P-079

PROPOSAL TO

OFFICE OF NAVAL RESEARCH

FOR RESEARCH ON

GUIDANCE TO PLANNERS

OF ADVANCED NAVY

COMMAND AND CONTROL

SYSTEMS

ATTACHMENT II

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1. INTRODUCTION

This is a proposal by Informatics Inc. to supply research services to the Office of Naval Research to produce documented information which will provide guidance to planners of advanced Navy command and control systems. The Project Plan calls for the consulting services of one man year from Hobbs Associates in the area of computer hardware.

The proposal is for two alternative contracts, one for Subtask 2 only (Current and Projected Technology) and the other for Subtasks 2 and 3 (Current and Projected Technology, Study Integration and Research Methodology). If Informatics Inc. is considered for only Subtask 2, the comments made herein regarding Subtask 3 will convey the fact that there is an appreciation by the proposer of Subtask 3 which will be important in the contract effort.

This is a lengthy proposal despite the fact that contributors were told to write "briefly but comprehensively" on the subject. However, we have organized the proposal in such a way that persons evaluating it can easily and quickly go to the subject of their interest. In addition to the outline provided by the table of contents, Section 2 provides a summary of the entire proposal. Section 3 is the Research Methodology and Technical Approach description which covers what will be done on the project and all of the technical areas. Sections 4 through 10 cover the data processing technical areas. Section 11 is the Project Plan which describes what, how, and by whom the work is to be done. Section 12 is the contractor qualifications.

One of the reasons why this is a lengthy proposal is that the subject matter is very broad. Future Navy command and control systems will use nearly every existing or conceived data processing technology or technique. The requirements of speed, storage and system organization are very broad. They encompass, at least potentially, the entire spectrum of developments for future systems. There is hardly a new technology which can be unqualifiedly said to be inappropriate for use in the operational command and control systems of 10 years hence.

Because the requirements are broad in scope, and consequently the technical areas likewise are broad in scope, so must the contractor and the project personnel have wide experience. Obviously this experience must cover the entire data processing field so that the key proposed project members must themselves have wide experience in the field. On the other hand, they must be incisive researchers and not people who develop general or platitudinous approaches.

We regard this work as a research effort in the strict sense. Our approach, while developed from the point of view of the pragmatist, is academic in nature. In this proposal for example, we have included a bibliography of 89 papers in the field, organized into appropriate sets of references to accompany each section. This obviously is not an exhaustive bibliography but is included as an approach to the literature and existing techniques.

The end results of the tasks of the proposed contract will be a comprehensive document on data processing technology and systems aspects, a meaningful and useful document to the system planner. Each research area or new technology will be discussed from the point of view of its meaning to efficient and economical computer systems or its application in anti-submarine warfare, intelligence, electronic countermeasures or whatever the functional requirement. It will explain what is happening in the field and will develop, analyze and evaluate the various approaches. Finally, the processes will be documented comprehensively and comprehensibly.

The project personnel must understand future Navy uses of the data processing techniques and they must have imagination which leads them to judge what is likely to be important for the future. This can only be accomplished by unusually highly qualified and experienced data processing personnel. The Informatics Inc. team we believe is thus qualified. We further believe that this proposal indicates our great interest in this project and our capabilities for performing capably.

2. SUMMARY

This proposal by Informatics Inc. covers two alternatives: Subtask 2 only (Current and Projected Technology), or Subtasks 2 and 3 (Current and Projected Technology, Study Integration and Design Methodology. Consulting will be obtained from Hobbs Associates in the area of computer hardware.

Our over-all approach to the task is one of a combination of the pragmatist and the researcher. We believe that the project team members must understand the practical future operational uses of equipments but, on the other hand, must also take an academic approach to investigating and developing new techniques. It will be important, for example, to survey the literature on the various technical areas. In discussing the various technologies in this proposal we have developed a preliminary bibliography, since at the end of each section there is a bibliography on the subject matter discussed. These are not comprehensive bibliographies but only illustrate the kinds of reference material to be examined.

Section 3, Research Methodology and Technical Approach, presents the over- all description of the technical tasks to be accomplished. There is first a discussion of the interfaces among the various subtasks. We have discussed the importance of understanding the technical aspects of Subtask 1 on requirements. Project personnel must understand the character of the functions to be accomplished in future tactical command and control systems and the implication of these in the requirements for data processing, hardware and techniques for designing and using it. Figure 3-1 summaries briefly some of the characteristics and requirements for various tactical command and control system functions. Also, an example of man/machine coordination is discussed to illustrate the interplay between the various subtasks of the project.

Technology research in the data processing field will consist of identifying technologies and techniques of potential application and, thereafter, analyzing, evaluating, and documenting them. We have discussed in Section 3 the various tasks to be accomplished under the general subtask of research in current and projected technology. We visualize a comprehensive reference document wherein the various technologies are described, analyzed and evaluated, and where certain trade- offs between approaches are discussed as well as the applicability of certain approaches, of the recommendations and their future use.

In Section 3.4 study integration is discussed. Three different examples are given to illustrate the kinds of trade-offs which will be important in this task. Also, a summary of certain equipment and design trade-offs is presented in the table of Figure 3-7. It provides a candidate list of technologies where design trade-offs must be thoroughly analyzed and understood.

A discussion of system design methodology is presented in Section 3.5. Figure 3-8 presents a general implementation procedure for on-line systems which will be used in future command and control systems. We believe it illustrates our appreciation of the over-all task of developing a concept and of accomplishing the other major tasks of system design, system specification, programming and testing and modification.

Additionally, two examples are presented on approaches to the development of a system design methodology.

Sections 4 through 6 cover six major technical areas of data handling systems: computer organization, input/output and displays, hardware techniques, memory techniques, programming, and advanced usage techniques. We believe they represent an exhaustive list of technologies to be considered. In these sections hardware and software considerations are considered together. We believe this is consistent with the modern viewpoint on date handling systems: the interchangeability and trade-offs between hardware and software. One of the major problems in all of the systems will be to decide whether the programmer should be relieved of his burden by having hardware to accomplish certain tasks, or whether flexibility and economy is best obtained through implementation by software. In Section 8 however, we have discussed programming from the standpoint of certain techniques not directly related to hardware.

In the section on computer organization we have emphasized the trends toward multi-computers and multi-processing. We have not neglected, however, the new types of machines referred to as "highly parallel" machines where the arithmetic and control logic is highly decentralized. Also, micro-programmed computers are discussed and it is pointed out that successful designs have emerged from a compromised micro-programming approach. We believe that analog/digital hybrid techniques could play a role, but this must be more fully investigated.

In Section 5 there is a lengthy discussion of input/output and displays. Displays and man/machine communication devices are becoming extremely important as increasingly more functions of command and control systems become automated. Figure 5-3 presents many of the key characteristics of existing consoles. This is typical of the work which must be done in understanding current and projected technology. Likewise, in Figure 5-4, a correlation is made between the application or functions to be performed in a typical command and control environment and the hardware requirements which result from those functions. There is also a discussion of the various system configurations of attaching consoles to computer systems.

Group displays and communications are discussed in Section 5. We point out for example, that the state of the art in group displays is lacking in many respects. Customers are not happy with present equipments. There are some uncertainties about the requirements and response times, and there are many interesting technologies such as electro-luminescence which look interesting for the future. This will be a challenging and contentious area for the project personnel.

In Section 5.6 there is discussed the very important area of communications. Today's command and control systems and those of the future are to a very great extent communications handling systems. In this section we discuss the functions, requirements, systems and uses in relation to communications and communications techniques and equipments.

In the section on input/output and displays, we have not neglected the important area of computer programming. In general the equipments are general purpose and a considerable design problem is present in implementing these equipments through computer programming. Programming systems will emerge, for example, for display consoles just as they have emerged for scientific problem solving.

In Section 6, hardware techniques are discussed from two basic standpoints: basic components and techniques and integrated circuits and other batch-fabrication techniques. We have noted, for example, the research and development effort in cryogenic components, magnetic logic components, tunnel diode circuits, kilomegacycle circuitry, and other more novel techniques of recent years. Radically new techniques involving the use of lasers and optical components are likewise discussed briefly.

We believe that integrated circuits and associated packaging techniques are not speculative future developments but are here today and should be carefully considered for future operational use. Logistics, maintainability and serviceability will be greatly improved by the use of integrated circuits.

Memory techniques, as discussed in Section 7, are most important to date handling systems since much of the technology in hardware and software centers around the computer memories. Memory hierarchies play an increasing part in computer design. Also, there are many techniques becoming important such as the overlapped access of independent memories. Addressing and searching raises important questions about the use of associative memory concepts. There is no doubt that content searching, list processing and the like will become important concepts in future computers. We point out that a number of important papers on associative memories and list processing devices recently appeared in the literature. Likewise the hardware techniques of thin film and cryogenics are not to be ignored.

Thin film memories are improving in cost and reliability. Under this section on memory techniques we have included a comprehensive discussion of mass memory. Much of this is summarized in Figures 7-1 and 7-2. Recentl developments in mass memory techniques make them important elements in future command and control systems.

A very great cost element in command and control systems in represented by programming. Assemblers and compilers represent the possibilities for economizing on system implementation. However, selection of languages and implementation of advanced compilers has not progressed very far at this time, especially in areas of importance to real time programming. The executive and master control concept for real-time systems is, however, a subject of increasing importance. This technology is discussed in some detail in Section 8.2. Understanding the total programming problem is likewise important. The experience gained on large military command and control systems such as SAGE, 465L, OPCON and the like should be carefully considered. Certain standards such as cost per instruction and the "instruction yield per man month" should be developed.

We have included a short section on advanced usage techniques covering areas such as learning and self-diagnosing techniques, heuristic problem solving and language translation. We point out that although these research areas are, in general, not far enough along for immediate operational consideration they will, neverthless, have important influences on the design of future hardware and software.

In Section 10 there is a short discussion of Naval tactical data systems and National Emergency Command Post Afloat (NECPA). A number of points appropriate to this project are developed therein.

Section 11, on the project plan, is a very important section since it describes what work will be done, how it will be done, and by whom. We have included in Section 11.1 a detailed work statement and delivery schedule. We have developed in Section 11.2 a work plan and milestones and schedules for the project as illustrated in Figure 11-1. In Section 11 we point out that a project control system to insure efficient and economic work is of great importance. It would be our plan to develop comprehensive project plans to assure good project management.

The project team members proposed for this work are presented in Section 11-4. Dr. Walter F. Bauer is proposed Project Manager and Mr. Werner L. Frank as Associate Project Manager. In Section 12 we point out the qualifications of the 11 people from which project personnel will be drawn. Six of the 11 personnel proposed have had over 12 years experience. As a group, they have had experience in many major command and control systems. Experience in all the technical areas is represented. We have summarized some of the experience of the personnel in Figures 12-1 and 12-2. The project personnel have published over 40 papers of direct applicability to this project. They are listed in Section 12.4.

Informatics Inc. and Hobbs Associates are both heavily committed in military data systems work for it is the main orientation of the organizations. We are extremely interested in participating in this challenging work for the Navy.

3. RESEARCH METHODOLOGY AND TECHNICAL APPROACH

In this section the approach to the tasks are described without specific relation to the individual data processing technologies. The intent of this section is to show our appreciation of the total job, our understanding of the relationships among the three subtasks, and the efficiency with which we can perform the tasks as indicated by our candidate approaches to the technical effort.

Our proposal covers subtasks 2 and 3, that is, the technology as well as the study integration and design methodology tasks. If the Navy does not wish to consider Informatics Inc. for subtask 3, Sections 3.3 and 3.4 which cover study integration and system design methodology are less applicable. However, these sections would still be useful in illustrating the appreciation of the Informatics team of the work tasks of subtask 3, an appreciation important to the qualifications to undertake subtask 2.

3.1 SUBTASK INTERFACES

The various parts of the study contract for tactical command and control systems interact heavily. To develop a list of candidate techniques and technologies for subtask 2 the contractor must have experience and an appreciation of the command and control operation and have the capability of readily absorbing the developments of subtask 1 (requirements).

To illustrate some of the points of interaction between the requirements subtask and subtasks 2 and 3 a chart is presented in Figure 3-1 indicating some of the computer requirements and conditions which are related to certain system functions. In the small space of the chart it is not possible to present the relationships in detail. Consider, however, as an example, "Status of Forces and Resources". This is essentially a file maintenance-file interrogation problem.

SYSTEM FUNCTIONS	CENTRAL COMPUTER ABILITIES	DIGITAL COMMUNICATIONS	DISPLAY CONSOLES	GROUP DISPLAYS	MASS MEMORY REQUIREMENTS
Weapon System Control	Fast and arithmetic	Probably little	Monitoring	Not likely	Little
Navigation (navigational satellites, inertial navigation)	Fast and arithmetic	Probably little	Monitoring	Not likely	Little
Status of Forces and Resources	File and character handling abilities	For Command reporting	Great usefulness	Some likely	Very great
Strategy and Tactics	File and character handling	For Command decisions	Great usefulness	Likely usage	Great
Surveillance System Operations	Character and arithmetic	Probably required	Useful	Useful	Considerable
System Simulation (training and test)	Fast, character, and arithmetic	Not required for locally generated inputs	Great usefulness	Useful	Great
Planning	File and character most desired	Probably none	Great usefulness	Some likely	Great

Figure 3-1 Computer Requirements Related to System Factors

3.1 SUBTASK INTERFACE (Continued)

Information is received from lower echelons about the status of weapons, logistics, materials, etc., over digital data links. The information is filed in mass memory devices. Consoles are used to interrogate the system in detailed ways. Group displays are used to obtain gross or total presentations, usually on a geographical basis.

There is much interrelation among all 3 subtasks of the total project. In a paper on Information Processing in Military Command, Bauer (1)* recently presented the diagram in Figure 3-2 showing man-machine coordination. This can be used as an example to illustrate the interplay among the various subtasks. In the first place, the functions to be accomplished by man and machine are listed on the diagram. These in turn can give rise to more specific technical functions such as data acquisition, data retrieval and the like. Information flow likewise comes into the picture since in this man/machine coordination the data volume, data rates, and frequency of operation are important considerations. Concerning current and projected technology, the question immediately arises as to what kind of device will interface between the man and the machine (computer). How much information should be shown on the cathode ray tube or display device, and what should be the size and number of characters displayed? Concerning study integration, questions arise concerning the techniques for attaching the console to the computer. Should it be attached to an input/output channel? Should it have its own buffering system? Should it have its separate computer to service the console apart from the main computer? Finally, of course, there is the question of developing a methodology for answering the questions -- for developing quantitative measurements of the trade-offs between the various possible system embodiments.

It is difficult to overemphasize the requirement that the various personnel employed on the three subtasks should remain in close communication at all times. The various measurement parameters developed

*Numbers in parentheses refer to the bibliography at the end of each section.

MAN/MACHINE COORDINATION

FIGURE 3-2

3.1 SUBTASK INTERFACE (Continued)

in the technology studies are dependent on the requirements of the integration subtask requirements. It will be necessary for subtask 2 project personnel to determine the point of view of the system project personnel. For example, in the consideration of disc file memories, the technology personnel will want to know the importance of multi-access files. They will further want to know from systems oriented people how many computers might be required to simultaneously access a file or how many positioners should be moved simultaneously by the various computers using the file.

3.2 TECHNOLOGY RESEARCH

Ideally, the completion of subtask 2 on current and projected technology should result in documentation which can be used as a ready reference for all questions of future system design. It should update planning capability. It should cover all technologies, and list all the parameters and characteristics which the future system designer would want. It should also include evaluations of techniques to allow the system designer to make decisions concerning whether the techniques and technologies are to be used and how they should be used.

More specifically, the following is a list of questions on technology which should be answered by subtask 2:

1. What techniques are available to perform the various functions and operations required of command anc control systems?
2. How have these techniques been used in the past? What degree of success have they emjoyed?
3. What is the likelihood of future developments along these lines? Will the future see a growth of this type of technique or is a new turn in the technology likely? What physical limitations such as speed of light, physical and topological layout of the components, size, and weight, and the like will be the future limiting factors?

3.2 TECHNOLOGY RESEARCH (Continued)

4. How can the technique or technology be used in future systems and in future system or subsystem developments?
5. What are the interfaces and trade-offs between this technology and its counterpart in software (hardware)?
6. What are the parameters which determine the applicability of this device, and what are the various parameters and values of the characteristics in present and projected technology?

Figure 3-3 shows the four work tasks in subtask 2. On the basis of inputs received from subtask 1 on data requirements and on a survey of the technology, techniques and technologies are identified which are candidates for consideration. Lists of present techniques are developed as well as techniques which appear to be necessary. An evaluation is made of the relative importance of the various techniques and the requirements for analysis are likewise developed.

With further reference to Figure 3-3, the next step requires an analysis of the various techniques. The various techniques are studied carefully on the basis of existing literature and verbal discussions. As a result of this analysis the various characteristics are developed and various application parameters are generated. Technical discussions and specifications are likewise developed as appropriate. This provides information on which to evaluate the techniques. The evaluation work task results in statements concerning the applicability of the techniques, recommendations for its future use and remarks on how the techniques can be used in systems and in subsystems.

The figure also shows that the process is not a linear one, that the various work tasks, as they are performed, give rise to changes in "previously" accomplished tasks. In other words, the tasks in reality proceed in parallel to a very great extent. Also the various work tasks develop outputs important to the study integration phase of the work even before the final documentation of subtask 2 is completed.

