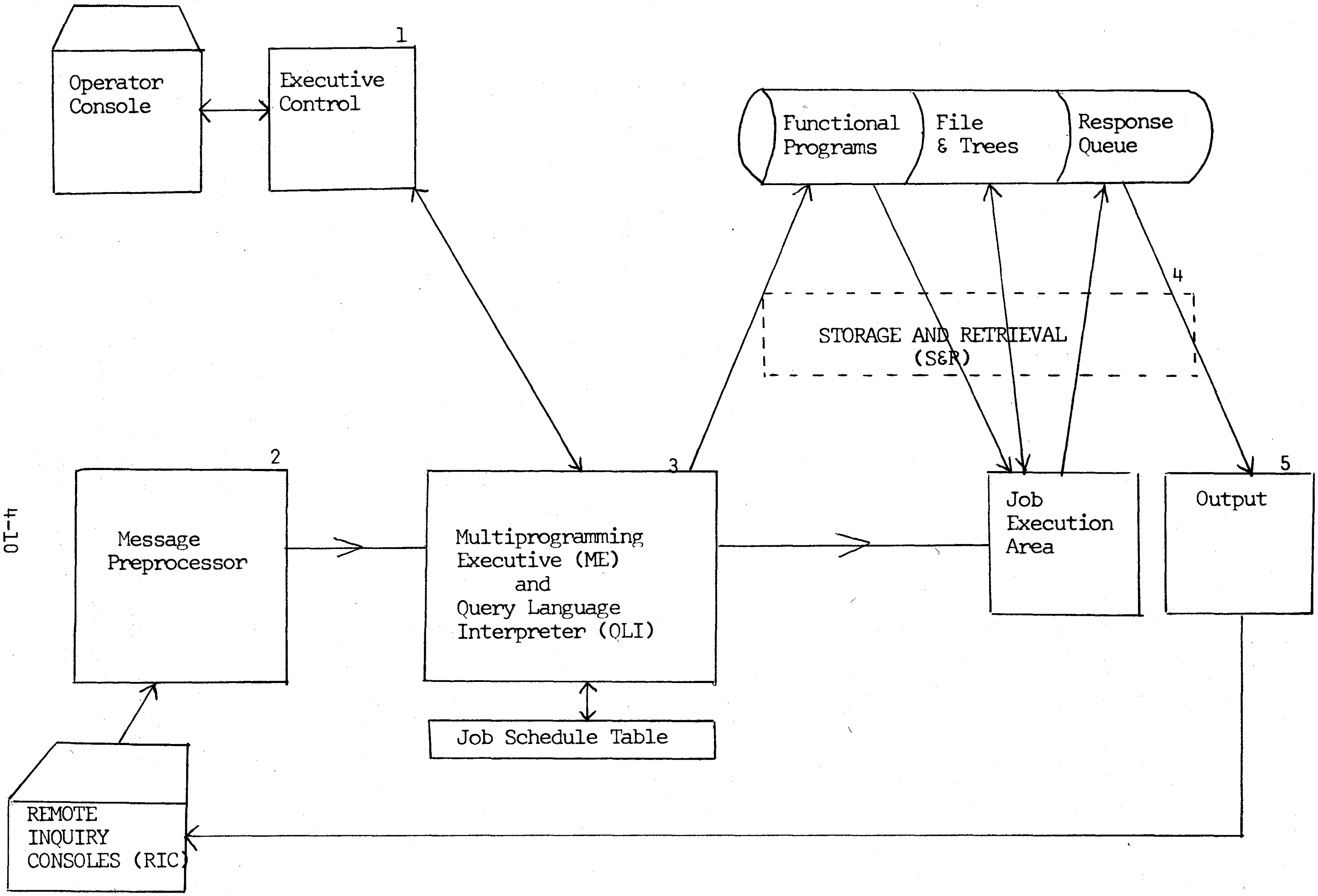

FIGURE 4-2 - THE EXECUTIVE SYSTEM.

described by a statement pertaining to each block of the diagram.

BLOCK 1. Executive Control.

The Executive Control provides an entrance for the operator to the entire system. It also enables the system programmers to assure control directly for the purpose of modifying the executive subsystems.

BLOCK 2. Message Preprocessor.

Console queries are entered from remote interrogation consoles (RIC). They are preprocessed for format and syntax errors and stored in the Query Queue on a disc file.

BLOCK 3. Query Language Interpreter and Multiprogramming Executive.

When a query's turn for execution comes up the QLI interprets each statement of the query for execution by the Multiprogramming Executive. The QLI indicates by means of a table called the Job Schedule Table, the functional program required by the statement. Multiprogramming Executive maintains the Job Schedule Table, including information such as the user's ID, query ID, Job number, priority, requesting console, security classification of request and total core requirement.

The Multiprogramming Executive performs the following four functions:

1) The functional programs that are stored in the disc in relocatable binary are located in a Job Executive Area in accordance with the requirements of the various Job Schedules.

2) The individual jobs in the Execution Area are put into execution in accordance with their respective priorities, and status of input/output buffers, which are filled or emptied by the Storage and Retrieval Module (Block 4).

3) A job may be removed from the execution area in accordance with its execution degradation time. The status of such jobs is stored in the Query Queue in a block along with the query. This information includes the current contents of the index registers and the accumulator and other non-addressable registers and counters.

4) Deletion of a job from core when an uncorrectable arithmetic or I/O error occurs. Only the core area of the job with the error is dumped.

BLOCK 4. The Storage and Retrieval Module.

The functional programs are located in the Job Execution Area by the Multiprogramming Executive. Every functional program that requires either the retrieval or storage of records in the Master File, stored on disc must provide buffer storage for the reading or writing of the record; however, no functional program actually performs the retrieval or storage in the disc. This function is performed, upon command from the functional program, by the Storage and Retrieval Module. The functional program transmits a storage or retrieval command, including the address of the complete operand expression and its internal buffer address. The S&R Module decodes the operand keys to determine the list to be searched and places the head of list address (or a link address, if it is already searching a list) in the Job Schedule Table and awaits the command from the Multiprogramming Executive to make the accession. The S&R accessions are scheduled in such a way as to keep as many disc heads as possible in motion and to minimize the head motion (i.e., to move to the nearest cylinder requiring accession) consistent with job priorities.

The S&R Module also checks the retrieval conditions, as discussed above. Once the record has been read from disc to the buffer, in the case of retrieval and checks the update inhibit in the case of storage. If the retrieved record passes the retrieval conditions, the S&R Module sets an indicator in the Job Schedule Table (for the entry of the particular job), which allows the functional program to go back into execution on the data currently in its buffer. If this indicator is not set, the S&R Module continues to read records into the buffer, and tests them for retrieval conditions until either one is satisfied or the list ends.

BLOCK 5. The Output Module

All output for the RIC's or to the system output files are made by a program called the Output Module. It formats the responses in accordance with the requirement in the query and executes the output.

One option causes output responses immediately as they are found by the functional program. Another option holds all responses on disc in the Response Queue (each job has its own queue) until the search is complete.

4.2.3 Past Implementation Experience.

An executive system which performs all of these functions in real time systems has been programmed for the CDC 1604 - 160 FOCCLANT computer complex for the Atlantic Sea Surveillance System. In that system it is called the 07EX Sea Surveillance Subsystem Executive. It controls the real time multiprogrammed and time-shared execution of queries to a list structured Sea Surveillance file stored in magnetic disc in the same way as described in this section. This Executive Routine is in the PFD for the Atlantic Sea Surveillance and in a report, "Outline of the Sea Surveillance Subsystem Executive Routine", Computer Command and Control Company, 10 June 1964.

4.3 General Message Interpreter.

There is a set of related program modules called the General Message Interpreter (GMI) whose purpose is to control the flow of information and control arising from console input processes. This scope includes validation, interpretation and execution of queries and initial processing of non-query information attached to messages, including user identification, security classification and file protection. Since a large portion of the GMI activity concerns queries, one of the major modules of GMI is a query language interpreter (QLI). The query language and its interpreter are described in Sect. 4.3.2 and 4.3.3; all of the other functions of GMI are described in Sect. 4.3.1.

4.3.1 Message Preprocessor.

The General Message Interpreter is the preprocessor for all messages which originate at the real time consoles. It scans them continuously as they arrive in ways which depend on message content. Each console is devoted entirely to one user until it is explicitly released by the GMI.

The initial processing on any message deals with its header, which includes user identification and all security classification information applying to the message. The Message Preprocessor checks the user security classification and eligibility against tables stored on disc and then (assuming approval) constructs a classification message for use by the subsequently called programs. It also identifies the user and the originating console with the message and maintains this identification for future activity. In general, all complete messages get a response at the console from some part of GMI, and in addition many partial messages receive response, such as security check failure, invalid message syntax of various kinds, and message receipt during program operation.

The header-processing module and the query language interpreter modules reside in core at all times; all other modules are called in from disc as needed.

For queries, the Message Preprocessor performs validation of the query syntax including the punctuation and control words. No checking for internal consistency or correctness of supplied content is performed, although some missing items are identified.

If the query is in the explanatory mode (described below) then a simple mode translation program converts to the equivalent concise mode query for the purposes of further processing. The user may also manipulate the query during the input process in certain simple ways, including insertion and deletion of labeled statements. After translation and validation have been completed for the entire query, it is stored and is executed if the user so directs. Execution is accomplished by a call to the Query Language Interpreter (QLI).

4.3.2 Query Language.

The query language provides the basic means for real time use of the system. Queries are used to initiate selective retrieval and processing, including any of the functional programs available in the system. The normal mode of query use involves a user at a console, composing queries which suit his purpose at the time of need, rather than using pre-stored queries. He may, however, store a query for future use if he desired to do so.

The query language described here is named QL-1. It differs in some significant ways from the language described in previous reports, as is noted in sections below. With some minor variations, the query language being implemented at FOCCLANT for sea surveillance is a subset of QL-1.

The query language makes extensive use of descriptions of file items, data, and programs. These descriptions are used in composing procedures of one or more statements. A procedure and certain header and control information together constitute a query. The fact that QLI accommodates multi-statement procedures is an important improvement over FOCCLANT's sea surveillance query language.

4.3.2.1 Descriptions.

A description is a formal combination of terms which may refer to file items of either programs or data or other program operands. It is most easily described with respect to its use in information retrieval, where it describes the file items desired and the information to be extracted from them. A formal Backus Normal Form specification of a description is given in Table 4-2.*

In a more general context of processing outside of pure retrieval, the description is a vehicle for describing programs and for conveying operands to a program. In the latter case, a description can be used for each operand.

Though capability for describing complex structures is inherent in QLI, the user may use a very simple version in a subset of the available capability. For instance, the complexity of the description is entirely up to the user. Similarly, the system may be addressed by a single statement or by a sequence of statements in a procedures. Existing procedures stored in the system may be used as element values in composing descriptions.

4.3.2.2 Statements and Procedures.

This section describes the composition, syntax and purpose of QLI (Query Language Interpreter) statements and procedures. Each procedure consists of a number of statements.

---

* Symbols in Table 4-2 are defined as follows:

a) anything enclosed in < > is a class of strings of symbols whose permissable forms are being defined.
b) ::= means "is defined to be".
c) the vertical bar separates possible definitions; for any string of symbols, exactly one must apply.
d) all other symbols are from the language being defined.

TABLE 4-2

SYNTAX OF QL-1 DESCRIPTION

```
< description > ::= < condition part > < abstract part >

< condition part > ::= < condition > | < condition part > 'AND' < condition >

< condition > ::= < simple condition part > | ( < simple condition part list > )

< simple condition part list > ::= < simple condition part > 'OR' < simple
        condition part > | < single condition part list > 'OR' < simple
        condition part >

< simple condition part > ::= < existence condition > | 'NOT' < existence
        condition > | < value condition >

< existence condition > ::= < element designator > | < element designator >
        'TO' < element designator >

< value condition > ::= < element designator > < relation > < value condition
        part > | < element designator > 'IN' < value condition part >
        'TO' < value condition part >

< value condition part > ::= < element designator > | < constant >

< relation > ::=  'LS' | 'LQ' | 'EQ' | 'GQ' | 'GR' | 'NQ'

< abstract part > ::= < empty > | , A ( < element designator list > )

< element designator list > ::= < element designator > | < element designator
        list > , < element designator >

< empty > ::=

< element designator > ::= < letter > < alphanumeric > < alphanumeric >
        < alphanumeric > < alphanumeric >

< alphanumeric > ::= < letter > | < decimal digit >
```

A line of coding in QL-1 is called a statement. A statement may appear alone in a message or with other statements in a QL-1 procedure. It corresponds roughly to a subroutine call with an arbitrary number of parameters. Upon interpretation, the interpreter program initiates the retrieval of the "described" routines and data. The storage and retrieval system programs perform the transfer of the information found in disc to core; items already in core are located; and control is returned by the interpreter to proceed with the programs being executed.

A schematic representation of a statement is given in Fig. 4-3.

```
LABEL   OPERATION / OPERAND 1 / . . . / OPERAND k

LABEL   OPERATION             OPERAND
PART       PART                 PART
```

FIGURE 4-3 - THE FORMAT OF A STATEMENT.

The QL-1 Procedure.

A sequence of statements in QL-1 is called a procedure. It consists of one or more statements together with certain identifying parts. Messages from consoles may include a single statement--for ease in usage, or a procedure, representing more complex instructions to the system. The QL-1 Assembler converts QL-1 procedures from the console message format to a compact internal format forming an item that may be stored in the simulated associative memory.

A procedure is nominally composed of seven parts, some of which may be omitted. Any statement may be labelled, and statements which are to be referred to by other statements must be labelled for that purpose. Labelled statements can be immediately identified based on their first character.

1) PROC Part:

Each procedure begins with the symbol "PROC" followed by the name of the procedure.

example: PROC EXAMP

2) SYN Part:

Additional keys are entered as alternate names for the procedure following the symbol "SYN" on the next line.

example: SYN HELP, RGT

Thus, constant values 'HELP' or 'RGT' are other names of the procedures by which it may be retrieved. This line is optional and may be omitted if no additional names are desired.

3) LOCNAM Part:

Descriptions may be quite lengthy and it may be necessary for more than one statement in a procedure to use the same description. To avoid the labor having to repeat the description, a "local name" may be defined to stand for the description and then the local (which has a much abbreviated form of a key hollerith) may be used in the statement in place of the description. An arbitrary number of local names may be defined, each definition consisting of the symbol "LOCNAM" followed by the local name (a key) then the description. A solidus (/) separates name from description.

example: LOCNAM WHO/LEFK'AND'E(10)'GO'E(27)

The Local Name "WHO" is defined as equivalent to the description that follows it.

A set of characters defined as a local name is so interpreted whenever it stands alone as an operand. Should the same set of characters be used in a description, the second use will be independent of the first and no ambiguity will arise. Keys defined in PROC and SYN fields may also be used in descriptions or as local names.

Thus far three parts that go into a procedure have been introduced, one mandatory and two optional.

4) BODY Part:

The next section of a procedure, present in every procedure, is the body consisting of one or more statements. Normal execution of statements is first, second, third, etc., in succession, unless one of the subroutines executed specified a "jump" to an out-of-sequence statement. Each statement may contain a specification of an output operation for the results from that statement.

5) ENDSTA Part:

Following the last executable statement is the symbol "ENDSTA".

6) DATA Part:

An arbitrary number of data elements may be assembled into a procedure item in the form of pseudo-statements--that is, sets of characters that look like statements but actually contain only data and are not executable. Each pseudo-statement generates a single data element and must contain at least one constant. Pseudo-statements must be labelled.