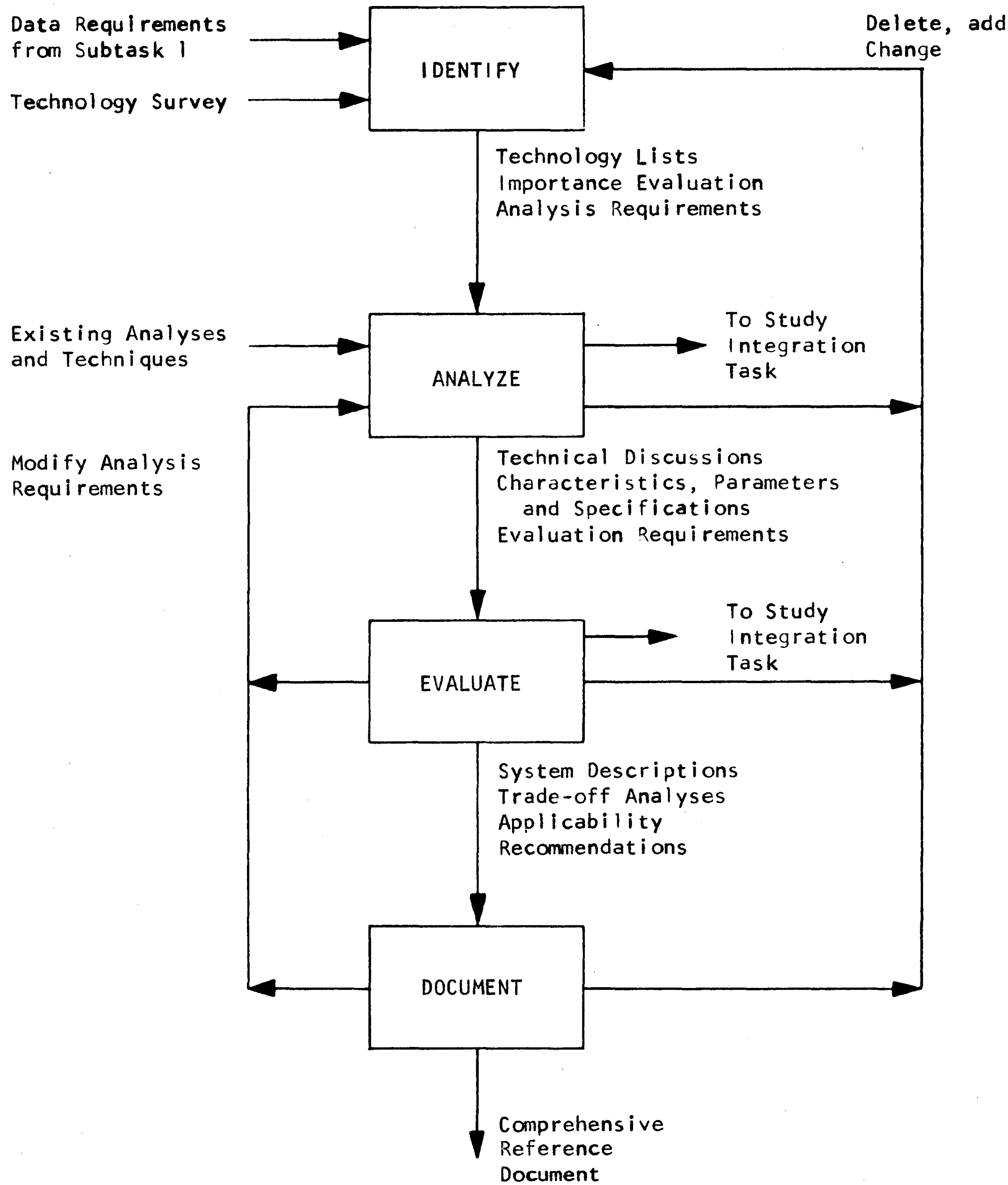


FIGURE 3-3

CURRENT AND PROJECTED TECHNOLOGY RESEARCH

3.2 TECHNOLOGY RESEARCH (Continued)

All of the work tasks described here would apply to all of the major technical areas of data processing. They are as follows:

computer organization,
input/output display,
hardware techniques,
memory techniques,
programming, and
advanced usage techniques.

These technical areas will cover all of those which are candidates for consideration in tactical command and control systems. These are discussed in Sections 4 through 9.

3.3 APPLICABILITY CRITERIA

3.3.1 Discussion of Criteria

A very important function of the proposed study will be the development of criteria for use by Navy planners in selecting the types of components, techniques, and operations to use in each specific portion of the 1970 - 1980 ear Navy Tactical Data System. During the study, while analyzing the different components and techniques that appear promising for that time period, careful consideration will also be given to determining criteria to use as a basis for comparing and evaluating these components and techniques. Criteria will be established for the major components, techniques, and operations to indicate the conditions under which they should be used and their relative advantages and disadvantages. For example, charts plotting the cost of magnetic core and thin/film memories as a function of capacity and speed can be used as a guide in determining which type of memory to use in a specific type of application.

In establishing such criteria and making decisions on the basis of them, it will be necessary to consider not only the performance offered by the component, technique, or operation but, also, to

3.3.1 Discussion of Criteria (Continued)

properly balance this performance against the cost, reliability, maintainability, and environmental conditions. It will be necessary to give adequate consideration to the compatibility of each component and technique with all others used in the system, and to give proper consideration to compatibility with existing equipment, systems, and software. Equipment and techniques developed and experience gained in connection with the present Navy Tactical Data System must be adequately weighed in proposing new components, techniques, software, or methods of operation for future systems.

3.3.2 Research - Operational Lag Times

In addition to considering the advantages and disadvantages of new and proposed components and techniques, and considering their technical feasibility it will be necessary to accurately estimate the date at which these new devices can be expected to be fully operational on an economic basis. For example, it is not sufficient to determine that associative memories can offer significant advantages in the operation of a Navy Tactical Data System. It is also necessary to determine correctly whether associative memories of appropriate size will be available on an economic basis at an early enough date to plan their inclusion in a Navy Tactical Data System for the 1970 - 1980 era. Cryogenic techniques are an excellent example of this. As early as 1956 research workers were proposing the use of cryogenic memories. Since that time, considerable effort has been spent in research and development on memories of this type. Yet seven or eight years later, no cryogenic memories are in commercial use,although they still offer great promise. This illustrates the necessity for knowledgeable consideration of the technical problems involved that might further delay the successful use of new techniques in an operational system.

3.4 STUDY INTEGRATION

The study integration phase of the work is probably best accomplished by identifying certain candidate systems and subsystems. For each of these different approaches to accomplishing the data processing tasks, the various trade-offs are investigated to develop the proper combinations of systems effectiveness, cost, maintainability and the like. Sometimes the approaches will consist of various ways of approaching the over-all system, and in some cases an input/output system might be considered. In still other systems various component technology combinations might be considered.

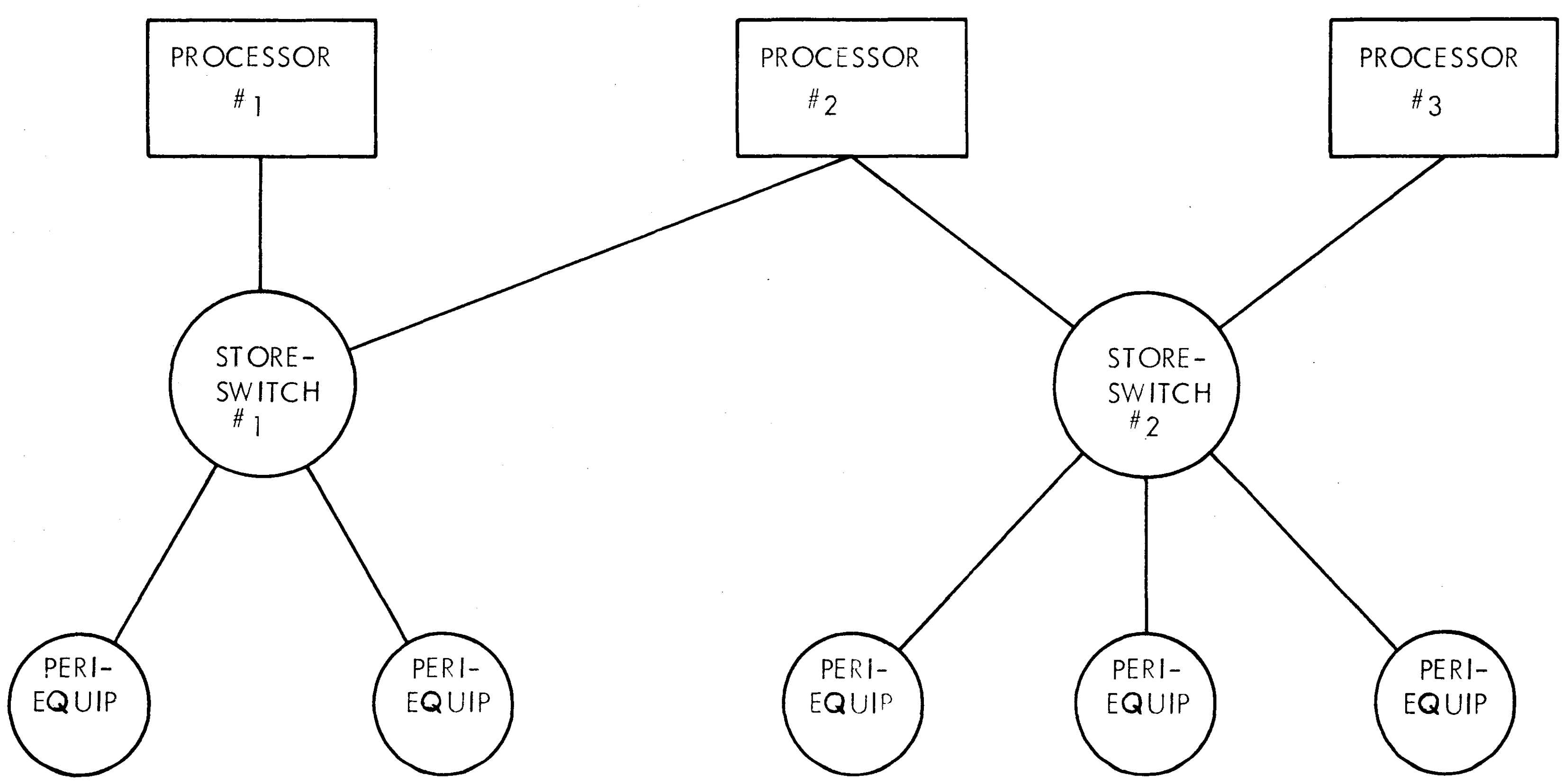
Just a few examples of some of the ways of approaching the task are as follows:

1. In multi-computer approaches there are two basic ways of handling the communication within the system. The two ways are shown in Figure 3-4.

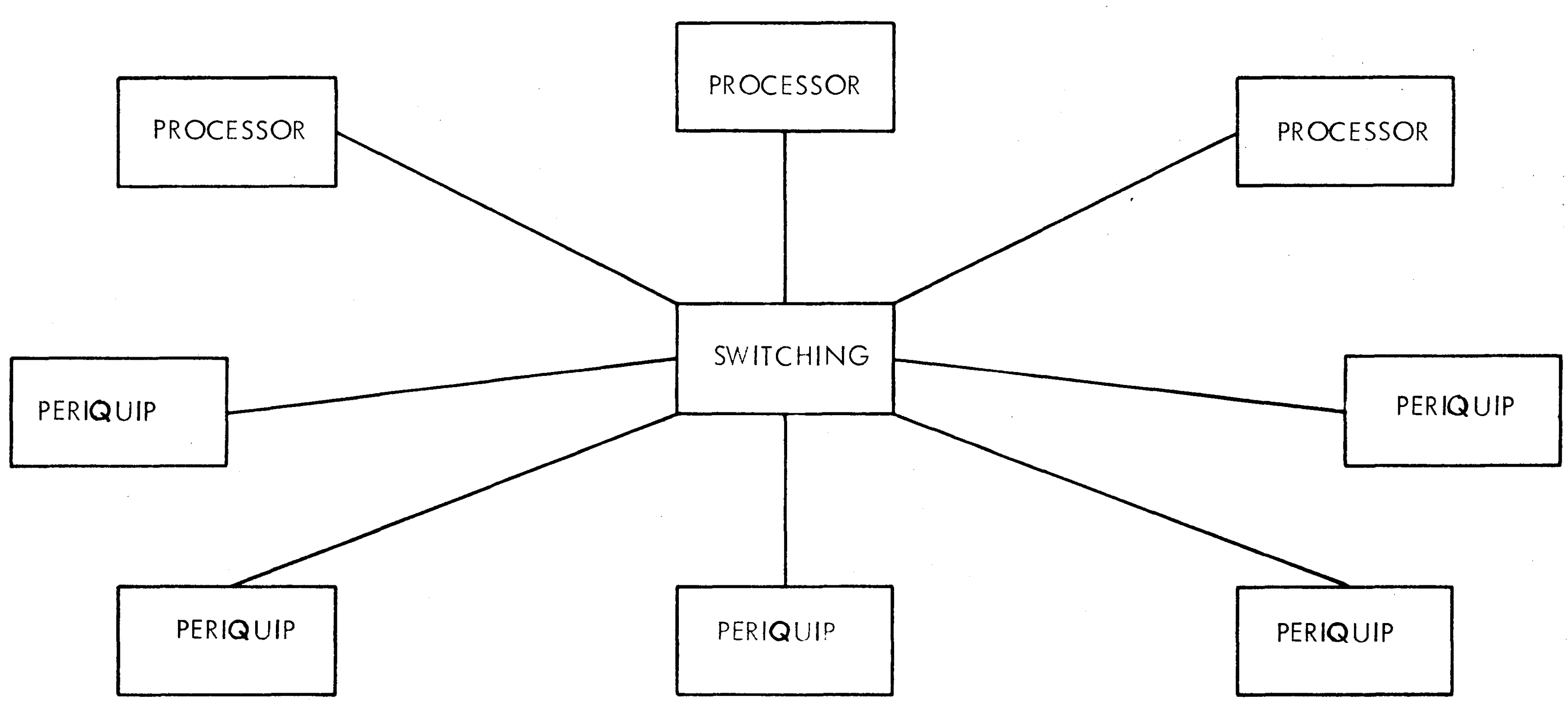
   The various trade-offs among reliability, cost, availability and the like, can be assessed for each of these systems and a comparison can be made in a clear-cut way which establishes the merits of one system over the other.

2. There are two basic ways of handling the input into a command and control system of communications. One of these is referred to as "internal multiplexing" and the other as "external multiplexing". Internal multiplexing involves the read-in of communications information directly into the computer which is to process it. External multiplexing refers to the receipt of the communications information in computers or buffers which are external to the computer processing it. To aid in the analysis of the two basic approaches we must consider some fundamentals of queuing theory involving such variables as processing speed and the delay of servicing of incoming messages. Figure 3-5 shows a relationship between

TOPOLOGY OF COMMUNICATION



SUBSTATION COMMUNICATION



CENTRALIZED COMMUNICATION

FIGURE 3-4

BASIC WAYS OF HANDLING COMMUNICATION WITHIN THE SYSTEM

3.4 STUDY INTEGRATION (Continued)

various factors in servicing incoming messages. Given a processing speed, a demand rate, and a unit processing time, the average delay for message processing can be determined from the graph. This topic was briefly discussed in a paper by Bauer (2), on computer design.

3. As a third example, consider the attachment of console displays to a computer system. There are three basic ways of accomplishing this as shown in Figure 3-6. In one technique, the console is tied directly to the input/output device of the computer. In another,as shown in the figure, buffering equipments are used. In a third technique a computer is used instead to provide buffering. Having determined these three candidate approaches, the benefits and applicability can be assessed for each in relation to the others.

A summary of certain equipment and design trade-offs is presented in the Table of Figure 3-7. In general the left-hand column represents a trend which is generally considered desirable in modern systems. However, always there are advantages and disadvantages when comparisons are made with an opposing or alternative approach. In the study integration work, comparisons such as these will be made in great detail with appropriate analyses which yield quantitative results.

3.5 SYSTEM DESIGN METHODOLOGY

Figure 3-8 shows a general implementation procedure for on-line systems such as those involved in command and control. The figure shows certain management functions as well as the documentation required in the orderly implementation of such systems. Descriptions of each of these tasks have been prepared by Informatics Inc., but for the sake of brevity they have not been included with this proposal. The figure does not show a design methodology but rather shows the tasks which must be

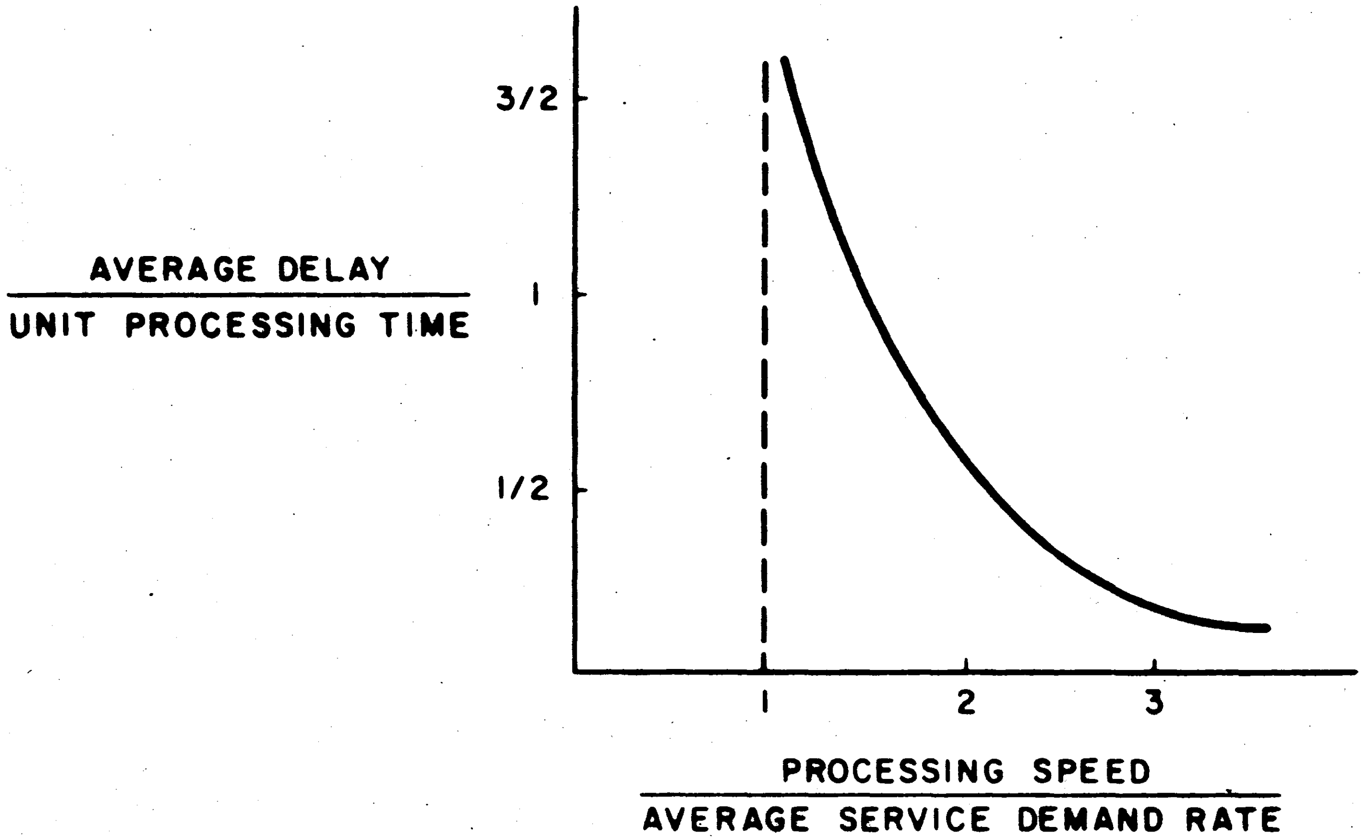
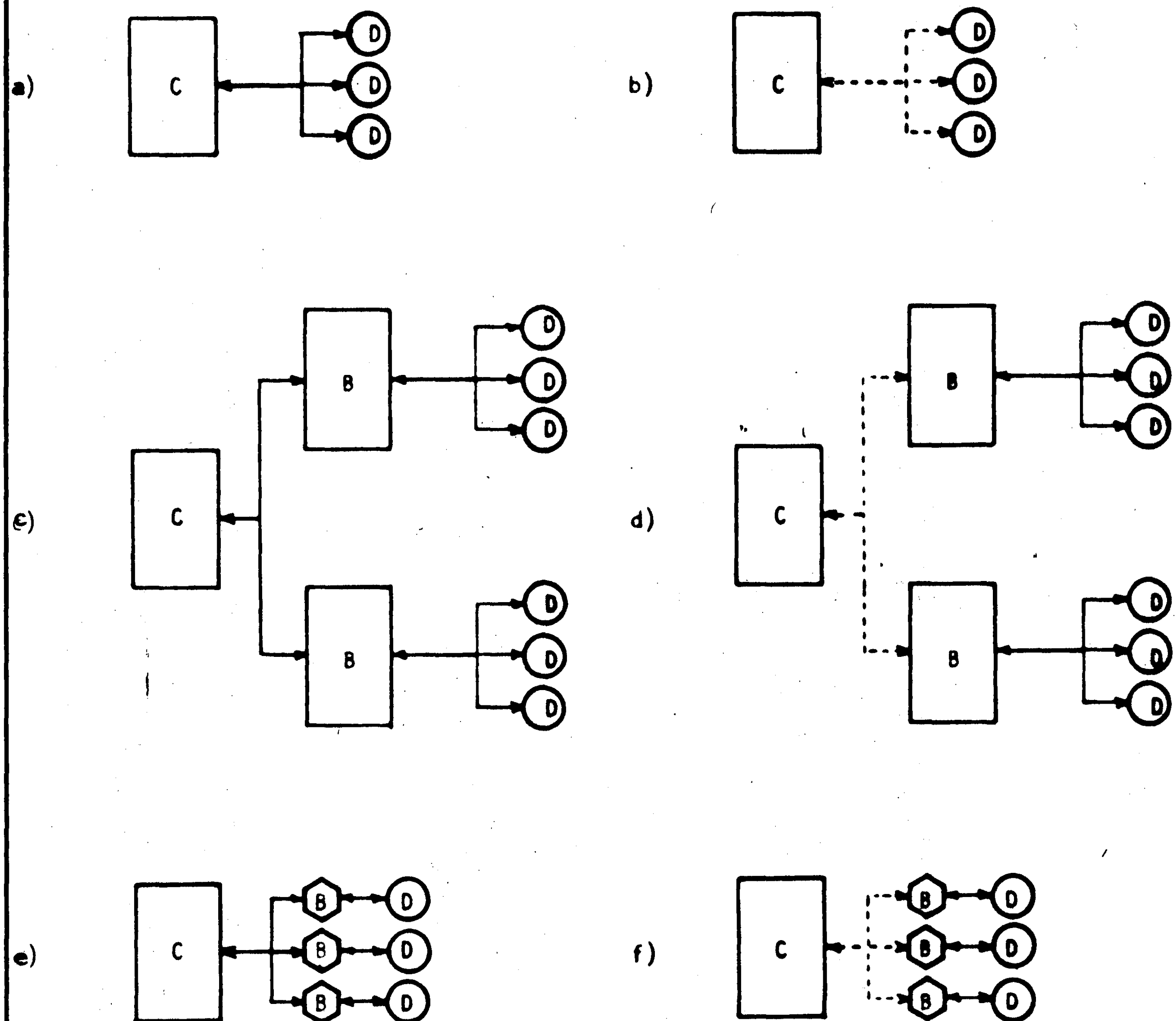


FIGURE 3-5

QUEUING THEORY APPLICATION



C - COMPUTER

B - BUFFER

D - ON-LINE DEVICE

——— UNBUFFERED I/O CHANNEL

- - - - - BUFFERED I/O CHANNEL

FIGURE 3-6

COMPUTER/ON-LINE DEVICE CONFIGURATIONS

EQUIPMENT OR CHARACTERISTIC DESIRED OR CONSIDERED	ADVANTAGES	DISADVANTAGES	OPPOSING OR ALTERNATIVE APPROACH
Parallel Processing	Higher speed for circuit component speed	Higher costs for switching and programming	Single-stream processing
Memory Hierarchies	Higher capability-cost ratio	Higher programming costs	Homogeneous memory
Crossbar type Switch (for system communication)	Low cost and high transfer rates for high number of modules	Greater cost for small number of modules	Information bus
Elaborate Display Consoles (CRT's, extensive keyboards, etc.)	Greater flexibility, multiple uses	Greater cost	Single-purpose consoles
Multi-computers and Decentralization	High system reliability Possible programming ease	Switching requirements Possible programming complexity	Centralized computer
Input-Output Pre-processing (independent of main frame)	Relieves main frame	Possible extra equipment design	Multiplexing into main frame
Photographic Type Group Displays	Greater flexibility	Faster response	Electric type
Problem Oriented Languages (for real time operations)	Lower programming costs	Lower system operating efficiency	Assembly languages or machine coding
Modularity	System growth and maintainability	Possible higher costs	Singleness or uniqueness
Extensive, Elaborate, Interrupt Logic	Programming ease, system efficiency	Cost; design problems	Simple interrupts or none

FIGURE 3-7

SUMMARY OF EQUIPMENT AND DESIGN TRADE-OFFS

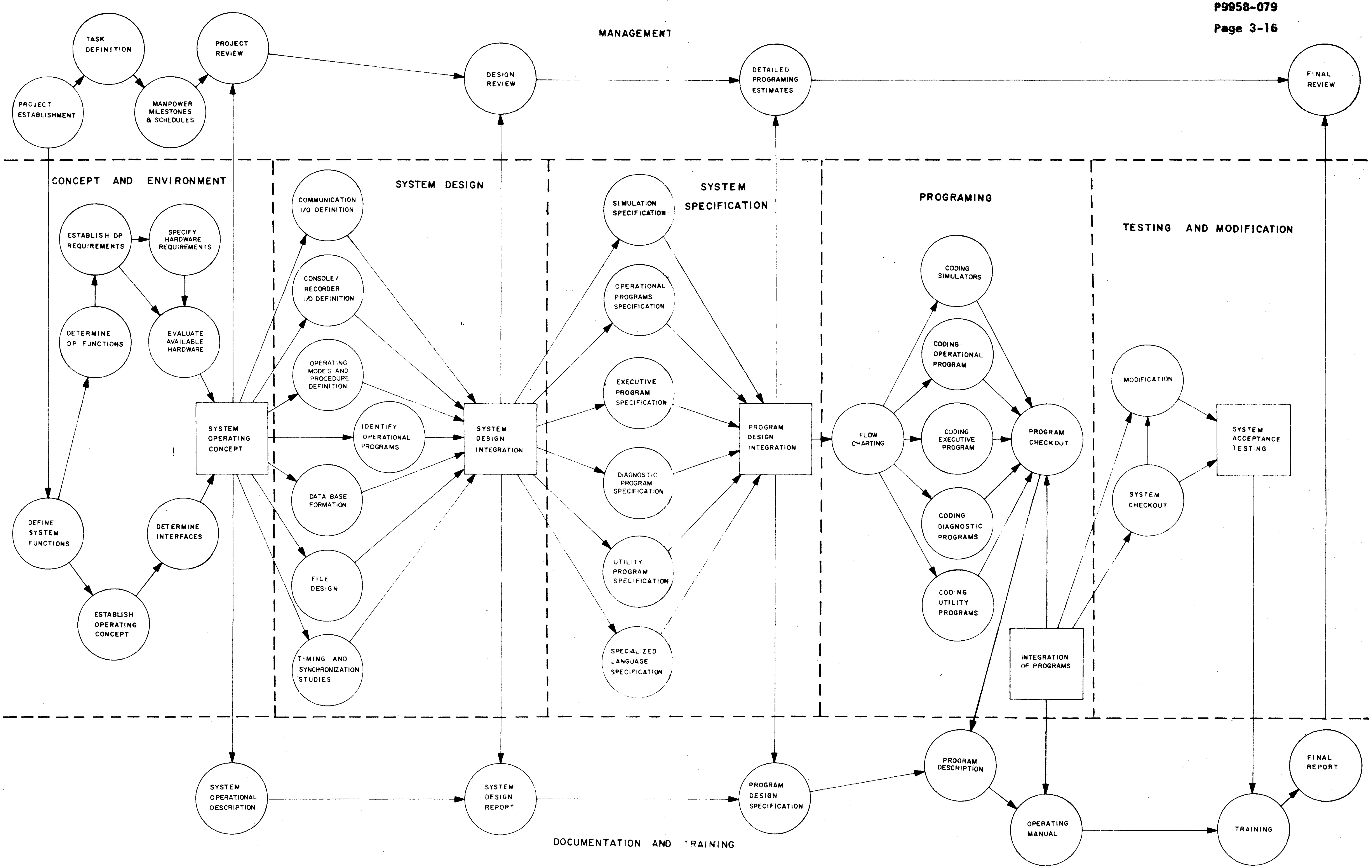


FIGURE 3-8
GENERAL IMPLEMENTATION PROCEDURE FOR ON-LINE SYSTEMS

accomplished in implementing a system. Further, it shows the interaction of certain tasks and the order in which they are accomplished. We believe it shows our appreciation of the entire problem of system implementation, and that it structures the whole task in a way that the various aspects (system design, system specification, etc.) can be discussed intelligently. The chart shows a more simplified procedure than really exists. Actually the major tasks do not run in a parallel fashion; the results of systems design and specification very frequently feed back to affect system design.

We visualize the work of System Design Methodology as the development of a system and techniques for accomplishing the implementation of an on-line or real-time command and control system. The Methodology especially affects the parts labelled "System Design" and "System Specification"; it further develops a comprehensive approach to these sets of tasks. The Study Integration discussed in Section 3.4 is aimed at bringing together certain technologies for comparison and trade-offs which are necessary for system design.

Modern computer systems for command and control can be considered as processing transactions of various types which arrive at various rates. Typical transactions are: receipt of radar data (every 50-100 milliseconds); processing a console request; receipt and processing of command messages; and feedback data for weapon aiming or control (every 10 ms. or less). In developing a design, the computer system requirements must be fitted to the operational requirements. The following paragraphs present an approach to a design methodology.

Figure 3-9 shows the total information system design method. The operational requirements give rise to the identification of certain data types, volumes of data, the processing required, and the distribution of requests for service. Together they define a problem. If an initial assumption is made as to the speed for processing each of these types of data, the entire process can be

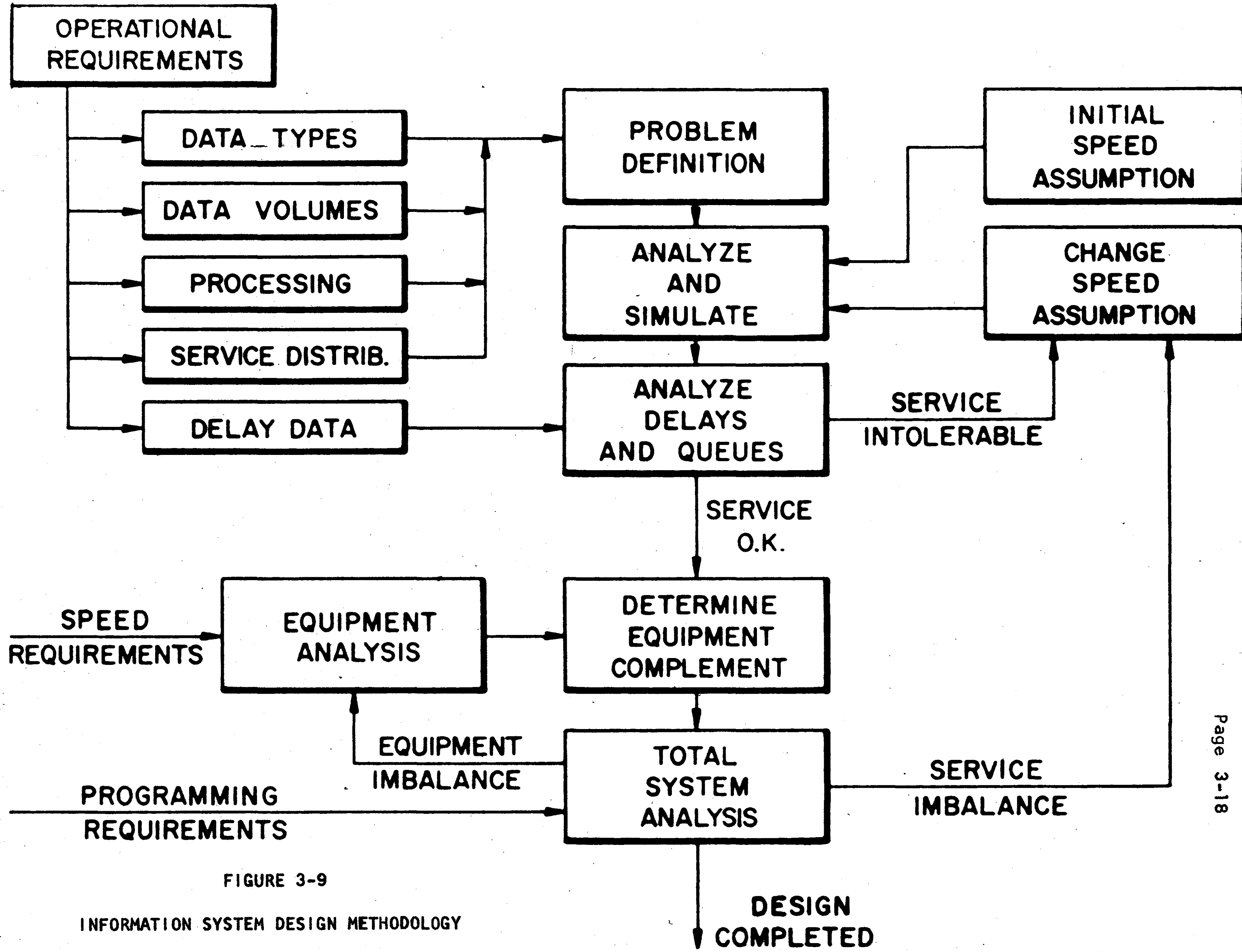


FIGURE 3-9

INFORMATION SYSTEM DESIGN METHODOLOGY

analyzed. Probably the technique used here is sumulation by large scale digital computer. This gives rise to information on the average length of delays which, when compared with the delay requirements imposed by the operational characteristics of the system, will determine whether the service is tolerable or not. If the service is intolerable, then assumptions must be changed as to the speed with which the processing is performed.

Having determined that the service is tolerable, and the speed requirements, an analysis can be made to determine the complement of equipment required. After this is done, the total system is analyzed from the standpoint of programming requirements to determine if the design is acceptable in all respects. Possible imbalances in the service, or in the amount of equipment, can result in a further analysis and a change in the equipment complement.

An analysis was performed at Ramo-Wooldridge similar to this and was reported by Rothman (2); the results are shown in Figure 3-10. The problem mix gives the characteristics of the problem. For example, 50 percent of the problem required servicing requests which had to be completed on an average of 0.5 minutes and with a total processing time of 1.5 minutes. Poisson distributions were assumed, and the frequency of arrivals is given essentially by the abscissa in terms of the average number of requests arriving translated to the number of computers to handle this average load. The zero percent curve shows that if the number of computers equals the average load, then there is a zero probability of servicing the problem mix. As an excess of computers is applied, service improves as the results indicate.