7) END Part:

The end of a procedure is signalled by the symbol "END" and if there are no pseudo-statements the ENDSTA may be omitted.

The minimum number of parts in a procedure is three: PROC followed by a key, one or more statements and END. Figure 4-4 shows a simple procedure.

```
PROC EXAMP
362 PROG
END
```

FIGURE 4-4 - A SIMPLE SAMPLE PROCEDURE.

This procedure called EXAMP has a single statement labelled 362 which is a call upon the routine PROG.

4.3.2.3 Explanatory and Concise Query Modes.

The real time command system is expected to serve a variety of users, some of whom will use it only occasionally. In order to provide an easy tool without requiring full familiarity with language abbreviations on the part of the user, two equivalent modes of query language input and output will be useful. QLI provides an "explanatory" mode for maximum readability and a "concise" mode for faster entry and printout. The design objective for the explanatory mode is that a query should be fully intelligible to officers with no training in system use. (This does not mean that such officers could construct valid queries without some instruction.) The concise mode is intended to provide all of the same power, but with far fewer characters in the query. The modes are equivalent in that translation from one to the other may be made at any time.

All of the basic retrieval routines of the system allow the user to use either mode (but not mixed mode) and any who wishes to do so may provide this option in future programs.

Figure 4-6 shows a sample query exclusive of header information in the two modes. The translation does not affect syntactic structure (except for some substitution of constant characters and punctuation.) It does substitute explanatory and concise designators for element designators, relations, query part designators and punctuation. Figure 4-5 which is related to the example query, shows some sample substitutions.

	Concise Mode	Explanatory Mode
Element Designator	MEDFL	MEDICAL FACILITY
Relation	'EQ'	'EQUALS'
Query Part Designator	PROC	PROCEDURE

FIGURE 4-5 - SAMPLE QUERY MODE SUBSTITUTIONS.

```
Labels

        PROC RESCUE SEARCH
123     RETRIEVE/LATUD 'IN' *D62.5 'TO' *D67.5 'AND' LNTUD
        'IN' *D37.0 'TO' *D42.0 'AND' (MEDFL 'EQ' DOCTOR 'OR'
        MEDFL 'EQ' HOSPITAL), A(SHNAM, LATUD, LNTUD,
        MEDFL, NTLTY, IRCSL, DESTN, COURS, AIRCF, HELIC) /*B
456     SORT/LIST/MEDFL/LATUD/*B
        END
```

QUERY IN CONCISE MODE

```
        PROCEDURE:  RESCUE SEARCH
123     RETRIEVE/LATITUDE 'IN RANGE' *D62.5 'TO' *D67.5 'AND'
        LONGITUDE 'IN RANGE' *D37.0 'TO' *D42.0 'AND' (MEDICAL FACILITY
        'EQUALS' *DOCTOR 'OR' MEDICAL FACILITY 'EQUALS' *HOSPITAL;
        ABSTRACT:  SHIP NAME, LATITUDE, LONGITUDE,
        MEDICAL FACILITY, NATIONALITY, INTERNATIONAL RADIO CALL
        SIGNAL, DESTINATION, COURSE, AIRCRAFT ABOARD,
        HELICOPTERS ABOARD/*B
456     SORT LIST/MEDICAL FACILITY/LATITUDE/*B
        END
```

QUERY IN EXPLANATORY MODE

FIGURE 4-6 - A SAMPLE QUERY IN TWO MODES.

4.3.2.4 Header Information.

A query in QLI consists of a header and a procedure of one or more statements. The header contains administrative information which is not normally stored with the procedure or data involved, but which is necessary for executive control of the query and identification of output. This information includes:

1) User name
2) User identification
3) Security classification of the query
4) Priority of the query
5) Query Mode Indicator
6) Query Number

in a suitable format. User identification is a number which is unique to the individual and which never appears in printed output. It is used as a lock combination is used to identify the user. Security classification is used to check the user's classification and to control access to the files. Priority is used as indicated in Sect. 4.2 by the executive. Query mode indicator controls the form of input accepted and output given, restricting it to either the "concise" mode on the "explanatory" mode; see Sect. 4.3.2.3. Query number is an arbitrary identification number assigned by the user for convenience.

4.3.2.5 Query Language Interpreter.

The purpose of the query language interpreter (QLI) is to interpret successive single statements of a QLI procedure into a call upon the respective program and to initiate execution. The scope of this purpose is further delineated by the description of operations which follows.

A single copy of QLI is maintained in core by the executive whenever one or more query language procedures are in the execution phase. For each procedure under its control, QLI maintains a storage area for its own control purposes. This storage area, called the Job Interpretation Table, includes the following information:

1) A copy of the procedure.

2) A "pointer" indicating the statement currently in process.

3) A table of the operands produced during the execution of the procedure, relating their symbolic form in the query to the identification of the record produced by the program.

In addition, QLI sends an initiating message to the Multiprogramming Executive setting up an entry in its Job Schedule Table. This message includes:

1) A job number created by GMI.

2) A copy of the header information (See Sect. 4.3.2.4).

3) The identification of the requesting console.

4) File protection and access key.

The operand table is used to identify records in core and mass storage which constitute operands for present and follow-on programs. It is constructed by QLI at the time the query procedure is first being prepared for execution.

Each statement in a procedure is translated into a fixed format called the Statement Interpretation Table. Providing information in this format is the only means for actuating a functional program. It is essentially a standardized form of the corresponding query statement.

The QLI consists of three nearly-independent parts, one for normal operation, one for termination and one for temporary suspension of a procedure to disc. The termination section performs a simple destruction of the working space and temporary files of the procedure by releasing them as available space to the appropriate space directories. In the case of terminating a suspended procedure the procedure is recalled to core and then terminated in order to assume that all of its temporary storage is released. Both the termination section and the suspension section depend on the executive to send the necessary confirming messages to the user.

The user may suspend a procedure nominally in execution at any time or the procedure may suspend itself. There are no restrictions on procedure state upon suspension; no identified "break points" are required.

Normally, a procedure will suspend itself after requesting information from the user or after supplying some part of a large amount of information.

4.4 Input/Output.

The input/output software is usually part of the machine's basic operating system. In section 3.3 it was indicated that this software would reside permanently in core as part of the Master Executive Control. Its general function is to enable data to be read into or written out of core memory from or to any of the peripheral devices, including magnetic tape, disc or drum, card reader/punch, paper tape reader/punch, line printer, on-line console printer, remote computer (when applicable) and remote consoles. It performs these functions in response to an I/C call from a program which is in execution by first issuing a channel and device selection command which connects the desired peripheral device to the processor via a data channel. Each device is permanently assigned to a given data channel and many devices may be attached to the same data channel; hence, the channel selection command may find that the channel is busy and the I/O routine would then put the I/O call on a queue.

Various I/O routines having various degrees of sophistication perform differently in this situation. Some give a number of options, which the programmer preselects as part of his I/O call. These may include assignment of a number of priority levels so that the queue is dynamically ordered, return to the calling program without going into the queue, priority assignments automatically made according to the device requested, etc. Once the channel is connected and transmission begins, the I/O routine checks for setting of transmission error flags and reinitiates (where possible) the process when errors occur. The I/O routine will deliver the incoming data (outgoing data) to (or from) the core locations indicated by the I/O call. It also attempts to keep all data channels busy so that overlapped reading and writing operations may be performed with greatest efficiency. The commands to data channels either for selection of transmission are executed independently of the normal execution of the program in the processor, hence, I/O operations may be overlapped with processing if the programmer can so write his program. The purpose of the I/O routines, therefore, is to relieve the programmer of the details of channel operation selection, queuing, error checking and reinitiates.

In general the status and execution of I/O operations is not unknown to the programmer. Certain data is placed in specified locations, which can be examined by the functional program, if desired. These include the number of words transmitted, the status of the operation (complete, incomplete, initiated, not yet initiated), error types and special indicators such as end of file, and of medium, etc.

The specific I/O functions that must be performed in addition to queuing (if desired), error checking, transmission of sense and status data, and reinitiates are listed in Table 4-3.

The level of programming discussed in the above is quite basic in that it is in the machine code itself and serves specifically the programmers of functional programs who would have assembled into their programs calls (as closed subroutines) to the I/O routine. The call merely indicates the device required, the core locations to read or to write queuing or priority options (if available in the I/O routine), and normal and special re-entries to the program in the event of normal or unusual termination of the I/O command. Examples of unusual terminations are, permanent read errors (bad tape) and device not responding (failure).

There is also a higher level set of routines which deals exclusively with output of information resulting specifically from a file search. This function has been referred to also in Sect. 3.3 as residing in the Output Module. At this point it is desired to make this function more explicit.

A common requirement of a file search is that the output be retained by the system and a summary sort, collation, tabulation or count be executed on the totality of response. This is quite readily handled by the recommended Phase 1 system in the following way.

The user includes in his query a call to a functional program for output. The called output program receives the set of records (one or more) produced by the previous program, which are named as an output variable in the producing program and as an input variable in the output program. Depending on the nature of the output program, the records are sorted, tabulated and formatted in accordance with internal conventions, the program call and the

TABLE 4-3

I/O FUNCTIONS BY DEVICE

MAGNETIC TAPE

- Read
- Write
- Rewind
- Write End of File
- Space forward n records or files
- Backspace n records or files

DISC

- Read
- Write

CARD READER

- Read one card

CARD PUNCH

- Punch one card

PAPER TAPE READER

- Read

PAPER TAPE PUNCH

- Punch

PRINTER

- Print Line of Data with Carriage Control

REMOTE CONSOLES

- Monitor Interrupt Signal
- Read
- Write

information received. This output program then processes the output to the user in the chosen format. The records used to produce the output are made available to following programs unaltered. In the cases in which one record at a time is being presented to the output program, the query procedure is written to loop between producing and output sections.

(Since the query language admits procedures which include other procedures, combination programs including a functional part and a selected output part may be written. These may then be called in one-statement queries if desired, with the output type implicit in the choice of the statement operator (program name). For example, a procedure called "Retrieve and Sort" might include both the general retrieval capability and a specific sorted output option; it could be activated by one query statement.)

The user may also elect to have the responses formatted and transmitted immediately (as they are available) from the functional program and also to have them accumulated without committing himself in advance to a particular sort or tabulation format. Then, when the search is complete, based on the real time display, he may use a second query to initiate a selected sort and tabulation.

Some examples of the sort and tabulation options that should be provided are given in Figs. 4-7 through 4-11. Each example presents the output as it would appear in the immediate (as soon as the S&R Module finds it) output form (called UNSORTED) and in the sorted and tabulated form (called SORTED).

UNSORTED OUTPUT	SORTED OUTPUT
DESRON - 92	DESRON - 92
STATUS - 4 HOURS	STATUS - 4 HOURS
DESTROYER - FAIRLAWN	DESTROYER - FAIRLAWN, FAIRMONT, FAIRWAY, FAIRFAX, FAIRLAMP
DESRON - 92	
STATUS - 24 HOURS	STATUS - 24 HOURS
DESTROYER - FAIRFIELD	DESTROYER - FAIRFIELD, FAIRCHILD, FAIRCLOTH
DESRON - 92	
STATUS - 4 HOURS	
DESTROYER - FAIRMONT	
DESRON - 92	
STATUS - 4 HOURS	
DESTROYER - FAIRWAY	
DESRON - 92	
STATUS - 24 HOURS	
DESTROYER - FAIRCHILD	
DESRON - 92	
STATUS - 4 HOURS	
DESTROYER - FAIRFAX	
DESRON - 92	
STATUS - 24 HOURS	
DESTROYER - FAIRCLOTH	
DESRON - 92	
STATUS - 4 HOURS	
DESTROYER - FAIRLAMP	

FIGURE 4-7 - STRATIFIED SORT OUTPUT.

OUTPUT UNSORTED

DESRON	STATUS	SHIP
92	4 HOURS	FAIRLAWN
92	24 HOURS	FAIRFIELD
92	4 HOURS	FAIRMONT
92	4 HOURS	FAIRWAY
92	24 HOURS	FAIRCHILD
92	4 HOURS	FAIRFAX
92	24 HOURS	FAIRCLOTH
92	4 HOURS	FAIRLAMP

OUTPUT SORTED

DESRON	STATUS	SHIP
92	4 HOURS	FAIRLAWN
		FAIRMONT
		FAIRWAY
		FAIRFAX
		FAIRLAMP
	24 HOURS	FAIRFIELD
		FAIRCHILD
		FAIRCLOTH

FIGURE 4-8 - COLUMNAR SORTED OUTPUT.

```
    OUTPUT
DESRON        -        92
  TYPE UPKEEP     -      TENDER
    STATUS             -  24 HOURS        4
                           24 HOURS        1
                                           5

TYPE UPKEEP     -     REST YARD
  STATUS            -    24 HOURS         3
                                           3

  STATUS            -  SUBTOTAL
  STATUS             -  4 HOURS           5
                         24 HOURS          3
                                           8
```

FIGURE 4-9 - STRATIFIED SORT WITH COUNT.

DESRON NUMBER	-	92	
MISSION	-	LANEX TWO	
SHIP		NO OFF PROGRAMMERS	NO ENL PROGRAMMERS
FAIRLAWN		1	3
FAIRWAY		2	4
FAIRFAX		1	5
		4	12
DESRON NUMBER	-	93	
MISSION	-	HUNKILL	
SHIP		NO OFF PROGRAMMERS	NO ENL PROGRAMMERS
CURTIS		2	5
CURTISON		3	6
KELLY		2	8
		7	19
DESRON	-	SUBTOTAL TABLE	
SHIP		NO OFF PROGRAMMERS	NO ENL PROGRAMMERS
FAIRLAWN		1	3
FAIRWAY		2	4
FAIRFAX		1	5
CURTIS		2	5
CURTISON		3	6
KELLY		2	8
		11	31

FIGURE 4-10 - COLUMNAR SORT WITH COUNT SUM OUTPUT.

SQUADRON NO.	SDIEGO TYPE MKX	SONAR MKY	SFRAN TYPE MKX	SONAR MKY	LOSANG TYPE MKX	SONAR MKY	MKX	MKY	TOTAL
92	0	0	4	2	0	2	4	4	8
93	4	4	0	0	0	0	4	4	8
94	1	1	0	0	3	3	4	4	8
95	1	1	1	2	1	2	3	5	8
	6	6	5	4	4	7	15	17	32

FIGURE 4-11 - OUTPUT EXAMPLE OF MATRIX TABULATION WITH COUNT.

5. FUNCTIONAL PROGRAMS.

5.1 List of Phase 1 Functional Programs.

The functional programs include all of the command's computer programs which are not explicitly included in the system programs.

The requirements cited in Section 1 would make a number of functional programs necessary, as listed below. As the responsibilities and information resources of a command change, the system is able to accept such programs in an open-ended fashion and thus keep the system functions up-to-date and efficient. This open-ended acceptance of programs allows the system to be easily modified and to avoid obsolescence. The following functional programs would support the cited responsibilities. Those marked with an asterisk (*) should be made available at the initiation of system operation.

Updating Programs (Sect. 5.2.1)

1. General Record Update *
2. Message-Initiated Update *
3. Dead Reckoning Update *
4. Key Formation *
5. File Rearrangement *
6. Land-Avoidance Update
7. Route Generation *

Retrieval Programs (Sect. 5.2.2)

1. General Query Retrieval *
2. User-Directed Retrieval *
3. Area Retrieval (sector, polygon or circle) *
4. Time-of-Arrival Point Retrieval

Services for Programmer (Sect. 5.2.3)

1. On-line Assembler
2. Debugging Aids
3. On-line NELIAC and Other Compiler

Other (Sect. 5.2.4)

1. Error Recovery Program *
2. Restart Services *
3. File Translator *
4. Ocean Clearing Plan Generator

In general the functional programs are written in assembly language. On-line programming in symbolic language would be available. In later phases compiler languages may be added as well. These programs must provide for all existing computer functions at the time of the switchover to the new system, in addition to the real time services.