The approach described in Figure 3-9 and described above is an over-all approach which must be developed in considerably more detail to be useful. There have been other approaches and tools developed. Simulation languages for computer programming have been developed. A simulation compiler for ease of simulating a new or

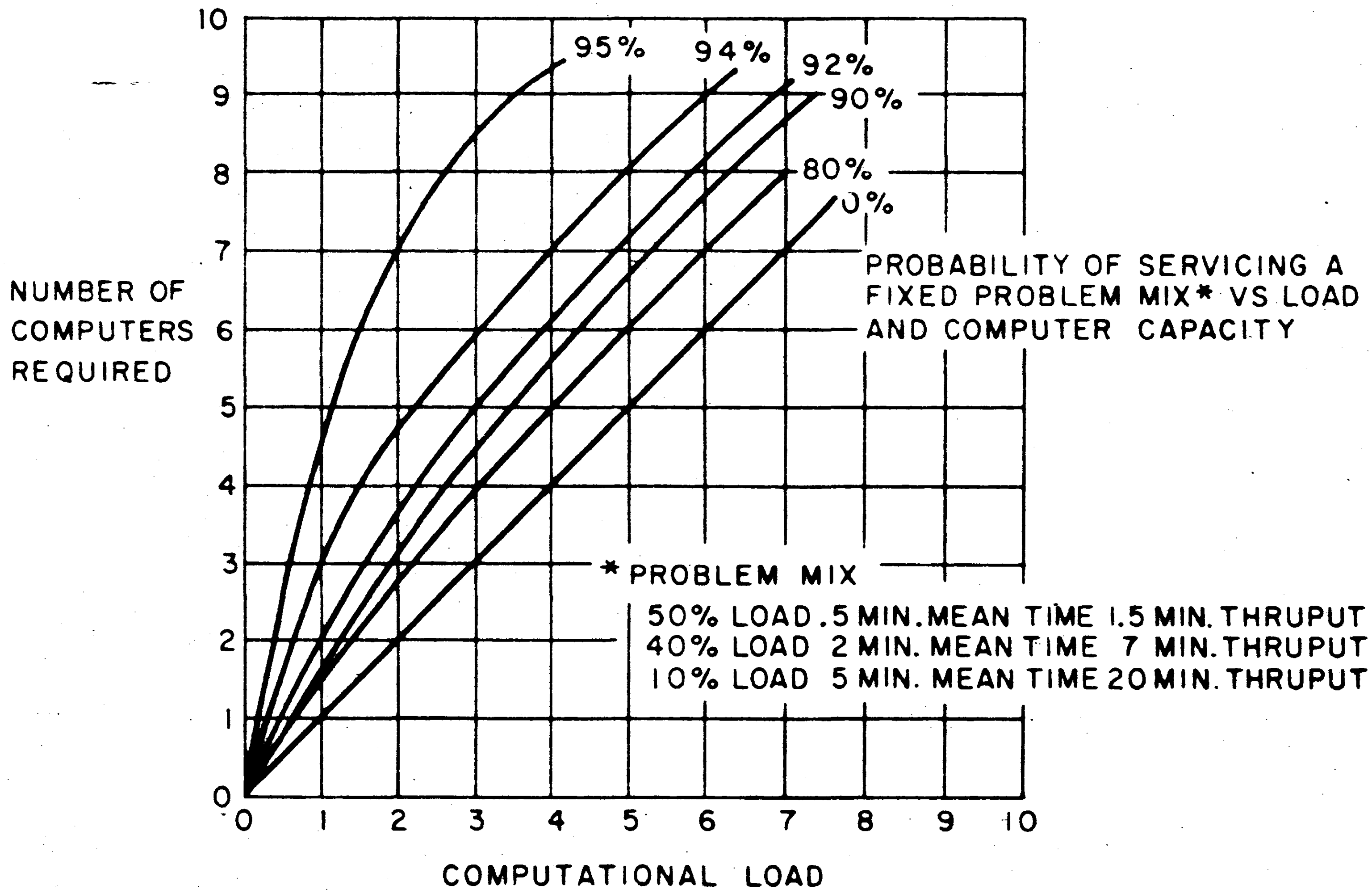


FIGURE 3-10

QUEUING ANALYSIS EXAMPLE

hypothetical computer has been developed by T. Sanborn at Space Technology Laboratories. It is called SIMCOM. A computer program has been prepared to simulate and analyze processing systems. This is known as the "Gordon Simulator" (3). These will be examined, as well as others, and certain procedures will be developed and recommended for use.

REFERENCES TO SECTION 3

1. Information Processing in Military Command, W. F. Bauer, PROCEEDINGS, ACM National Conference, Syracuse, September 1962.

2. The RW-400 Data Processing System, S. Rothman, PROCEEDINGS, Auto-Math Conference, International Congress of Information Processing, Paris, June 1959.

3. A General Purpose Systems Simulation, G. Gordon, PROCEEDINGS, Eastern Joint Computer Conference, Washington, D. C., December 1961.

4. COMPUTER ORGANIZATION

4.1 INTRODUCTION AND DEFINITION

Computer organization is the newest and fastest growing area of technology of computer design. Whereas logic design refers to the design and interrelation of components and circuits, computer organization refers to the design and interrelation of larger system elements such as memory units, control units and the like. Computer organization emphasizes the point of view of the system designer and the user.

Computer organization will be an extremely important item in tactical command and control systems. It is closely related to use of the computer in the total command and control system. The choice of the computer organization will have a heavy influence on system responsiveness and cost as well as on the total operational characteristics of the command and control system.

Some of the questions or considerations involved in computer organization are as follows:

1. How should data processing functions be divided among the various computer units?
2. What should be the degree of modularity of the system?
3. To what extent should the system have parallelism in the operation of its major components?
4. How is switching and communication effected within the system?
5. What should be the degree of decentralization of the system?

The above questions have a profound effect upon reliability, cost, maintainability, and programming ease. Since system reliability can be achieved by duplicating certain modules, the choice of modules and the

4.1 INTRODUCTION AND DEFINITION (continued)

degree of modularity is important. Likewise, maintainability is improved by having modules of similar types. Cost is affected since, if a high degree of modularity is achieved, reliability can be bought with the addition of just a few redundant modules rather than duplication of the entire system. Also, costs are affected by the degree of centralization since highly decentralized computer systems have "overhead costs" in switching and communication equipments. Last, but certainly not least, ease of programming is very much dependent upon how the above questions are answered since a certain amount of parallelism in computing systems simplifies programming whereas extensive parallelism complicates it.

4.2 MULTI-COMPUTERS AND MULTI-PROCESSING

There is a considerable trend toward multi-computers and multi-processing. The term multi-computers refers to the attachment of a number of computers or major components in an integrated system while multi-processing refers to the "simultaneous" processing of problems through multi-computer systems or through time sharing. Multi-processing allows a higher duty cycle of the various major computing units. It allows high speed to be achieved by duplication of units without pressing circuit speeds or approaching physical limitations such as the finite speed of light. Multi-processing is often referred to as multi-computing.

Time sharing is another important technique. Time sharing is not as intimately involved in some of the over-all system considerations as multi-processing obtained through multi-computers. Time sharing will be important as a programming technique to gain adequate response of the computer system to communications devices, peripheral equipments, and man/machine interface devices such as display and interrogation consoles. Some of the country's more interesting time sharing projects are underway at System Development Corporation and MIT.

4.2 MULTI-COMPUTERS AND MULTI-PROCESSING (continued)

Multi-computers have been defined generally by Bauer (1)* In that paper four main criteria are presented which delineate the degree of parallelism achieved among memory and arithmetic units before the system can qualify as "multi-computer". The paper describes types of multi-computer systems. For instance there is a choice between the hierarchy and distributed concepts in the assignment of functions as illustrated by Figure 4-1. Likewise, there are the substation and centralized approaches to communication in considering the topology of communication. Finally, communications and switching techniques are divided into the information bus and the centralized switch types. The paper goes on to explain the advantages of multi-computers: lower equipment cost, reliability, expansibility and flexibility, control hierarchy establishment and ease of programming organization. Each of these advantages is discussed in some detail.

Multi-computers are in use or are being planned for immediate use in present day Naval tactical data systems. The combination of USQ-20's** used in the Naval Tactical Data System as explained by Chapin (2), underscores this use. Also, there is extensive use being made of multi-computers in a Navy system being planned at the Pacific Missile Range as explained by Bauer and Simmons (3). In both of these uses part of the multi-computing characteristic of the system is achieved through high speed digital data links connecting remote computers. Significantly, in both applications, computers of the NTDS family are used with multi-computers at the nodes of the networks and with the nodal points connected with the high speed digital data links.

4.3 HIGHLY PARALLEL MACHINES

One of the newer aspects of computer organization can be referred to as the "highly parallel machine" organization. This organization

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* Numbers in parentheses refer to the references at the end of each section.

** Official name CP642A/USQ-20

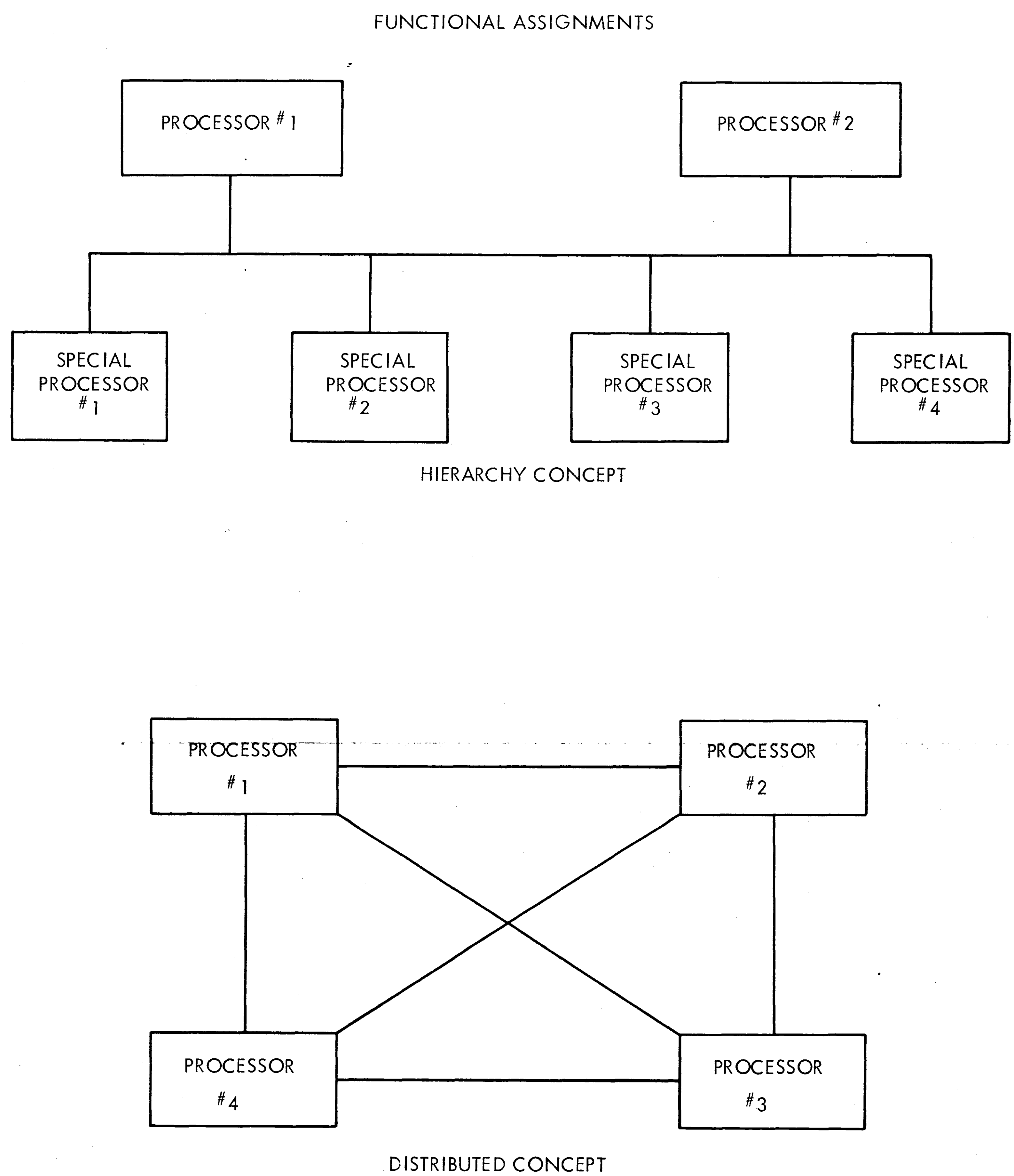

FUNCTIONAL ASSIGNMENTS
PROCESSOR # 1
PROCESSOR # 2
SPECIAL PROCESSOR # 1
SPECIAL PROCESSOR # 2
SPECIAL PROCESSOR # 3
SPECIAL PROCESSOR # 4
HIERARCHY CONCEPT
PROCESSOR # 1
PROCESSOR # 2
PROCESSOR # 4
PROCESSOR # 3
DISTRIBUTED CONCEPT

FIGURE 4-1

4.3 HIGHLY PARALLEL MACHINES (continued)

represents an extrapolation of the parallelism ideas discussed in Section 4.2. In these machines a network of arithmetic and control units up to 32 x 32 matrix size or higher, is visualized.

Two of these computers have been discussed in the literature. One is the Solomon computer discussed by Slotnick, et al (4). Another is the Holland machine or a modification of it, discussed by Comfort (5). These machines are conceptual designs and the computers have not been built or are in only the early stages of development.

One of the important aspects of the contract work proposed is to evaluate these types of computer designs for future command and control activities. It appears that these computer designs will not satisfy the requirements of the central computer operations in these command and control systems. However, there is a distinct possibility that the computer designs will prove efficient for certain specialized operations.

At the present time the designers of these highly parallel machines point to the solution of equations of the diffusion type, such as those involved in weather prediction and neutron reactor flux analysis. However, there is a possibility that these computers can be used efficiently for such operations as the correlation of radar information thus making them good candidates for command and control system usage.

4.4 STORED LOGIC AND MICRO-PROGRAMMED COMPUTERS

Completing the spectrum of the different kinds of computers that are in use or are visualized are the stored logic and micro-programmed computers. Micro-programming has been a technique which has been discussed over the last 6 - 8 years. It consists of the design of a computer which the programmer can program at a micro-instruction level; using this computer he can construct his own macro-instructions or conventional computer instructions. The advantages claimed for this technique are the

4.4 STORED LOGIC AND MICRO-PROGRAMMED COMPUTERS (continued)

flexibility of application through the construction of an arbitrary instruction set, the simplicity of the hardware design through the reduction in the number of logical operations which need to be performed, and the resulting lowering of cost through these benefits of increased flexibility and simplicity.

One of the "purer" approaches to micro-programmed computers was explained in a recent article by Timofeev (6). He stated that one of the disadvantages of stored logic computers -- a slower operating computer than a computer with equivalent circuit-component speed -- can be removed by an optimizing technique. The "pure" approach has not gained much favor. However, recently designers have actually built machines along micro-programmed lines, but have compromised the purer approach by adding instructions of the macro-type such as those in conventional computers. An example of this is the PB 400 described in a recent paper by Boutwell (7). This computer uses two types of memory system in which one of the memories services the micro-programmed operation of the computer.

Significantly, a micro-programmed computer (or stored logic computer) is used in Naval tactical data systems. It is the AN/UYK-1 designed and built by Ramo Wooldridge, and used extensively in the navigational satellite program. It uses micro-programmed instructions and macro-type instructions and is, therefore, not a pure micro-programming approach to computer design.

Still another technique of interest in micro-programming is the use of read-only memories to implement the micro-programmed logic. To cycle through the various small micro-programming steps in executing an instruction, memory devices can be used which dictate the micro operation choice and sequence. Since there is no need to read into these memories certain high speed storage techniques can be used for implementation. The read-only stores frequently require one microsecond or less, using

4.4 STORED LOGIC AND MICRO-PROGRAMMED COMPUTERS (continued)

standard ferrite memory techniques. The design of such a computer was described and evaluated by Wheeler (8).

4.5 ANALOG/DIGITAL HYBRID TECHNIQUES

It is not likely that pure analog techniques will find their way into Naval tactical command and control systems except for very special purpose devices of weapon or instrument control type. However, analog/digital techniques represent a segment of the computer technology which is at least a candidate for use.

The advantage of an analog computer is that a great deal of efficiency is gained in certain types of problems through highly parallel operations. In other words, many integrating amplifiers connected in a circuit can operate simultaneously and achieve efficiency through this parallelism. These systems are especially efficient on problems involving ordinary differential equations such as those in trajectory analysis. Since many systems also involve digital techniques, and since the digital computer is better used for higher precision operations, data manipulation operations, and decision processes, the combination of analog/digital sometimes appears attractive.

In the solution of differential equations, such as those in trajectory computations, the analog computer can handle high frequency variables in the integration processes whereas the digital computer can provide the high precision requirements. The combination can be used in interesting ways to achieve highly efficient differential equation solutions. One of the country's earliest analog/digital systems was described in a paper by Bauer and West (9) in which a number of these considerations were discussed.

One of the interesting aspects of the proposed project will be to ascertain if and where analog/digital systems can be used efficiently in Tactical Command and Control systems.

REFERENCES TO SECTION 4

1. "Why Multi-Computers?", W. F. Bauer, DATAMATION, September 1962

2. "Organizing and Programming a Shipboard Real-Time Computer System", G. G. Chapin, PROCEEDINGS Fall Joint Computer Conference, November 1963

3. "The PMR Real-Time Data Handling System", W. F. Bauer and Sheldon Simmons, to be published in DATAMATION, January 1964

4. "The Soloman Computer", D. L. Slotnick, W. C. Borck and R. C. McReynolds, PROCEEDINGS Fall Joint Computer Conference, December 1962

5. "A Modified Holland Machine", W. T. Comfort, PROCEEDINGS Fall Joint Computer Conference, November 1963

6. "Microprogram Control for Digital Computers", L. B. Emelyanov and A. A. Timofeev, Symposium on Advanced Computer Organization, IFIPS-62 Conference, Munich, August 1962

7. "The Logical Organization of the PB 440 Microprogrammable Computer", E. O. Boutwell and E. A. Hoskinson, PROCEEDINGS Fall Joint Computer Conference, November 1963

8. "Read Only Stores for the Control of Computers", D. J. Wheeler, Symposium on Advanced Computer Organization, IFIPS-62 Conference, Munich, August 1962

9. "A System for General Purpose Analog-Digital Computation", W. F. Bauer and G. P. West, ACM JOURNAL Vol. 4, pp 12-17, 1957

5. INPUT OUTPUT AND DISPLAYS

5.1 DEFINITIONS AND FUNCTIONS

Input/Output and Display is one of the more interesting aspects of data processing for tactical command and control systems. The reasons are obvious: computer systems in command and control are on-line systems which receive information from many sources and must present it to many destinations. This requires a full range of instrumentation and data handling devices attached to the computer. In the modern on-line system, data must be formatted from the external sources, multiplexed into the memory of the computer or buffering device, then read in and serviced. For output it must again be formatted, read out of the computer and multiplexed through the outputting channel to the receiving device.

The input/output devices and techniques fundamentally provide an interface between the computer and a device (or person) external to the computer. For instance, the computer receives information from sensors such as radar and radar receivers. This data must be properly quantized and digitized. It receives information from humans. In the past this information has come through switches, punched cards and punched paper tape. In the future it will, with increasing frequency, come through complex on-line interrogation consoles. The computer must interface with communications equipments to provide capability of receiving data from remote sensors, people or other computers.

Also, the computer must, of course, interface with conventional peripheral equipment such as printers, tapes and the like. Likewise it must communicate with displays, not only console displays employing devices such as cathode ray tubes but also group displays such as electric and photographic types. Another interface might be referred to as the instrumentation type which would include devices like analog/digital conversion equipments, digital data registers and similar devices. All these interface elements are used in many combinations.

5.1 DEFINITIONS AND FUNCTIONS (Continued)

A comprehensive introduction to the problem of input/output has been provided in a paper by Bauer presented in the IFIP 62 conference in Munich. The following paragraphs briefly summarize what was said there:

Buffering control and synchronization. This is the process of holding computer words temporarily and of providing "ready" and "lock out" signals which allow the synchronization of the computer with the device. A significant trend is the increased use of the interrupt signal.

Interleaved memory access. As a part of the buffer process, cycles of the computer memory used for the input/output process are interleaved with memory cycles of the main computational stream to allow the automatic multiplexing of input/output data into the memory.