5.2 Program Descriptions.

The programs described below are recommended for implementation in Phase 1.

5.2.1 Updating Programs.

All of the update programs operate under a file protection mechanism which requires that each individual who attempts to update a file card be authorized to change information in the update authority category for that record. Up to twenty-nine authority categories can be accommodated; one additional category is set aside for records which no one may update.

1) General Record Update. This functional program is a general purpose file record modification program.

2) Message-Initiated Update. This process provides a general framework for processing highly formatted messages which arrive in high volume from some mechnical information system. Its normal mode is intended to cause updating under operator control with a minimum of intervention. It performs, in succession.

a) Parsing of the incoming message into elements.

b) Calling and performance of any specified internal checking or verification process.

c) Conversion of the set of elements into elements suitable for filing.

d) Retrieval or creation of records for update.

e) Update.

The process is intended to be suitable for update processes in which the initiating record contains elements to be transferred into the files, but for which no special computation is required. The following conversions are allowed in addition to direct transfer:

a) Binary integer to octal or decimal character representation.
b) Octal or decimal character to binary integer representation.
c) Character set conversion.

Variable length incoming record elements whose limits are distinguished by terminal characters or by pairs of numbers in the record are accommodated.

This program includes the format-directed file translator described below. It can accommodate a wide variety of formats and message types easily.

3) Dead Reckoning Updating. A program which advances the position of a ship along its sailing route will be provided. A format for storage of a sailing plan will be designed. Given a ship's position, the time at which it was at that posiition, its sailing plan, and the time for which it was at that position, and the time for which a new position is wanted, this program will compute the position of the ship at the new time.

4) Key Formation. The Index Formation Program would be used it is desired to form a new index for an existing file by designating a specific element designator as a new index.

The values of the designated element, for each record in which it occurs, will be extracted--carrying along the positions of the records--and entered into the key tree in their proper places. The table of contents in the record is also modified to contain the thread of link addresses for each value of the element. Following this, records may be accessed by means of the new index. There would be no change in the query language call for such records, but the efficiency of the process which locates them would go up drastically.

The operation of deleting an index is part of the file rearrangement program.

5) File Rearrangement and Purging. As additions and deletions occur, the available space decreases. A File Rearrangement Program will be

employed which re-orders records on the discs to recreate a maximum size available space. The rearrangement process will delete records whose permissable age (in rearrangement cycles) is exceeded and will appropriately modify the age notations of all other records. Records marked as permanent records will not be purged.

The rearrangement process will construct an image of the rearranged disc file on magnetic tape. The rearranged file will then be written onto the backup disc unit and tested against the source file on a sampling basis for validity. The system will then operate on the rearranged file. During all of this period, updating will be inhibited but passive queries will be allowed. It can be seen that this process would be performed during a period in which update activity was expected to be light and that it would take on the order of one hour.

6) System Snapshot. In order to make documentation of the system history and specifications possible, a "snapshot" of the entire file will be taken at regular intervals, copying the file onto tape. While this snapshot will be too voluminous for direct use or even for printing, it can be used in conjunction with appropriate report generators to produce more specialized documents of direct interest.

5.2.2 Retrieval Programs.

All retrieval programs operate under the control of a protection mechanism which assures the privacy or limited availability of certain parts of the file. Each record contains an access control word which denotes the access control category of the record. One of the access categories is "private", which means that the record is accessible only to the individual who created it. Other categories are for groups of individuals and require that the individual requesting access be authorized for such access according to a filed table. This mechanism acts in addition to normal security access limitation.

1) General Retrieval. This retrieval capability contains all of the options discussed in the sections on query language and on the storage and retrieval system. Specifically, it will accept any description for retrieval and, it will retrieve and select from records according to the description.

If the user genuinely needs an exhaustive examination of the entire file this is made possible by another program. The general retrieval program has modes for delivering either one record at a time or all records.

2) User-Directed Retrieval. This program is a special retrieval program for particularly difficult retrieval and for the user who is not familiar with the files and file vocabularies. It is designed to provide aids to the user beyond the other retrieval programs. The program's features include:

a) The ability to provide responses a few at a time in groups whose size is set by the user.

b) The ability to alter the retrieval query between groups by adding additional restrictions.

c) Automatic output to the user of the length of the thread to be searched by the query.

d) Automatic output of an estimate of the total number of records meeting the request, based on the first 100 records on the searched thread.

3) Area Retrieval (sector, polygon and circle). This is similar to the General Retrieval program, except that retrieval is affected by the position of a ship. The area of retrieval may be specified as a polygon, sector number or circle. The coordinates locating such areas are provided in the operands.

5.2.3 Services for Programmers.

The continued effectiveness of the system depends on maintaining computer programs which are effective in meeting current responsibilities of the command. This requires that the stock of functional programs be growing and changing more or less continuously. This in turn requires that the system provide features which make growth and change by programmers convenient, and that it provide services which will allow rapid and efficient programming to take place without reducing the system's operational effectiveness. This section describes the latter services, which include an on-line assembler and a number of programmed debugging aids.

There is a conflict between the requirement that the operating programs and data be kept safe from accidental change and the desire of programmers to debug programs freely. This can be resolved as follows. A program test mode will be provided in which one program has full control of the machine and thus cannot be disturbed by any other program. By the procedure of setting up this mode, vital information will be safeguarded before debugging is initiated. In addition, multiprogrammed console debugging will be permitted for those who are willing to accept the risk of trouble from an outside program. This multiprogrammed debugging mode will incorporate the same safeguards. Only tested programs will be allowed to operate with sensitive operational programs and data in the operating (non-debugging) mode.

5.2.3.1 <u>On-line Assembler</u>.

The on-line assembler operates as a functional program. It will include the following facilities:

1) Line checking - This is a check for the internal consistency and validity of a line of assembly language program on entry.

2) Line numbering - Generation of a number for every line not numbered by the programmers; this can be done by counting from a given point supplied by the programmer.

3) Storage of pieces of program in assembly language.

4) Construction of a program from stored and supplied pieces, including designated pieces extracted from other programs.

5) Assembly of stored programs into machine language.

6) Off-line entry - Acceptance for storage and later on-line manipulation of blocks of assembly language program on cards.

7) Program display - Print of all or a part of a stored assembly language program on request, on either the printer or the requesting console.

8) Program update - Modification of a stored program by insertion and deletion of lines; this includes the capacity to remove the entire program from storage.

9) Program copy - Making and storing a copy of a stored program, giving it a new name.

In general, programs in assembly language are stored as disc records identified and retrievable by the following descriptors:

1) Programmer's Name
2) Date of Entry
3) Program Name

The programmer may use the standard system update routine to add or modify descriptors.

5.2.3.2 Debugging Aids.

A number of debugging aids are included in the system. Their basic purpose is to minimize the total effort required to produce, test and document the software system. It is not recommended that debug routines be written simply for inclusion in the total software package. However, since the debug routines are expected to be useful after the basic software system is complete, they should be documented and furnished along with the other programs.

The debugging aids should be effective in both of the debugging modes described above. In either debugging mode, the following programs are expected to be available:

1) Selective dump, for use after various kinds of successful and unsuccessful program terminations; total dump of working areas is included as a mode of this program.

2) Snapshot, for recording of selected information at chosen points during program execution.

3) Changed-word post mortem, a listing of memory state changes after a snapshot.

4) Cross-index of Assembly Language Program, a list of the instructions which refer directly to each symbolic address.