Assignment flexibility. This refers to the ability to use input/output devices in many combinations so that, for example, a tape unit is not dedicated to a particular input/output channel but is switched to the using device of the computer system.

Simultaneous input/output and computing. This refers to the technique of performing extensive input/output operations while computing takes place. This is an extension of the buffering and interleaving memory cycle techniques. A further step is taken in this technique by performing predigestion of data and parallel processing of input/output with central computing. Often it appears desirable to perform many complex input/output processes and perform the processing of the input and output data independently from the main computer. Thus the main computer receives only totally digested data.

Man/Machine communications. A most rapidly growing area is the use of a display interrogation console at which a person sits and communicates with the computer in a manner convenient to him. This allows the development of a close man/machine relationship in which the computer becomes a close intellectual partner of the man.

5.1 DEFINITIONS AND FUNCTIONS (Continued)

These are the areas of growth in input/output techniques. These are areas to be carefully defined, examined, and documented in the proposed program to insure that future command and control systems employ these techniques to the greatest practical extent. The following sections discuss these areas from system, equipment, and usage points of view.

5.2 INPUT/OUTPUT BUFFERING AND INTERRUPT HANDLING

If there is an area of system design that concerns the planner more than any other it is the general problem of input/output. It is relatively simple to develop from known requirements numbers reflecting required storage capacities, required access times to data, and required processing times for a variety of operations as a function of machine cycles or arithmetic steps. It is another problem, however, to analyze and trace the data interactions and to comprehend the operational effect of the various design alternatives associated with input/output handling. In particular, this relates to the techniques for interfacing computer peripherals and communication lines with data processors, which ultimately depends upon the buffering process and interrupt features inherent in the equipment.

5.2.1 Input/Output Buffering

An important aspect of this project is the identification of the various equipment parameters and features associated with I/O channels and I/O handling, and the subsequent relating of these to the parameters characterizing data on the one hand and to the data carrier on the other.

Examples of terms that are typically used in describing I/O capability are tabulated below.

Data channel, simplex and duplex
Device Controller or Adapter
Party lines

5.2.1 Input/Output Buffering (Continued)

Assembly and disassembly registers
Computer to computer transmission
Buffered transmission, partially and fully
Cycle stealing
Memory partition
Number of devices per channel
Independence of operations
Simultaneity of operations
High speed data rates
Low speed data rates
Automatic data collection
Register scanning
Multiplexer
Formatter, assembler, decommutator
Compatibility
Parallel character/word transfer
Interlaced operations
Saturation rates.

It is important first to find a basic set of such descriptors which will serve the system designer both as tools for evaluation alternatives and as standards for making equipment comparisons. It is next essential to review the spectrum of buffering configurations which range from computer I/O channels, through special purpose multiplexing buffers, to buffers that are computers in their own right. An example of a question that may be posed concerning the last point is: what are the economics of a satellite computer acting in a communication/buffer role? In fact, when should a satellite computer be of a different size or class, from the central computer?

In this analysis it is important to indicate the consequences of

5.2.1 Input/Output Buffering (Continued)

increasing capability. For example, it must be made evident that increasing numbers of data channels and increasing data flow rates will ultimately affect internal processing throughput (if for no other reason than an increase of core cycle stealing).

The most important contribution, however, will be to associate the I/O interface attributes with typical information that will be known to the system designers in each application concerning the data and the peripherals. Thus preferred buffering schemes will be advanced for such examples as:

hundreds of message originating stations,
video transmission,
block transfer of data,
volatile display refreshing,
sampled readout,
continuous data collection,

and will also be looked at from the point of view of the devices themselves including discs, typewriters, conventional peripherals, communication lines, analog sources, etc.

5.2.2 Interrupt Handling

In addition to the I/O buffering discussed above the system designer wants to know the function and effect of the computer interrupt capability, especially as it relates to the external interrupt. In general this feature signals:

(a) End of an operation - as with the termination of a buffered tape transfer.

(b) Beginning of an operation - as when it signals the presence of data in a register, which may be overwritten with new data if not recognized in time.

5.2.2 Interrupt Handling (Continued)

(c) Status condition - as in the case of an alarm signal or making a mark with a real-time clock.

These signals aid in the management of the housekeeping, timing and scheduling inherent in on-line systems.

The increasing number of I/O channels, decentralization of the processor to multi-computer and memory modules, and varying sources and rates of input data have led to considerable sophistications of the interrupt. For example, in most modern computers the number of unique interrupt locations has increased (to the thousands) and the concept of priority sequencing of interrupts has been promoted. The effect of this additional capability is compared to the conventional processor in Figure 5-1 where the hardware-software balances are shown.

The value of these modern interrupt systems must be presented in the light of their utility to specific operations and system requirements. In addition to citing the attributes commonly ascribed to interrupt handling, an analysis will be performed to show how to use and assign priority levels for typical problem mixes, involving digital and analog readouts, real-time clock, I/O conventional interrupts, keyboard message generation, etc. Tables such as shown in Figure 5-2 will be valuable to point out features and trends and to indicate the relevance of such characteristics to system requirements.

The work on Subtask 2 and 3 will require a careful analysis of interrupt techniques in view of their profound effect on computer and programming efficiency. For instance the Table of Figure 5-2 will be updated and made more comprehensive. An analysis will be made and recommendations made for interrupt systems to be included in future computers for use in Navy Tactical Data Systems.

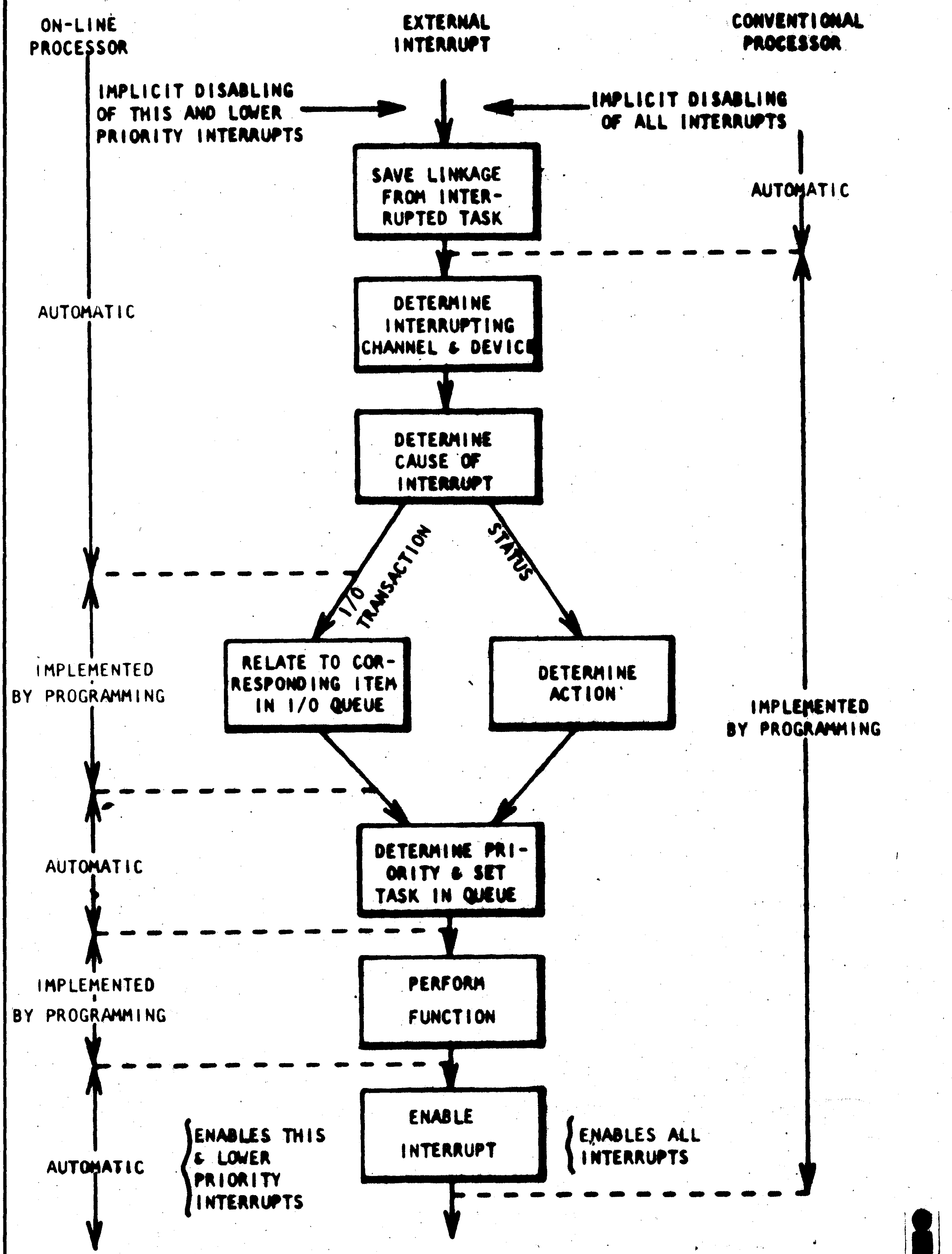


FIGURE 5-1

INTERRUPT HANDLING IN CONVENTIONAL & ON-LINE PROCESSORS

Computer	Number of Interrupt Locations		Priority Sequencing	Linkage	Disabling	Inhibition	Alert	Comments
	Ext.	Int.						
IBM 7090	9	3	4 levels	Automatic; Stores IC only	All interrupts	Selective individually and collectively	Yes	7909 provides 8 additional interrupt locations
UNIVAC 1107	65	9	8 levels	Programmed; Use a return jump	All interrupts	Selective individually and collectively for I/O	Yes	I/O priority levels in channel number sequence
CDC 1604A	7	2	2 levels	Automatic; Stores IC only	All interrupts	Selective individually	Yes	1 priority interrupt
UNIVAC 1218	33	1	8 levels	Programmed; Use a return jump	All interrupts	Collectively	Yes	Status word provided with interrupt. I/O levels in channel number sequence
SDS 920	2-1024		2-1024 levels	Programmed; Use a return jump	All lower priority interrupts	Collectively	No	Interrupt priorities can be changed by hardware change
UNIVAC 490	42	2	5 levels	Programmed; Use a return jump	All interrupts except fault	Selective individually for I/O	Yes	I/O priority levels in channel number sequence
GE M236	3-256		3-256 levels	Programmed; Use a special instruction	All lower priority interrupts	Selective individually and collectively	No	Interrupt priorities can be changed by hardware change or by program

FIGURE 5-2

INTERRUPT CHARACTERISTICS FOR A SELECTED HISTORY OF COMPUTERS

5.3 INPUT/OUTPUT DEVICES

The major types of conventional input/output devices are: punched cards, punched paper tape, magnetic tape, keyboards, printers, and analog-to-digital and digital-to-analog converters. Any or all of these may be applicable to the NTDS for the 1970-80 era. However, it is anticipated that magnetic tape units, keyboards, and printers will be the preferred devices for dealing with the human and digital input/output requirements.

Analog-to-digital and digital-to-analog converters will be used in dealing with other equipments that provide inputs or accept outputs in the form of analog voltages, shaft positions, or pulse trains.

Punched cards or punched paper tape may be used for specialized purposes, but for shipborne use they will probably not be as desirable as the other devices listed.

Keyboards and printers can now be operated on-line under direct control of the computer thus eliminating the need for punched card or punched paper tape as intermediate storage for input/output functions.

Extensive militarized peripheral equipment does not exist at present. However, attention is turning to this area. IBM has an R&D contract for a militarized disc. Data Products Corporation has a similar contract to develop a militarized printer, and tape units are available as noted below.

Data can be entered into computers by properly buffered and multiplexed on-line keyboards and printed out by on-line printers. Historical data and files can be written on magnetic tape (or in mass memories discussed in a later Section) to be read later by the computer for further use. Magnetic tape will also be useful for storing and inputting programs, and for keeping a time-sequential chronological file of all input/output transactions. Militarized magnetic tape units

5.3 INPUT/OUTPUT DEVICES (Continued)

are now available as the result of a joint Navy, Army, and Industry program described recently by Tyrrell, Morrison, and Staller (1).

During the study these conventional types of input/output devices will be reviewed to ascertain their usefulness in the NTDS. The trends for future improvements in these devices will be analyzed to provide a basis for estimating the performance that can be expected in the time era under consideration.

Less conventional input/output devices include display devices, on-line digital data transmission links, character sensing devices, and pattern scanning techniques. Display devices are discussed in detail in Sections 5.4 and 5.5 of this proposal. The present NTDS system makes extensive use of displays and digital data links (2). Digital data transmission is covered in Section 5.6.

Extensive development efforts have been devoted to character sensing devices in recent years (3, 4). An example of a specialized commercial application is the use by many banks of magnetic ink characters on checks. It is quite possible that further improvements in more generalized character sensing devices will provide equipment useful for input purposes in future Naval Tactical Data Systems.

Developments in pattern or image scanning and recognition techniques may be more important to future command and control systems. This type of input coupled with internal computer pattern recognition programs may permit the automatic interpretation of aerial photography and other types of tactical imagery. One study in this area and some of the problems involved have been described by Holmes, Leland, and Richmond (5).

The Graphden device in the Army Tactical Operation Center is an example of a unit that permits automatic input of graphical and hand-drawn data (6). The TACDEN device in the same system is an

5.3 INPUT/OUTPUT DEVICES (Continued)

example of an alphanumeric message composer that permits keyboard entry of data, formatting, visual verification, and editing.

5.4 CONSOLE DISPLAY AND INTERROGATION

5.4.1 Requirements, Systems and Uses

The incorporation of individual visual display devices into a computer system had its origins with the SAGE project and the NTDS. In this application the primary requirement is to present the console operator with a tactical situation, having a geographical relationship. From this information decisions are made by the operator and the computer working together. The emphasis is the readout display and requires the hardware feature of line drawing to indicate, for example, vehicle tracks. Similarly, such interest is exhibited with the FAA and NASA although with a somewhat different purpose in mind.

At the opposite end of the spectrum of console applications is the man/machine communication function typified by the query requirements of Command and Control. An example is the formulation of questions of a data base concerning the status of forces and resources. An early contribution in this area was the console development associated with the Air Force 117L program. Here there was as much emphasis given to the input process as the readout. Current interest in such devices pervade the systems being developed by the NMCS, NORAD and 473L, all of which are developing operational systems using display consoles for the basic task of human query and response.

Pertinent to this project will be the identification of application areas together with user techniques to suggest to system planners the potential of such devices and their limitations. It is, for example, important to provide guidelines concerning such items as:

a.) Amount of training required to operate a console;

b.) Type of personnel (officer or enlisted) to be assigned as operators;

c.) Degree of programming familiarity required;

d.) Degree of familiarity required concerning particular data base content and structure;

e.) Possibility of remoting device from the processing center.

5.4.1 Requirements, Systems and Uses (Continued)

In particular, the application areas would include data editing, data entry, data base query, system control, system maintenance, on-line analysis, on-line monitoring, etc. The important result of this study will be the identification of console features necessary for the execution of the cited applications. Such consoles may range from a typewriter keyboard to highly complex instruments such as the integrated console for the IOC of 473L.

5.4.2 Equipments

As a result of the large amount of current interest in display consoles several dozen manufacturers are now offering a variety of devices for this purpose. These range from strictly CRT or TV readout monitors to consoles which include background projection on the CRT (even with color), full typewriter keyboards, light pens and, as in the case of TRW, ITT and IBM, on-line modifiable labeling of special function keys (the so-called overlay concept).

Aside from such basic features the equipment environment also involves detail features such as shown in Figure 5-3 for a number of commercially available consoles.

A chart such as this can however only be useful if the physical characteristics are related back to requirements. Hence it is necessary to develop charts such as Figure 5-4, where the applicability of hardware features is shown for the indicated requirements of a specific command and control system, the NMCS.