5) Active Trace, a record of all conditional and unconditional transfers, accumulated by running the machine language program in what is nominally an interpretive mode.

5.2.3.3 Machine Language Interpreter.

A program which will run a machine language program interpretively is required. This program should control the program being checked to assure that it does not exceed its allotted memory bounds on writing. It allows the programmer to check his program for errors which would cause it to unintentionally destroy information.

5.2.3.4 Compilers.

For economic programming, compilers may be added to the system. They may operate as functional programs within the framework of the executive. NELIAC may be of particular interest. More than one language can be accommodated easily in this manner; mixed language programming may be made available with greater effort.

5.2.4 File Translator and Other Special Programs.

1) File Translator. In order to begin operation with the real time system a data base must be constructed by translation and merging from existing data bases. In addition, in wartime there is a need to accept sudden changes of command responsibility and concomitant changes in the command data base. These latter changes can be accomplished in large part by translating computerized files which were created by the command giving up the responsibility. For almost all of the candidate pairs of commands this requires translating a relatively large number of files which are only partly compatible and which to some extent have unique internal conventions.

The translation of such data bases for local use can be accomplished using either of two approaches. They are:

1) General Format-Directed File Translator.
2) Specific Programs written for each Translation Job.

The first option is a general program which will accept any formatted source file as data, together with a formal description of that file's format and conventions and produce an equivalent destination file in another set of conventions, using a formal description of the destination file's format and conventions. This is made possible through the use of a powerful "meta-language", i.e., a language for describing languages (in this case, two file languages) and a program which operates on files by decoding their meta-language descriptions. The program is equally capable of handling card images, paper tape message, tape files or other formats because of the general nature of its meta-language and translation processes. This program would certainly be more satisfactory than specific job-oriented programs because

1) Once programmed, it is immediately available.

2) It covers small data bases for which specific translation programs would not be economic.

3) It accommodates future changes in source or destination files.

4) It is adaptable to the processing of formatted messages on line.

The chief advantage of the second option, specific programs for each translation job, is lower initial cost, although the cumulative cost of such programs is almost certainly much greater over the life of the system. This conclusion is greatly reinforced when the translation is used for message conversion as well as data conversion.

The recommendation of this report is that file translation must be provided for in the set of programs which initiate the real time system, and that a general purpose format-directed file translator is preferable but not absolutely necessary.

2) Error Recovery Program. A program is required for orderly recovery from an equipment failure. Much of the detailed specification of such a program must depend on the specific equipment involved.

3) Restart Services. In order to avoid the necessity of returning to the beginning of a program if something goes wrong, a restart facility will be provided. The following description is based on the provision of a primary disc and a physically separate backup disc unit for all files.

At a point in a program where a restart point is to be set, the state of the system will be recorded to the extent permitted by the equipment, except for the disc memory. That is, the core memory will be dumped, the contents of registers will be recorded, the positions of tapes will be recorded, the address to which control will go (in the routine in operation) will be noted, etc. Further from this point on, the backup disc is not written upon but is held at the restart state. Records which are changed on the primary disc are noted. Upon successful completion of the restart interval, these records are copied into the backup disc during a temporary suspension of updating. Real time query services are not suspended.

5.3 Expansion of Functional Programs.

Many of the functional programs which would be of significant aid in prosecuting the command's responsibilities (Sect. 1) are not specifically identified with one of the three phases because of their general task-oriented nature. Those below which are required at a specific phase are so identified.

The capacity of the projected system is adequate to handle a substantial number of additional functional programs. A number of the functional programs projected below would be of this character.

The future functional programs may be separated into two groups for convenience. The first group is directly associated with the data base and its management and the second is intended to aid in specific planning responsibilities. Some typical instances of each are described below.

5.3.1 Data Base Management Programs.

The following are typical programs in this class:

1) Exception Reporting Test - For specific content checks defined by the programmer, the program performs the set of checks in a cyclic order. Typical checks would compare summary files with things being summarized, compare planned figures with actual figures, compare partial plans with overall plans, and the like.

2) Data Base Comparison Test - For two data bases which were prepared separately, for specific comparisons specified by the programmer, the program checks the consistency of the data bases and reports disagreements. The intended use is for maintaining coordination between commands.

3) Remote Request Report Generator - Phase 3 - Remote computers communicate directly with the local computer in Phase 3 and beyond. Certain recurrent status reports are processed through the computer to computer link by this program. The program is designed specifically to format the report in an efficient-to-communicate binary form for formatting and printing under the control of the remote computer.

4) Query Language Translator - Phase 3 - Queries may be written in a "local" language for use with a system which does not accept that language. This requires a query language translator which will not only translate the query but will send a message to the originator so that he will understand the response. The program is an augmentation of the general format-directed file translator.

5) Sensor System Update - New and expanded sensor systems will generate message for input to the command files. In some cases special programs to control and interpret these messages will be necessary.

6) Combined Plans Consistency Test - For any combination of filed plans specified by the user, with starting dates specified for each, the program compares their stored resources. The program is intended to accept formatted plans files and combination statements to act as a rapid response coordinating aid. It is useful in checking changes of plans.

5.3.2 Strategic Planning Programs.

A number of strategic planning processes can make effective use of extensive data manipulation which can be anticipated and programmed for the planner's repeated use as he evaluates alternative actions. The titles of a number of such programs are listed below.

1) Ocean Clearance Plans Generator
2) General PERT chart preparation and update

3) Aircraft Scheduling
4) Reserve ship callup generator
5) General Transportation Algorithm
6) Emergency Multi-rescue Planner
7) ASW Multi-contact Prosecution
8) War-gaming against actual files.

In every case, the program would be designed for man-machine use, with the program providing a stream of plan suggestions in response to inputs and changes inserted by the user.

The Ocean Clearance Plans Generator is discussed further here as an example of this type of program. It will operate in a series of steps as follows:

Step 1: Port Clearance. The problem of clearing a port is, in this case, essentially the problem of finding a minimum-time scheduling of the ships through the port's entrance according to an appropriate discipline. Once the discipline is selected, this reduces to a relatively simple job in the job-shop-scheduling area of Operations Research. The selection of the discipline can be done from stored tables on the basis of such inputs as:

1) Submarine Present?
2) Mines Present?
3) Restrictive Weather Present?
4) Sea State Number
5) Day or Night
6) Specific Vessel Priorities or Exceptions

Step 2: Dispersal Destination Planner. Using the previous program's outputs, this step generates a range of plans for immediate dispersed location points. The plans could include:

1) Minimized time to get all ships a specified distance apart (separation of nuclear weapons tolerable damage).

2) Maximum smallest separation by a given time and maximum overall separation.

3) Forming a single antisubmarine convoy.
4) Forming a specified number of convoys.

The planner could modify or select among these plans as required.

Step 3: Diversion of Arriving Shipping. This program would modify a plan previously produced by the man-machine effort of Step 2 to include arriving shipping at a selected time. After Step 2 or Step 3 the program could produce a set of orders for each ship for approval.

6. OPERATIONAL CHARACTERISTICS.

6.1 General Overall Operations.

The magnitude of the responsibilities of the commander of a command and control center have been shown in Sect. 1. The staff can perhaps cope with one or two emergencies arising individually in peacetime but the capabilities are severely taxed to cope with more than this number in a wartime environment.

Only by providing the staff an automatic system which can offer a number of services can there be any assurance that the command and control center will be able to perform its responsibilities. These services permit the command to manage and to process a large volume of diversified data and information in a timely fashion. In addition and in conjunction with the information and data handling system the staff is given a tool to do computations and to assist in problem solving. Many members of the staff can query the data base simultaneously, thus reducing the overall time in which the staff can present to the commander a recommendation for a decision based on completed staff work.

Specifically, the system can do the functions listed below. It should be noted that these functions permeate all the responsibilities of the commander. It was emphasized in Sect. 1 that each of the responsibilities could be classified into a relatively small number of similar tasks and these tasks can likewise be classified into the functions that will be performed by the computer:

1) Storage of Information
2) Retrieve Information/Present alternatives
3) Sort and reclassify information in accordance with a flexible format.
4) Do computations such as updating of ships tracks and others.
5) Prepare tapes/discs for file transmission to other commands.

The System will have the following attributes:

1) Real time operation.
2) Flexible entry and query format.
3) Multiprogramming.

4) Time-sharing, with 16 remote teletypewriters (easily expandible).

5) Open-ended acceptance of functional programs.

6) Flexible to rearrange, augment and delete portions of a system economically.

7) Very small incremental cost to go from a tape to a real time system.

Thus, with a relatively small expenditure of funds and manpower, as indicated in Sect. 7, the command can have the system with the above attributes and capable of performing the aforementioned functions.

It is difficult to estimate computer personnel requirements without reference to a particular command, but for the class of commands described in Sect. 1 the following might be typical for 24 hour operation:

Computer programmers for system maintenance	3
Preparation of entries to files	6
Computer operators	5
	14

Sections 6.2, 6.3, and 6.4 discuss in more detail how specific performance in the update, retrieve and file translation functions affect Naval operations.

6.2 Typical Update Operations.

As stated previously (Sect. 1) update functions are part of all of the responsibilities of the command. With the passage of time, positions, capabilities, readiness, and procedures change. For some functions it is a dynamic change; for others it is almost imperceptible. For ocean surveillance, and for ASW operations real time updating is of great importance.

Taking ocean surveillance as an example, the recording of the positions of ships is done on a routine basis. MOVREPS and other input notices are entered into the file. Assume a system is designed to do all the routine updating at two hour intervals. The file is always current within about 2 hours. Every ship's position is known to an accuracy of its steaming distance for one hour. This is within a radius of no more than forty miles. However, for ASW operation and search and rescue an immediate updating of the information is required. In an elapsed time of 2 minutes the average steaming distance for surface ships is almost insignificant. Processing 100 ship records should take only about a minute. It is assumed for the update process that a series of dual accessions--one to the key decoding tree and the other to the file--is required for each ship. This series is then repeated since the updated record must be restored to the file and sometimes the tree must also be updated. Hence four complete random accession times are required per ship. This would amount to 500 ms or 0.5 seconds per ship. To this may be added around 100 ms of processing time (10,000 instructions). Hence, the time to update 50 to 100 ship records would be around 30 to 60 seconds.

It should be noted that in a real time system the updating must occur concurrently with the response to queries. Provisions are made for this in the executive system and in the task programs.

Future evolution of the system envisions inputting the information directly from an external sensor system into the computer thus further reducing the spatial information errors created by the time delay or operator errors.

A large updating deficiency is the incapability to keep track of a large number of high velocity aircraft. The computing equipment envisioned in this report is not sufficiently sophisticated to have this capability. It does however, have features to handle a small number of aircraft--possibly up to 100.

In summary, the update function enables the operator to have a large amount of information concerning locations of ships, logistics, and intelligence which are currently accurate. The management of data is simplified because of a consolidated location of the information. Many inconsistencies in the data are made readily apparent.

6.3 Typical Information Retrieval for Operations.

A number of the command responsibilities cited in Sect. 1 require rapid retrieval of filed information. Some of these include:

1) Search and Rescue.
2) Antisubmarine Warfare operations.
3) Continuity of operations.

Taking a search and rescue as an example, the organization of a search and rescue at sea involving naval and merchant ships might require thirty-five queries broken down roughly as follows:

Procedures and plans	5
Organization and responsibility	5
Resources and facilities	10
Spatial (Vehicle's position)	10
Communication	5
	35

A typical query might set a number of conditions to be met for a piece of information to be relevant. For instance, the first query might seek all the U. S. (1) Naval ships (2) of 1650 tons or greater (3) having a medical officer aboard (4) and not engaged in a specific operation (5) and within a certain latitude (7) and longitude (8). This query has eight conditions which are indicated by the numbers in the parentheses. On other occasions a query might have very few conditions; a query requesting a list of all ships in a certain latitude and longitude range would have only two. At the same time a number of items of information would normally be extracted from each record for processing. Using a ships file as an example, there might be 200 records which would require examination to select the required information, and of these 5 might be found actually relevant.

Such a query would be answered in 35 or 60 seconds depending upon whether a summary sort were required. This time is reconstructed in two ways as follows:

Assume that the query is stated as "retrieve all ships within the area bounded by latitudes X_1^o to X_2^o and longitudes Y_1^o to Y_2^o." Assume that there are 200 ships located on 50 different lists in the specified area and that the intersection of these 2 conditions is 5 ships. The ship records are retained in a disc buffer until all have been found, and then the records are sorted by increasing distance from a fixed point within the designated rescue area and then printed. In both cases the output message will be assumed to contain 70 type characters per ship.

The process by which this query is answered can be broken down into the following steps:

1) Determination of the shortest aggregate list. (50 in this case, on condition 1).

2) Accession of all lists in the condition selected for search by 1). (50 in this case.)

3) Accession of all records on each list accessed by 2). (An average of 4 per list in this case.)

4) Processing of all records retrieved. (200 in this case.)

5) Write accepted records onto disc buffer. This may be overlapped with 2) through 4).

6) Sort the records in disc buffer.

7) Write the sort output onto the teletype.

The timing for these 7 steps is as follows. It is based upon finding an average of 2 records in a cylinder. All times are in milliseconds.

1)	Access key decoding tree randomly twice	2 x 50* = 100
	Read the 50 from 2 tracks	2 x 38** = 76
	Processing Time	0***
2)	Access 50 heads of lists and read	50 x 50 = 2500
	1st record.	50 x 38 = 1900
3)	Access 3 (additional) records per	3 x 50 x 50 = 7500
	list and read.	3 x 50 x 38 = 5700
4)	Processing of records in core	0

* 50 ms means random access for head positioning. The average access will generally be less than the nominal 85 ms due to the disk accession strategy employed by the Multiprogramming Executive, whereby it moves to the nearest cylinder, given equal job priorities. Hence, the Mean access time of the multiprogrammed system would probably be around 50 ms.

** 13 ms latency plus 25 ms track read.

*** Processing time is overlapped in these examples and so will be ignored throughout.

5) Write accepted outputs onto	1 x 50 = 50
disk buffer.	1 x 38 = 38
6) Read from disc buffer and sort.	1 x 50 = 50
	1 x 38 = 38
7) Write sorted output onto teletype.	5 x 7000 = 35000

Totals:

System Processing	18.0 seconds
Teletype print out	35 seconds
	53.0
Total Time for response	53.0 seconds
First useful response in 18 seconds	

If a sort was not required the output may be overlapped with the processing. The total time would be 37.5 seconds, with first output after 2.5 seconds.

If delegation of work allows each officer to submit 20 queries at most, then the series of queries would take about 20 times 35 sec = 700 seconds or about 12 minutes notwithstanding any additional personnel time taken for decision making.

Since accurate positional information on ships in a particular area is required, a position update of the records of all ships in the immediate area is necessary. If 2 minutes are allowed for all relevant updating, 200 nearby ships could be accommodated, a number which is certainly adequate.
In summary the system might require from 14 to 22 minutes for all processing required in organizing information for a search and rescue operation. During this time the responsible personnel indeed would be actively responding to the actual situation as revealed by the first set of queries.

Such an operation would not preclude other queries since the processor is only occupied about 10% of the time and the disc unit is occupied only about 70% of the time. The remaining time is free for other simultaneous uses, for update, other queries, etc. It should be noted that queries which lead to short threads or few specific file items do not substantially load the system and so could be accommodated simultaneously with the above query in large numbers. Using the same basic response figures, a minimum query would occupy the disc unit for 176 ms. At this rate the system could accommodate about 21 queries per minute at each of 16 consoles, well beyond the man's working capacity.