Associated with these equipment considerations is the important question of console/computer interface. Here it will be necessary to indicate problems and their solution involving:

a.) Desirability of standardizing logic of interface, e.g., IBM 729IV tape interface;

b.) Effect of remoting consoles, e.g., cables, amplifiers, etc.;

	TRW DC-400A	TRW 85	General Dynamics SC-1090	Data Display Inc. DD-13	Electrada Datacom 408-2	Information Products Corp. 1504/3603/4000	ITT Integrated Console
KEYBOARD CHARACTERISTICS							
Control Keys	45, Program Control	20, Fixed Control*	24, Fixed Control	8	46, Fixed Control	2, Fixed Control	
Character Keyboard	Full Typewriter	Full Typewriter	None	None	Full Typewriter	Full Typewriter	Full Typewriter
Function Keys	One Removable Overlay of 30 Keys	Two Removable Overlays of 30 Keys each One standard, one Option	None	None	None	4	62, Switchable sets of 30 keys
ENVIRONMENTAL INDICATORS							
Status Indicators	24	30		1	none	1	
Audible Alarms	None	Yes	No	Yes	No	None	
Blinking Signals	1	yes	no	Yes	No	None	
Intensity/Defocusing				Yes			
CRT CHARACTERISTICS							
Size of Scopes	10"	12" X 16" (23" tube)	19"	19"	17"	4" X 8"	Two 19" Scopes
Number of Mesh Points	20 X 36	384 X 512	256 X 256	1024 X 1024	16 X 63	10 X 50 or 7 X 72	
Repetition Rate	Program Control	30 or 60 cps	Program Control max. 30 cps	Variable	60 cps	45 cps	
Resolution Power		500 TV lines	4000 TV lines	1000 TV lines			
Brightness		50 ft. l. (in Lab)	20 ft. l.				
Registration	± 24% Char. Height	± 12% Char. Height	± 20% Char. Height		± 5% Char. Height		
Spot Size		20 mils	25 mils	20 mils	20 mils		
Background Color	Light	Dark	Dark	Dark	Dark	Light	Dark
CHARACTER REPERTOIRE							
Number of Characters	62	62	64	46 Wired 18 Programmed	64	64	64
Size of Characters	∽ .3	Variable - .125 to .375	.100" + .015"	Variable	.22"		
Max. No. of Characters Displayed	20 x 36 = 720	32 x 64 = 2048	1000		16 x 63 = 1008	10 x 50 or 7 x 72	
Variation on Size	None	2 levels	Yes*	4 Levels	No	No	

* Options

FIGURE 5-[illegible] (Part I)
CANDIDATE CONSOLE CHARACTERISTICS

	TRW DC-400A	TRW 85	General Dynamics SC-1090	Data Display Inc. DD-13	Electrada Datacom 408-2	Information Products Corp. 1504/3603/4000	ITT Integrated Console
CRT USER FEATURES							
Marker	Programmed	Hardware	No		Yes	Available	Yes
Tab Function for Marker	Programmed	No	No	No	Available	No	
Background Projection	No	No	Available	Yes	No	No	Color
LINE DRAWING							
Maximum Line Length	N.A.	∽ 3" if Arbitrary Direction	2"	Full	N.A.	N.A.	
SPECIAL DEVICES							
Light Gun	No	Yes*	No	Yes	No	No	
Hairline Cursor	No	Yes*	No	No	No	No	No
CONSOLE OVER-ALL CHARACTERISTICS							
Associated Buffer	No	4096 Words, 9 Bits	Available	2048 x 24	Drum or Core	3603 can Service 12 1504's	Yes
Associated Hard Copy	No	Available	No	Yes	No	Available	Yes
Localized Maintenance	Yes	Yes	Yes*	Yes	Yes	In 3603	
Time Sharing Possibilities for Multiple Consoles	No	No	No	Character Generator up to 4 Consoles	No	Yes	
Parity Check	No	Yes*		Yes	No	Yes	
CONSOLE PACKAGING							
No. of Units	1	2	1	2	1	3	3
Size, Wxhxl	34" x 39" x 55"	Console: 46" x 48" x 44" Buffer: 46" x 48" x 24"	33" x 47" x 66"		72" x 51" x 33"	1504: 14" x 14" x 26" 3603: 41" x 64" x 24" 4000:	
Power Requirements	117 Volts AC	115 Volts AC	115 Volts AC	208 Volts AC	115 Volts AC	1504: 117 Volts AC 3606: 117 Volts AC 4000:	
PRICE							
Basic Unit Price	$115K		$25K	$150K to $143K	$48K	$23K to 8K	Approx. $200K
With Basic Options	----	$157K to $122K	$42K	----	----	----	
Rent	No		Yes	Yes		Yes	

* Options

FIGURE 5-3 (Part 2)
CANDIDATE CONSOLE CHARACTERISTICS

APPLICATIONS \ REQUIREMENTS	BASIC INPUT: Button Signal, < 10 Characters	Formatted Message > Characters	Free Text	Alpha/Numeric	Special Symbols	Line Drawing	Cursor Positioning	Pointing	OUTPUT IF ON CRT: Character Display < 500 Characters	Character Display > 500 Characters	Special Symbols	Line Drawing	CONFIGURATION: Single Station, Support Center	Multiple Stations, Support Center	Remoted Stations, Customers	SYSTEM ASPECTS: Functions on Demand	Computer Generated	Alarm Used	Produces Auxiliary Hard Copy
DATA BASE INTERROGATION																			
SOF/MOP																			
Weapon Totals		x		x				x		x		x			x	x			x
Uncovered Targets									x			x			x		x	x	x
Weapon Status Summaries		x		x				x		x					x	x			x
Weapon Delivery Analysis		x		x				x		x	x	x			x	x			
RDA																			
Point Target Detail		x		x				x	x						x	x			x
Fallout		x		x				x		x	x	x			x	x			
Casualties & Facilities		x		x				x		x					x	x			x
Residuals		x		x				x		x					x	x			x
Damage		x		x				x		x	x	x			x	x			x
Attack Pattern		x		x				x							x	x			
DISPLAY AND ANALYSIS																			
Composition of Ad Hoc Displays		x	x	x	x	x	x	x					x			x			
Player Participation in War Gaming	x	x	x	x	x	x	x	x		x	x	x		x		x	x	x	x
Scheduled Outputs	x							x	x	x	x	x			x	x	x	x	x
Questions and Answers		x		x				x	x	x	x	x			x	x			x
DATA INPUT																			
NUDET Entry	x			x				x		x				x		x		x	x
Strike/Launch Entry	x			x				x		x				x		x		x	x
Exception Processing		x	x	x				x						x			x	x	x
Damage Reports		x	x	x				x		x				x		x			x
Message Accounting		x								x				x		x	x	x	
SYSTEM MONITOR & CONTROL																			
Queue Manipulation	x			x				x		x			x			x	x	x	
Mode Selection	x							x					x			x	x	x	
Equipment Environment & Diagnostics	x							x					x			x	x	x	
Startup	x							x					x			x			
Breakpoints for Rollback	x												x			x	x		
PROGRAM DEBUGGING & MAINTENANCE																			
Data Base Updating		x		x				x		x			x			x			x
Data Base Subsetting		x		x				x		x			x			x			x
Film Maintenance		x		x				x		x			x			x			x
Film Chip Library Maintenance		x		x				x	x				x			x			x
Generate CRT Backgrounds		x	x	x	x	x	x	x		x	x	x	x			x			

FIGURE 5-4

CONSOLE APPLICATIONS AND REQUIREMENTS

	TRW DC-400A	TRW 85	General Dynamics SC-1090	Data Display Inc. DD-13	Electrada Datacom 408-2	Information Products Corp. 1504/3603/4000	ITT Integrated Console
ASSOCIATED ASPECTS							
THIS AND OTHER MODELS							
Customers	RADC 473L NMCS	None	NASA Lockheed FAA JPL	MITRE 425L NEL NPGS NSA NASA, etc.	438L NSA RADC	U.S. Steel GE Lockheed Blue Cross Aerojet Allstate Westinghouse Navy	473L
Engineered Computer Interface	CDC-160 IBM-1401 RW-400	NTDS	IBM-7090 CDC-1604	IBM-7090 STRETCH S-2000 CDC-1604/160	None	RR-490 IBM-1401, 1410, 7040, 650, 1440, 7010 NCR-315	Librascope 473L Computer
Delivery Schedule	6 months	8-9 months	90 days	9 months	6 months	6 months	6-9 months

Options

FIGURE 5-3 (Part 3)
CANDIDATE CONSOLE CHARACTERISTICS

5.4.2 Equipments (Continued)

c.) Security of system when remoting;

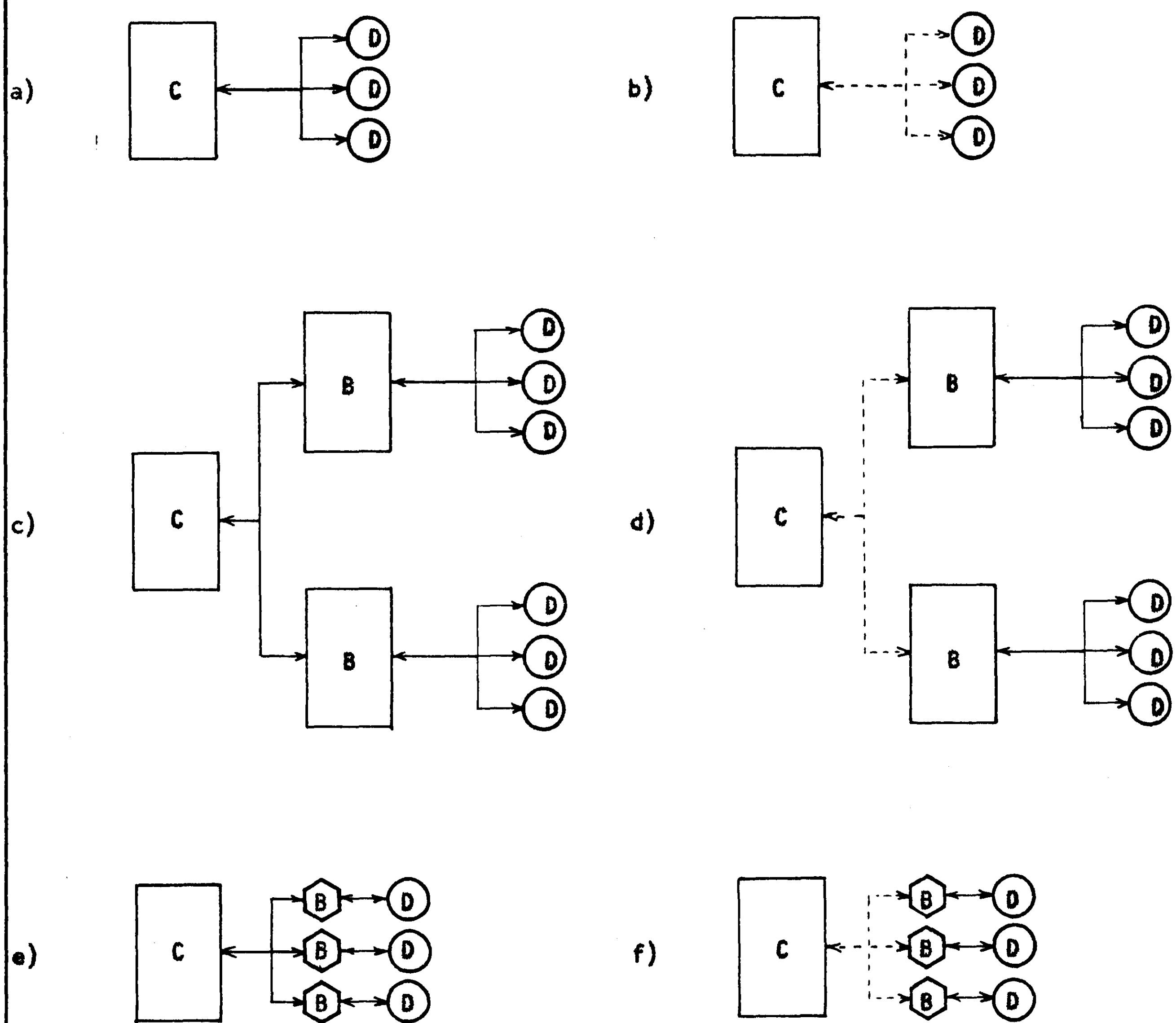
d.) Possibility of time sharing buffers and character generators among several consoles;

e.) Need for interrupt capability in message entry.

It will be desirable to consider alternatives in system configurations since cost is related. There are several possible methods for tieing the on-line device to the computer. The appropriate method for each application must be determined during the system design when the system equipment is being specified. The various configurations are illustrated in Figure 5-5 and are:

Configuration	Description
a.) & b.)	The on-line device is connected to a buffered or unbuffered computer I/O channel. Additional devices may be connected to the same channel up to some maximum number. Then additional devices must be assigned to another channel.
c.) & d.)	The on-line device is connected to a separate buffer unit which in turn is connected to the computer via an unbuffered or buffered I/O channel. Additional on-line devices may be connected to the buffer unit up to some maximum number.
e.) & f.)	The on-line device is connected to its own buffer unit which in turn is connected to the computer via an unbuffered or buffered I/O channel. Each on-line device requires a separate buffer unit.

The separate buffer units appearing in configurations c.), d.), e.), and f.) perform such functions as automatic CRT display regeneration



C = COMPUTER

B = BUFFER

D = ON-LINE DEVICE

——— UNBUFFERED I/O CHANNEL

- - - - - BUFFERED I/O CHANNEL

FIGURE 5-5

COMPUTER/ON-LINE DEVICE CONFIGURATIONS

5.4.2 Equipments (Continued)

and character-by-character message accumulation for subsequent transmission to the computer or on-line device.

Operational examples of these configurations include the following: NMCS Developmental Center uses configuration a.) with the CDC-160 computer; System 473L OTC uses configuration c.) with two consoles and the IBM-1401 computer. In this system the buffer can accommodate up to eight consoles; MITRE uses approach f.) in tieing consoles to the Stretch computer.

Special timing - The special nature of the communication device interface and possible electromechanical responses may impose special timing requirements on the computer program. This depends upon how much of the detailed bookkeeping and control is actually committed to hardware. Following are some representative examples of special timing:

a.) Scanning - It may be necessary to insure the clearing out of the communication device output register sufficiently often, say every 200 milliseconds, if keyboard entry is to continue at operator pace.

b.) Outputs - Special devices may require output data that must meet specified timings. This may be true for example, of electro-mechanically driven devices where start/stop problems may arise.

c.) Refresh - In the case of display consoles, if automatic buffers do not refresh the volatile CRT displays then the computer must re-transmit the information sufficiently often, say every 20-25 milliseconds, so that the display will not flicker.

Auxiliary storage - The requirement for rapid response and the servicing of a number of communication devices, each actively spread over a long period of time relative to the effective computing rate, leads to the need for large capacity auxiliary storage such as discs or drums. This store will hold programs, working displays, and the basic data base.

5.4.2 Equipments (Continued)

Ease of use - The programming system should provide as much user-operator flexibility as possible. User simplicity and flexibility should not be sacrificed simply to avoid complicated "one time" programming.

Flexibility and growth - Usage of communication devices will invariably lead to improvements in procedure and techniques, and as new uses are found, the application areas will grow. Hence, it will be desirable to frequently and easily modify current functions and to add new functions to the programming system.

5.4.3 Programming Techniques

In designing the programming or software system for console applications it is necessary for the planners to recognize characteristic requirements and relate these to software/hardware tradeoffs. Such considerations include:

Real-Time - The system must provide the information of interest as it is required. This refers to both the performance of the total problem and the responsiveness of the system to individual user-operator action. Since user-operator response and action is involved, real-time is measured in human terms.

Large data base - Systems with on-line communication capabilities invariably are systems involving large amounts of information in a data base. Since man and his judgment are involved, there is a requirement that this data be randomly accessable. Hence file design storage media are important design considerations.

Many short demands - The programming system must be capable of processing many short duration demands for service spread over a comparatively long time span. These demands generate individual information entries that are built up to comprise a complete message. In turn, a number of messages may be connected to form a complete transaction.

5.4.3 Programming Techniques (Continued)

Time sharing of processor - Based on the preceding, there will be available a considerable amount of processor capacity which must be fully utilized to achieve system efficiency. This means that time sharing and possibly multi-programming techniques must be employed so that the processor capacity can be allocated to the basic system tasks as required.

The basic system tasks and their requirements are:

a.) Communication device servicing which requires a small percentage of available capacity even when multiple devices must be serviced.

b.) Executing functions initiated by completed operator messages or requests which requires the majority of the available capacity.

c.) Performing other computations, related to the total problem or secondary in nature, which utilize any remaining capacity.

User orientation - The communication subsystems should be as much user oriented and user understandable as possible. Hence, it is desirable that the design, implementation, and modification of specific functions be as much "professional" programming independent as possible. Optimally, the system should be manageable by the user, once the basic programming has been accomplished.

It is possible to separate the application oriented tasks from those tasks that are general purpose and apply to all on-line system applications and processes. A division is made between the processes required in generating a message and the actual procedures for executing the action that may be required. The former concerns the mechanics of handling displays and composing messages. The latter is concerned with actual file handling, retrieval, processing, summarizing, and formatting. In this discussion we restrict attention to the first aspect, the general purpose processes.

5.4.3 Programming Techniques (Continued)

The design objectives for the programming system are as follows:

1. Provide general capability and flexibility so that virtually all applications can be accommodated.
2. Standardize techniques and procedures so that individual program segments or subroutines can be shared by as many functions as possible.
3. Maintain order among contending users for the same files.
4. Service each station as if its operator were the only user making demands on the processor.

Based on the above discussion the programming system must include:

Display Subsystem Executive Control

This program performs the basic scanning, sequencing, and queue control for servicing the on-line devices. In addition, it links to the Master Executive Control which may be supervising the total processing system. The degree of complexity of the Executive Control program will be greatly influenced by the presence or absence of such hardware features as a real-time clock and external interrupts.

Function Monitor

This program maintains the history tables and establishes the action sequences to be carried out as a function of the keys that are depressed by the operator.

Utility Program Package

This is a collection of service routines used primarily by the Function Monitor and Executive Control. The availability of these general purpose programs precludes recoding of common functions.

User Language

This is the language which must be used by the application programmer in writing his program. The system must provide the

5.4.3 Programming Techniques (Continued)

programmer with the ability to express his program in both the symbolic language of the computer, where each command generates one machine instruction, and in higher order languages, where each command generates many machine instructions.

To be effective, the higher order language must possess the following chief attributes:

a.) It must be powerful enough to express the application problem.

b.) It must be such that non-programmers can use it with a minimum amount of training.

c.) It must be readily expandable so that new commands and functions can be added.

The existence of a system as described above implies that application programmers must conform to certain coding restrictions and procedures so that all of the possible programs can be accommodated by this approach. While this may seem a disadvantage it is, in fact, a saving grace since:

a.) It simplifies the programming because of the existence of service routines.

b.) It simplifies the implementation of a new application since the design must fit within the logical framework set forth by the system.

The importance of the second point cannot be over-emphasized. Without a well-defined organizational and procedural philosophy, the programming design and implementation of the individual application can become much more complex and time consuming than is necessary.

Apart from the hardware and software requirements for support of an on-line console system it is also necessary to indicate the load which display consoles will place on total system performance. This includes the amount of core storage required on a continuing basis as a function of

5.4.3 Programming Techniques (Continued)

number of consoles, the expected amount of transactions at each console translated to required machine time over a period of time, and the potential traffic problems that may occur with regard to I/O transfers. With respect to the latter point it will be desirable to prepare probability tables reflecting waiting times for multiple console users for varying parameters. An example of such a table for the specific case of a ten console system is given in Figure 5-6. Here is assumed a service time of 1.5 and 0.9 seconds per request, with a thirty second interval between requests.

By using the theory associated with Poisson processes it is possible to estimate the waiting time from knowing the service factor. This number is the ratio of service time to total elapsed time between requests and is 1.5/30 or 0.05 for one of the cases. The results of the traffic analysis are given in Figure 5-6.

The results show that a waiting time will exist 19% of the time for the 0.05 service factor. Since the service time is 1.5 seconds the average wait on the waiting line will be slightly under 3 seconds. For the second model a waiting line will exist about 7.4% of the time. The average wait on the waiting line will be approximately one service time of 1.5 seconds.