ASW operations lean heavily on a rapid supply of current updated information. In general an ASW short term planning action would use queries that were technically similar and would be subject to the same restrictions as the search and rescue operation. A larger number of queries might be spread among a larger number of individuals but the resulting delays would be comparable.

6.4 File Translation for Operations.

Continuity of operations requires that information seldom used by a command center--that is, information that is applicable to another command--be retrieved and put into almost instantaneous use.

Several problems become apparent. Foremost is the problem of transmitting or transporting a file from one command to another. If these commands are geographically separated by several thousand miles, such as Pearl Harbor is from San Francisco, it is not presently economical during routine operations to transmit update information by electromagnetic transmission. If the update information is airmailed on a daily basis it will generally be about 24 hours out of date. The second problem is the incompatibility of formats, equipments, and procedures. File translation as described in Sect. 4, provides a solution to many of the compatibility problems. It should be noted that additional standardization would make many translation operations unnecessary. The real time system will insure that the information is as up-to-date as possible. It will be completely up-to-date only when it can be entered into the system in real time by the command that generates the information.

A general purpose file translator can be adapted for either message interpreting, in which input volumes at any moment would be small, or data base construction, in which the input volume would be substantial. For the latter use, the source would ordinarily be magnetic tape and the destination either disc or a tape image of disc. The translator can be assumed to be tape-limited at all times. Assuming a file of 4000 records of 500 characters average length, a tape pass would take 4 minutes at 1000 records per minute. For a typical four pass translation the total elapsed time might therefore be 16 to 20 minutes.

It was pointed out previously that in order to maintain continuity of operations for the foreseeable future, file translation is mandatory. The above calculation indicates it is reasonable for a command to have either a translated or an untranslated data base or file from another command and thus be prepared to assume their responsibilities in a way which is not now effectively practiced.

Several other benefits or operational potentials accrue from file translation. It should be possible to maintain a certain amount of security by retaining untranslated files and not have the means to translate them except with a "locked" code of some sort. The other potential is to uncover inconsistencies in planning and errors in the one or the other commands data base. This will lead to a higher state of readiness for both commands and a greater interchange of ideas.

7. IMPLEMENTATION PLAN.

Previous sections of this report have indicated the requirements for a Command and Control Center, the technical approach to meet these requirements and the operational characteristics of the new system. It is the purpose of this section to indicate specific tasks which must be performed to bring the new system into being in order to demonstrate the feasibility of rapid conversion to the contemplated method of operation.

7.1 Characteristics of the Implementation Phase.

The implementation process described below envisions the following representative set of starting conditions:

1) A working USQ-20B computer at the command.

2) A set of operable non-real time programs doing useful daily work on the computer.

3) Adequate physical space for installation of the necessary additional peripheral equipment (probably less than 400 sq. ft. of floor space).

4) Adequate spare I/O channels for the added equipment.*

In order to maintain the command's effectiveness during changeover, the following set of relatively easy rules should be followed:

1) The new system should be able to run the previous programs.

2) The checkout of the new software system should share time with the daily activities of the old system.

For installation of the Phase 1 system described in this report, these two rules can be followed, since neither the peripheral equipment nor the new programs require any changes in the basic configuration. The use of

* For reference, it is believed that all of the conditions would be fulfilled at EASTPAC, the command used previously as an example.

the non-real time system can be discontinued after the real time system has been installed and checked out.*

The installation of such a system at either an active command site or at a demonstration site will demonstrate the feasibility and advantages of the real time system. Such a system could then serve as a prototype for other command and control centers in addition to the one for which it was developed.

7.2 Implementation Effort.

Performing the tasks listed in this section will take about twelve to fifteen months to perform. The manpower estimate is given simply to show that the implementation could be performed with a relatively small amount of effort. The man year effort is based on analysis of the work and similar experience in implementing the programming for the Atlantic Sea Surveillance system.

	Tasks	Manpower
I.	Hardware Study for Specific Command	.1 man years**
	a) Type of discs to be used	
	b) TTY interface	
II.	Systems Programs	10 man years
	a) File maintenance programs	
	b) Retrieval module	
	c) Multiprogramming Executive	
	d) Query Language Interpreter On-line Assembler	
	e) I/O	
	f) Debug Programs	

* It would also be possible, of course, to perform such a demonstration using a separate computer co-located with the one currently handling the command's work. There is no apparent advantage to this expensive alternative, since the changeover process can be held under 30 seconds, a negligible time when compared with the long execution time of many of the processes of the non-real time system. Thus the non-real time system would be fully available whenever it was required.

** Elapsed time, 30 days.

III.	Functional Programs	4.4 man years
	a) General update	
	b) D.R. update	
	c) File rearrangement	
	d) Key formation	
	e) General retrieval	
	f) User-directed retrieval	
	g) Report generator	
	h) Remote generator	
	i) Error recovery	
	j) Restart	
	Subtotal	14.5 man years
IV.	Optional Functional Programs	7 man years
	a) File translator	
	Message version	
	Large file version	
	Total	21.5 man years

8. ACCRUED BENEFITS.

This section reiterates the anticipated benefits outlined in Sect. 1.5. They can be achieved by the implementation of the phased development plan described in this report. The table below describes the means of achieving the expected benefits.

TABLE 8-1

MEANS OF ACHIEVING EXPECTED BENEFITS

Expected Benefit	Fulfillment
More Effective Data Management	The system provides an integrated file system with a flexible cross reference structure and a flexible access structure. Information items are normally stored in a single location rather than being scattered through several applicable files. The information is kept current by real time updating. Its accuracy is thereby improved; joint use of the information also tends to improve its accuracy. The integrated system (Phases 3 and 4) allows much information to be maintained remotely by its source activity further improving both the quality and quantity of the information actually available for command decision.
Efficiency	The speed of access to filed information averages less than 200 milliseconds per item, in sharp contrast to tape-oriented performance. The file structure allows the search to be restricted to potentially highly relevant items rather than whole files. The multiprogramming strategy provides for efficient use of the central processor, effectively removing it from the "critical path" of computer operation in many cases. The use of powerful and general assembly language program rather than an inefficient macro-language provides continuing efficiency. Together, these measures raise the machine capacity to a level suitable for wartime needs.
New Services	Real time query capability is a new command service which has no counterpart in non-real time systems. The capability to use the continuous attention of a skilled person in problem solving and the capability of assuming a dependent series of queries, of increasing depth (in a reasonable time) are both significant new aspects of this service.

TABLE 8-1 (Contd)

Expected Benefit	Fulfillment
New Services (Contd)	The machine capacity gained by the measures described above allow the use of machine aid in new ways. The prospective uses include automatic exception reporting, data base comparison as a coordination aid, combined plans consistency checking and file translation for continuity of operations. In addition, a number of specific planning aids are made feasible, including a real time weather file, and an Ocean Clearance plans generator which uses current files.
Flexibility and Growth Capacity	The system is designed for progressive growth and ultimate inclusion in an integrated Navy-wide strategic command and control system. Immediate flexibilities include open-ended acceptance of functional programs, programming languages, file capacity, file structure and query vocabulary, the capacity for integrated multi-user files and open-ended acceptance of new message formats and input file formats from any data medium. The system growth phases allow for indecision of remotely located consoles, computer-to-computer query and message activity and finally shared maintenance of an integrated data base held in common in computer at many commands.

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13. ABSTRACT

The existence of a technological explosion in computer equipment and programming makes it necessary to re-examine strategic command and control for possible applications and to find effective ways to implement the applications which are identified. The report indicates the applications to which presently installed equipment can be made by adding multiprogramming features to the system and to introduce equipment and programs for time-sharing. The technical description includes equipment characteristics, system programs for control of job priority, execution, information retrieval, interrupt and recovery, functional programs for a variety of command responsibilities, a flexible file structure, a powerful query language, and specific means for achieving flexibility and growth capacity.

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