5.4.4 Console Hardware Techniques

Hardware Techniques required in various types of console displays include buffer storage, symbol generation, cathode ray tubes, photographic imagery, digital read-out devices (e.g. counter wheels, NIXIE tubes, etc.), and hard copy printers. Newer techniques under development are photochromic dynamic displays (7) and electro luminescent displays (8). In using these hardware techniques to design console display equipments such as those described in Section 5.4.2, it is necessary to determine the proper trade-offs between characteristics such as capacity, speed, legibility, resolution, brightness, color, contrast,

Number of Consoles	Number of Consoles Waiting	Probability of n consoles requiring service: Service Factor = .05	Probability of n consoles requiring service: Service Factor = .03	Cumulative Waiting Probability: Service Factor = .05	Cumulative Waiting Probability: Service Factor = .03
0	0	.538	.712		
1	0	.269	.214		
2	1	.121	.057	.121	.057
3	2	.049	.013	.170	.070
4	3	.017	.003	.187	.073
5	4	.004	.001	.192	.074
6	5	.001	.000	.193	
7	6				
		1.000	1.000	.193	.074

FIGURE 5-6

PROBABILITY OF N CONSOLES OF TEN
REQUIRING SERVICE AT THE SAME TIME

5.4.4 Console Hardware Techniques (Continued)

ratio, color capability, frame rate, and computer interface requirements to determine the type of display that best meets the specific requirements of the problem. In different systems some of these characteristics will be more important than others. The periodic regeneration required in devices such as cathode ray tubes can be accomplished by providing sufficient storage for an entire frame in the display device or by periodically retransmitting the data from the computer. In this case, a trade off is possible between the complexity and cost of the display devices on the one hand and the required computer time on the other hand.

For future Naval Tactical Command and Control Systems, it will be necessary to evaluate conventional display techniques, special cathode ray tubes such as the Printapix and the Charactron, and newer techniques such as the light valve projector, photochromic displays, and electro-luminescent displays.

Cathode ray tubes will probably continue to be the dominant form of display for consoles although electro-luminescent techniques may be feasible by the time this planned Tactical Data System is to be operational. The capabilities and potential improvements in cathode ray tube displays will be analyzed to provide a basis for determining the design criteria for console displays. New cathode ray tube techniques, such as the ability to project a photographic image on the face of the tube to superimpose it over an electronic image, will be investigated. The relative advantages and disadvantages of storage type tubes for display versus standard cathode ray tubes with storage functions provided by another memory (e.g., a magnetic drum) will be determined. Any anticipated changes in the relative merits of the different techniques by 1970 will be evaluated and recommendations will be made as a guide for planning.

5.4.4 Console Hardware Techniques (Continued)

Keyboard techniques for interrogation will be studied with particular emphasis on the question of whether to use completely free manual keyboards or to use keyboards with a format control imposed on the operator. The methods of communications between the interrogation console and the computer, and the requirements for storage in the interrogation console will have a direct effect on the type of keyboard selected and the ease of using the console.

5.5 GROUP DISPLAYS

5.5.1 Requirements and Uses

Group displays range from static tote boards employing manual updating procedures to dynamic systems modified by computer signals. These systems may have a response time varying from seconds if completely electronic to several minutes if they employ electro-mechanical processes. Photographic, electronic, or mechanical techniques may be used, or combinations of them.

Typically, the requirements for such systems arise from the need of making information available on a continuing basis for monitoring purposes, as is done in NORAD, or for purposes of simultaneous view by a group of individuals gathered together periodically as a decision making body as, for example, the Joint Chiefs of Staff. In this latter situation formal briefings may be delivered or presentations given as a result of ad hoc requests for information.

The translation of the various requirements and operating situations to display hardware will be an important result of this portion of the study.

5.5.2 Equipments and Systems

To date military users have been dissatisfied and perhaps even disenchanted with the group displays developed by industry. In terms of review there are perhaps three systems in operational use typifying stable aspects of techniques. These are the Iconorama, Kelvin Hughes projection system, and the Philco and IBM wall boards of the Defense Communication Agency. The first of these affords color through the use of multiple projectors. It is electro-mechanical and has been known to be unreliable and inflexible. The second represents a class of systems in which a continuous roll of silver haloid film is exposed by a small CRT which is under computer control, development takes place, and the frame is available for view in 15 to 30 seconds. The third is a static background with a

5.5.2 Equipments and Systems

fixed number of neons whose on/off state and color selection is under the control of the computer.

There is an interesting new family of group displays emerging. They are probably best characterized by the fact that they employ photographic techniques. The process results in film chips (unmounted single frames of 70 mm film) which can be projected and viewed as slides. Other principal characteristics of these systems are as follows:

1. They are on-line with a computer. The computer performs such functions as the selection of background slides and the selection and placement of data on the slide.
2. They are used for periodic briefings of high ranking officers.
3. The processing consists of taking full color background slides and placing overlay information in color on the background. The number of symbols traditionally is 64.

Examples of this automatic slide generation type of equipment are those built by Ramo Wooldridge and International Telephone and Telegraph. In both these samples the color separation process is used. Background pictures can be taken with a color separation camera which provides three black and white images representing each of the three primary colors. To view a slide prepared by a color separation process white light is passed through the three black and white images and then through appropriate filters to reproduce the three primary colors. Projection of the three colored images to produce one image provides full color reproduction of the original.

In these systems overlay information is placed on the background by a photographic process involving the background films. It is usually desirable to blank out the overlay information so that there will be mixing of the colors of the overlay symbols with the background. This is a complex process but is accomplished, for example, in the Ramo Wooldridge system.

The Ramo Wooldridge systems uses Kalvar film which is exposed by ultra violet light. This film has excellent environmental characteristics. It can be developed very easily by simply heating it after exposure. The three images of the color separation process are then prepared with the

5.5.2 Equipments and Systems (Continued)

Kalvar film and become one film, probably of approximately 70 mm size.

The major difference between the ITT and RW systems is in the method of exposure of the film to place the overlay information properly. The RW system uses a mechanical technique to position the characters on the film. The ITT system uses a Charactron tube to position the figures. Since the Charactron tube does not produce enough light for direct exposure of the Kalvar film, an intermediate step of exposing silver haloid film must be taken before the final film product can be obtained. Because the RW system uses mechanical positioning its response time per chip is of the order of 1-2 minutes. The response time of the ITT equipment is on the order of 15 seconds.

It is significant to note, however, that in neither case of this automatic film generation equipment has there been a satisfactory system developed from an operational point of view. The RW machine is installed in the basement of the Pentagon and is used by the National Military Command System Support Center. Although it works "satisfactorily" it does not have the reliability needed for use by the Joint Chiefs of Staff. The ITT machine is reportedly in a similar or worse state.

There is a question about the future and value of these types of film generating equipments. When the ITT and RW contracts were let there was a great deal of enthusiasm within the Department of Defense for systems of this kind. This enthusiasm seems to have waned during the last year or so, possibly because of the poor operational status of the equipment.

As a first step in developing an approach to displays it is pertinent that users of systems described above (such as NORAD, SAC, NREC, DCA, JCS) be consulted regarding the application and use of the equipment. For example, it is known that the projection system at DCA, analogous to the Kelvin Hughes system described above, is not used. On the other hand the Iconorama at NORAD is the main presentation for CINCNORAD.

5.5.2 Equipments and Systems (Continued)

For systems such as described above it is intended to organize a state of the art summary such as is suggested by the information in Figure 5-7. In addition to the indicated information in this table the results of the review and evaluation will be included.

Beyond this it will be most important to consider and evaluate the work currently under way as, for example, the light valve at GE and the illuminated panels at RCA. Hardware techniques are discussed in Section 5.5.4.

In addition to such equipment reports there will also be a set of conclusions regarding operating characteristics and how they are reflected in the hardware, including considerations of:

speed - the time lapse between the generating of data and its projection,

clarity - the ability to register and produce saturated symbols,

reliability - the development and use of mean-time-to-failure parameters,

cost - the total cost of implementation including programming and offline procedures.

5.5.3 User and Programming Techniques

A significant aspect of making a display system operational is the joint effort of the end product user, the output designer and the programmer. Each affects the other and there is a continual feedback and desire to modify, enhance, or make additions to the basic capability. In such an environment it is mandatory that a programming system be specified which has general purpose attributes and is modular. Hence, it is absolutely essential that systems of the kind represented by the NTDS have, as a basic element, general purpose retrieval programs and output generators. As an example of a very desirable system with these attributes we cite the FLEET Intelligence System developed at CINCEUR and known by the name Formatted

EQUIPMENT

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
STORAGE AND RETRIEVAL	YES	YES	WITH MODIFICATION	NO	NO	NO	LIMITED
COMPUTER TO SCREEN TIME (in seconds)	10-12	30-240	11	REAL TIME	15	REAL TIME	1 SEC/CHARACTER APPROX.
FILM RECORD	COLOR	COLOR	COLOR	B & W	COLOR	B & W	COLOR
LINE DRAWING CAPABILITY	YES	YES	YES	YES	YES	YES	YES
QUALITY ANALYSIS VIEWING STATION	NO	YES	YES	NO	NO	NO	NO
PROJECTOR LOCATED REMOTE FROM GENERATOR	YES	YES	NO	NO	NO	NO	NO
DELIVERED	YES	YES	NO	YES	NO	YES	YES
NUMBER OF SLIDES REQUIRED FOR FULL COLOR	3 plus background	1	2	N A	2	N A	Separate Projectors for each Color
NUMBER OF BACKGROUNDS STORED IN PROJECTOR	100	200	300	0	-	N A	-
BACKGROUND ACCESS TIME (in seconds)	1	4	4	-	-	-	-
RANDOM ACCESS SELECTION	YES	YES	YES	N A	BACKGROUND ONLY	-	BACKGROUND ONLY
SYMBOL COLORS	WHITE plus 3	BLACK, WHITE plus 6	WHITE plus 5	BLACK, WHITE	WHITE plus 6	BLACK, WHITE	WHITE plus variable number (no black)
SYMBOL GENERATION TECHNIQUE	CRT Silver Halide Kalvar	DRY Stencil Direct to Kalvar	CRT Silver Halide	OIL FILM in Vacuum	CRT Silver Halide Kalvar	DIRECT CRT Projection	SCRIBED Silver Mirror **
MASKING FOR UNAMBIGUOUS COLOR	NO	YES	MANUAL ADJUSTMENT	NO	NO	NO	NO
RESOLUTION	GOOD	GOOD	VERY GOOD	POOR	GOOD	POOR	POOR
BRIGHTNESS	GOOD	GOOD	GOOD	FAIR	GOOD	POOR	FAIR

* Equipment:
(1) Aeronutronic
(2) TRW DODDAC Full Color System
(3) TRW Integrated Multicolor Display Console
(4) GE Eidophor
(5) International Electric Corporation
(6) RCA
(7) Fenske, Fedrik & Miller Iconorama

** Glass Slides Need to be Changed Often

FIGURE 5-7

COMPARATIVE CHARACTERISTICS OF SELECTED DISPLAY SYSTEMS

5.5.3 User and Programming Techniques (Continued)

File System. With such programming systems it is only necessary to append specialized formatting routines whenever display systems are appended to the computer.

There are other problems however which the system planners must consider. These are well illustrated in the paper on the DODDAC system and the complete system documentation of the DODDAC displays*. In particular the system planner must recognize and choose among the hardware/software trade-offs in the display/computer interface and with respect to the degree of automatization desired. Amongst such items are:

a.) Are displays physically created, stored, and retrieved or are they computer generated each time they are accessed?

b.) In what way are displays requested? What flexibility in format will there be?

c.) What feedback signals should there be from the display system to the computer such that the entire system is integrated?

d.) What are the timing limitations, as, for example, in driving a line drawing servo?

e.) Shall backgrounds be digitized or on accessible hard copy?

Finally it will be desirable to present some typical configurations and indicate their ability to satisfy the kinds of parameters system designers will be expected to develop such as expected frequency of requests, expected response times, type of characters or symbols desired, amount or density of information to be supplied on individual presentations, etc.

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*See References (9) and (10).

5.5.4 Hardware Techniques

Many of the hardware techniques for use in console displays described in Section 5.4.4 are applicable to group displays. However, group displays have the added requirement of bright, large screen images. Techniques such as direct cathode ray tube viewing are, therefore, not applicable. To date, projection systems using photographic images made from cathode ray tube exposures have been more widely used for group displays. A study by the Rome Air Development Center, "Criteria for Group Displays Chains for 1962-65 Time Period" (ASTIA 283390), recommends film base systems for group displays at least through 1965. For a Naval Tactical Data System for the 1970-80 era, it will be necessary to determine whether film-based systems will still be the best or whether newer techniques such as the light valve projector, photochromic storage, electroluminescent screens, or other large screen display techniques will be feasible and more desirable.

For optical projection systems, it is necessary to choose between techniques such as conventional silver halide film, photochromic film, Kalvar and other Diazo materials, zeographic processes, and thermo-plastic recording. Each of these techniques offers some advantages that must be balanced against its shortcomings with respect to the requirements of the specific application. Most of the display techniques investigated to date and their advantages and disadvantages have been covered in the proceedings of three symposia on display systems (11, 12, 13).

5.6 COMMUNICATIONS DATA HANDLING

5.6.1 Requirements, Systems and Uses

Today's tactical command and control systems are largely communications handling systems. The emphasis on communications handling will continue; it will be an essential ingredient of future systems.

In a general sense the data to be received by command and control computer systems can be divided into two types, structured data and unstructured data. Structured data refers to data which is highly formatted and arrives at the computer at a known rate, known word structure and with a pre-determined meaning of the digits. Unstructured data comes to the computer for example as English language paragraphs, or as data implicitly recorded in photographs. One of the prime examples of unstructured data is intelligence information although some high level command information might be unstructured as well. It is likely that most of the information handled in tactical data systems will be structured. However, careful consideration must be given to unstructured information for there will undoubtedly be some of this to be handled.

Structured data is by far the easiest to handle. Decisions need to be made on the equipment to perform the logic and electronic functions, and consideration must be given to timing and synchronization. Unstructured data needs decisions by people before it can be placed into the computer. This decision process can be aided by on-line consoles where the computer aids the man in the structuring process, "telling" him how this is to be done step wise. The man can then extract the information for the computer or correct garbling, and the like.

Much of the communications problem immediately relates to the general input/output problem which is discussed elsewhere. There are, however, a number of operations which take place:

5.6.1 Requirements, Systems and Uses (Continued)

1. Information is received at a communications terminal device.
2. It is then multiplexed into the computer system probably simultaneously with other communicating devices.
3. The information is then buffered until it is ready to be entered for use by the computer.
4. The message is then decoded and serviced.
5. Very frequently the message is logged and then the message itself is recorded.
6. Concerning the output of data, an output message is composed and formatted and forwarded to a proper device.
7. After the usual operations of multiplexing and buffering, the message is finally transmitted.

Often, of course, where the message is received on a short cycle basis such as the receipt of radar data every 100 millisecond, there is no need for certain operations such as logging.

Communications in systems have many functions. Some of these are listed as follows:

1. Due to physical and topographical requirments, information is required to be transmitted from one position to another. An example of this is radar horizon limitations which limit the placing of radars.
2. Frequently it is desirable to have redundant computers for reliability -- that is, in case one computer becomes inoperative; thus requirements for communications are generated.
3. Frequently it is desirable to have communications from computer to computer to allow a smoothing of the work load of the total system of computers.
4. It is usually necessary to use communications for centralization of the command and to coordinate the entire tactical command and control system.

5.6.2 Terminal, Multiplexing, Storage and Buffering Equipment

One of the unresolved problems that has arisen with the use of tactical command and control systems has been the determination of the equipment configuration to perform the interface functions of terminal, multiplexing, storage and buffering for communications and real-time inputs and outputs. Figure 5-8 is a schematic of these interface functions.

At one extremity it is recognized that terminal equipment is required to perform the terminal functions of digitizing and grouping of information. At the other end the interface to the computer requires that there should be a suitable electrical interface and that grouping of data be performed that is acceptable to the computer. However, there are a number of ways for performing the functions of multiplexing, storage and buffering. The various technqiues are described in the following paragraphs.

Figure 5-9 is a schematic of the Saturn Stage II checkout system which is representative of the philosophy that requires that the computer perform the bulk of the work for the interface functions. Simply the system requires that the programmer program every function. A very rapid and large amount of information, such as is developed when either the flight control or engine test sequences are exercieed, requires that the computer be dedicated to this function only. The program is required to control the storage and buffering. The multiplexing in these sequences has been built as part of the equipment. For less critical functions, the programmer has to perform the multiplexing by using a set of special addresses in the desired sequence.

Figure 5-10 is a schematic of the PMR real-time data handling buffer which is representative of the philosophy that reduces the workload to the computer to a minimum. These systems receive the data automatically and perform the functions of multiplexing storage and speed changing. At the end of a complete data frame the computer is informed that a complete data frame is now available.

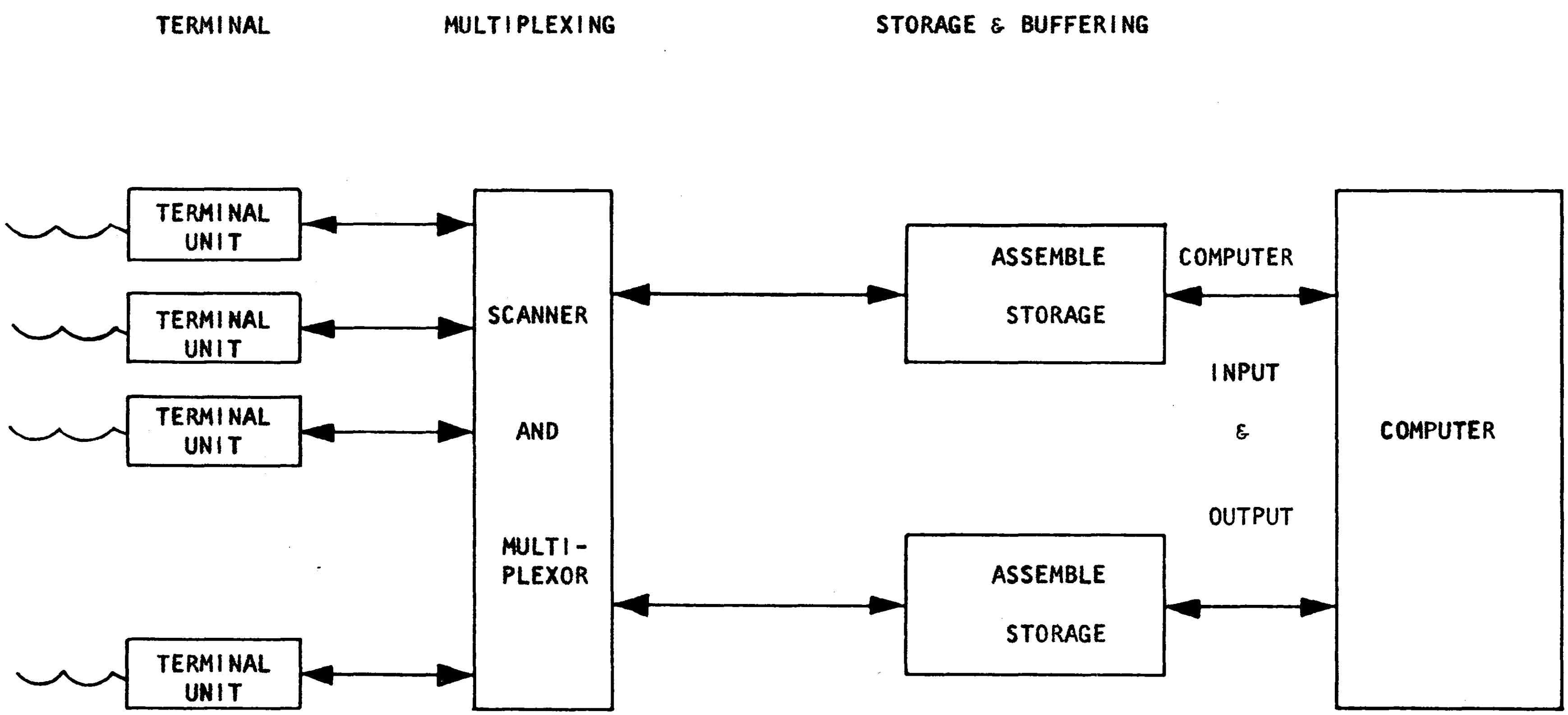

FIGURE 5-8

SCHEMATIC OF INTERFACE FUNCTIONS

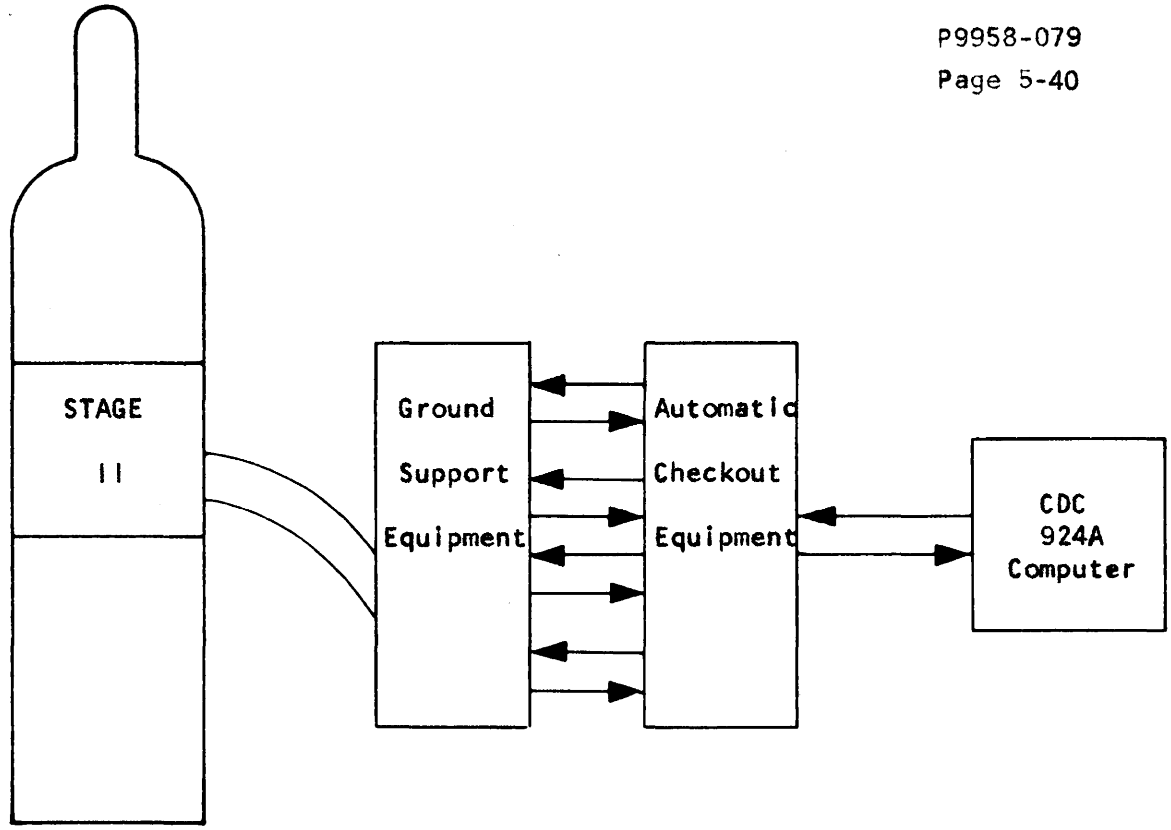

FIGURE 5-9

TYPICAL SATURN V STAGE II CHECKOUT CONFIGURATION

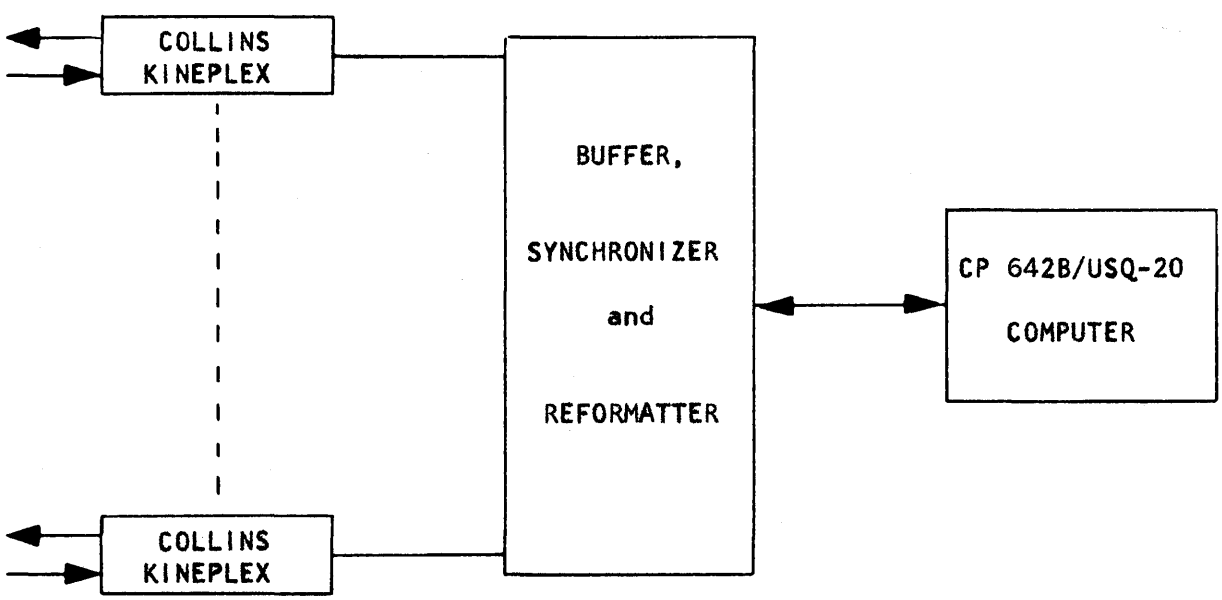

FIGURE 5-10

TYPICAL PMR REAL TIME DATA HANDLING BUFFER CONFIGURATION

5.6.2 Terminal, Multiplexing, Storage and Buffering Equipment (Continued)

For shipboard command and control systems similar types of missions are required. A problem arises as to which approach is best. However, it is more probable that the approaches will be compromised for optimum use of resources.

a.) Cost - This factor has two aspects, the first is the actual dollars involved, and the second is the time expended to develop, design and implement a system.

b.) Reliability - The concept of reliability enters in the desire to make the interface equipment as trouble-free as possible. In general the simpler the functions the simpler the maintenance.

c.) Computer Capacity - Although it is possible to assign to the computer the interface function, an important factor is to consider the basic workload of the computer. Will the incremental addition of interface function seriously reduce the computer capacity reserve? In the PMR example the Buffer, Synchronizer and Reformatter were implemented because of the effect on computer capacity reserve. Of course if the reserve is exceeded, then special equipment and/or computer capacity has to be increased.

d.) Programmer Workload - Related to computer capacity is also the problem of computer programming workload. In the Saturn example, the programming cost has become a significant factor. Programming resources are relatively scarce so that some considerations to husbanding these resources are important.

e.) Flexibility - In developing, designing and implementing interface functions there arises the need for frequent changes in requirements; such as input-output characteristics of timing volume, electrical characteristics, available information about input characteristics, and a host of other changeable specifications. The use of specialized gear has to be considered as compared to the general

5.6.2 Terminal, Multiplexing, Storage and Buffering Equipment (Continued)

purpose computer. The choice is not clear, especially if the special gear has plugboards that are well designed to anticipate changes.

The above cited factors indicate the extent of the problem and indicate the areas in which further investigation should be made.

5.6.3 Programming Techniques

A specific programming subsystem is contemplated for handling the communications data for both reception and transmission. Such a subsystem is in reality a kind of store-and-forward system from a functional point of view.

Three kinds of programming pieces must be identified. First there are the special input/output routines, including the programs permitting flow of data into and out of the computer. Then there are the message management programs which control buffer size, transmission checks, error detection and correction routines, format control etc. Finally,there are the programs that deal with content itself, determining the nature of the message and their disposition. Actual operation with the data is relegated to processing programs.

From the point of view of the system designer this programming system is very much machine dependent for the first set. It is communication process dependent for the second, and is message oriented in the third. Always,however, the programs will be specified modularly -- so that new peripherals or new messages can be added without disrupting the entire system.

Among the processes that will be studied and specified are:

Redundancy checks

Field validation

Duplicate searching

Batch or single entry processing

Correction vs. re-transmission economics

5.6.3 Programming Techniques (Continued)

Exception file processing

Message logging and accounting

Distribution

Of considerable influence in this endeavor will be the efforts already initiated by the Navy to improve the JOPREP message system in addition to its own fleet and logistics reporting procedures. The current efforts on AMPS at Ft. Ritchie is another important area which will influence such considerations.

The result of the programming system design and selection of techniques will then afford design parameters in terms of required buffer sizes, processing times and, as a consequence, message throughput rates. Hence if given the input loads, it will be possible to come up with a "best" system concept where trade-offs may be made in computer memory size, speed, auxiliary storage capability and computer organization. It is, for example, important to compare and evaluate the single processor approach versus the de-centralized system, especially for the input process where a specific computer may be delegated the communication function. Such systems are now becoming more pronounced as evidenced, for example, by the IBM 7740 and 7750.

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6. HARDWARE TECHNIQUES

6.1 GENERAL

New and improved components and hardware techniques will play an important role in obtaining greater capability, higher reliability, and easier maintainability in computers and data systems for use in the 1970-75 area. New techniques that have already been proven feasible will permit significant reduction in size, weight, and power consumption. These can be divided into two major categories - (1) basic components and techniques; (2) integrated circuits and other batch - fabrication techniques.

During the course of this study both existing and future components and techniques will be studied and analyzed to evaluate their relative merit and potential effect on the computer field. Their feasibility and time of availability will be evaluated for those functions in tactical data systems for which each shows the greatest promise. The advantages and disadvantages of different types of existing and future components and techniques will be related to the requirements of the future Navy Tactical Data System. Recommendations will be made as to which ones offer the greatest promise in specific types of uses in the planned system.

Existing components and techniques are capable of providing sufficient speed and performance capability for the planned tactical data system. However, significant reductions are necessary and possible in the size, weight, maintainability, reliability, serviceability, and logistics requirements for digital equipment used in shipborne tactical data systems. In this study, particular emphasis will be placed on components and techniques that offer promise for improving maintainability, reliability, and serviceability.

6.2 BASIC COMPONENTS

A large number of digital components and techniques have been proposed and investigated during the last few years. It is difficult to evaluate the relative merit and value without a knowledgeable survey of the state of the art for each component or technique conducted within the framework of the specific applications in which they might be used.

At present, and for the foreseeable future, semiconductor elements offer the best combination of feasibility, reliability, performance, and cost for use as digital logical components. However, considerable research and development effort has been devoted to cryogenic components (1, 2)*, magnetic logic components (3), tunnel diode circuits (4,5), kilomegacycle circuitry (6, 7), and other more novel techniques in recent years.

W. B. Ittner, III, has pointed out that cryogenic techniques offer promise in the memory area, but that their use as logical elements is questionable(2). Tunnel diodes are practical circuit components. As stated by Electronics magazine, "Tunnel diodes have passed the stage of being glamorous new semiconductor elements with great potential. They've arrived! They are now just another element that the engineers can choose from to build faster, more reliable, or more sensitive circuits."(8) Attention has been called to the problems of packaging, interconnectors, and communications involved in the use of kilomegacycle circuits; by D. J. Chesarek and others.(7)

New and radically different techniques, such as the use of lasers and optical components, have been proposed and are being investigated (9, 10, 11). All types of advanced components and techniques should be considered and evaluated for any computer or data processing system planned to be operational in 5 to 10 years - even though at present semiconductor integrated circuits appear to be the most feasible and promising for that time span. It is important that such consideration and evaluations be conducted within the framework of a knowledge and

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* Numbers in parentheses refer to the Bibliography at the end of this section.

6.2 BASIC COMPONENTS (Continued)

understanding of their operational use to assure that they offer worthwhile advantages for the specific application. Their advantages must be commensurate with their feasibility and state of development, cost, and effect on reliability and maintainability. The unique requirements of Navy shipborne applications will place different values upon the various characteristics of new components and techniques than will commercial or fixed site applications. Therefore, it is extremely important that these new components and techniques be investigated and evaluated with particular reference to the environmental and operational requirements imposed by their use in Naval Tactical Data Systems.

6.3 INTEGRATED CIRCUITS AND BATCH FABRICATION TECHNIQUES

Integrated circuits are not basically new components in the sense that cryogenics or lasers are, but rather they represent radically new methods of fabricating and packaging conventional semi-conductor circuitry. With integrated circuit techniques, complete circuits, such as flipflops or multiple gate circuits, can be fabricated as a unit and packaged as a single component. This reduction in the number of discrete components offers significant advantages in terms of improved reliability and reduced size. When large volume production quantities are achieved significant cost savings will also be realized as a result of the lower cost of the use of batch fabrication techniques, the hand wiring within a basic circuit package and much of the interconnection between closely related circuits will be eliminated. Advances in integrated circuit techniques have been accompanied by associated advances in packaging and fabrication of integrated circuit modules.

Integrated circuits and the associated packaging techniques are not speculative future developments. They are here today. Digital computers utilizing integrated circuits are now available that provide

6.3 INTEGRATED CIRCUITS AND BATCH FABRICATION TECHNIQUES (Continued)

capabilities roughly equivalent to those of the AN-USQ-20 in less than one cubic foot.

Integrated circuit computers are currently in production (12, 13). M. Weissenstern has predicted that by 1970 "digital computers will be most probably completely integrated, including the memory, which will probably be a very compact thin-film type" (14). A study by a Harvard Business School team predicts that integrated circuits will take over 20% of the total circuit market by 1975 (15). For the Improved Minuteman Computer (D37B) alone, over "200,000 integrated circuits are currently on order from four suppliers" (12).

The widespread use of integrated circuits will create a situation in which the computer and other digital electronic sections of future command and control systems will be an almost negligible part of the system in terms of space requirements. This raises many interesting questions for those planning future C&C systems - e.g. determining trade offs between logic and storageequipment on the one hand and input/output and display equipment on the other. In multi-computer systems, it is much more feasible now to disperse the computing, data processing, and logical hardware, placing some sections in different peripheral devices such as displays or input units.

The impact of integrated circuits and associated packaging techniques on future C&C systems must be carefully considered since these will undoubtedly have a profound impact on the planning of such systems. The consideration of integrated circuits in this study will also serve to emphasize areas in which increased development efforts should be devoted to peripheral equipments such as displays, mass memories, and input/output devices.

6.4 RELIABILITY, MAINTAINABILITY, AND SERVICEABILITY

Paramount in the evaluation of any existing or new components or techniques for an advanced Naval Tactical Data System will be their effects on the reliability and maintainability of the system. The AN/USQ-20 used in the present Naval Tactical Data System has an enviable record of reliability. However, integrated circuits discussed previously offer the promise of even higher reliability within the time scale of the tactical data system to be planned following this study.

With respect to serviceability, maintainability and logistics, the widespread use of integrated circuits will greatly simplify the logistics problem and the space required for spare parts. This widespread use will facilitate maintenance by making feasible the replacement of major parts of the computer if failure occurs. Such parts can then be repaired independently of the operation of the machine or system. In a multi-computer system, it may be feasible to carry a complete spare computer which can be rapidly plugged in to replace another machine if failure occurs. Integrated circuits offer great promise for higher reliability, better maintainability and serviceability, and simplified requirements for logistics support. These factors will be given heavy weight in any evaluations of components or techniques for future Naval Tactical Data Systems.

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7. MEMORY TECHNIQUES

In any computer-based system memory hardware and software technology provides the basic framework on which the system is built. Memory devices consistently cost 30 to 80% of the total cost of the computer system. Too much high speed memory can cause costs to soar while too little high speed memory, or poorly utilized high speed memory, can cause system time response to soar. Much of the new computer hardware and software technique developments center around memory.

The Navy will undoubtedly contract for a new computer for tactical systems in the next 2-3 years. Many of the ideas described herein should be part of the specifications for that computer.

7.1 OPERATIONAL CONSIDERATIONS

7.1.1 Memory Hierarchies and Types

There is an increased usage and complexity of memory hierarchies in computers. In the past the high speed computer memory frequently has been augmented by auxiliary memory, such as the bulk storage of tapes and drums. There is currently coming into view a more definite hierarchal structure. This consists of various memories of speed and storage such that there is a small amount of high speed storage, and successively larger amounts of lower speed storage, with very large amounts of bulk storage such as that provided by drums and discs.

One of the more interesting aspects of this hierarchal structure is the technique for utilizing the various memories. There will undoubtedly be increased examples of automatic (no programmer intervention) refurbishing of high speed memories from bulk storage. Some of this has already appeared in the system design of the ATLAS computer with its "word and page" concept. At the lower end of the speed spectrum are a number of very high speed

7.1.1 Memory Hierarchies and Types (Continued)

registers with nanosecond access times. These registers were formerly only the accumulators or quotient registers. In today's new computers there are larger numbers of these devices ranging up to 100 or so. In the Navy's new USQ-20B and 667 NTDS* computers, these registers are thin film type. Tannel diodes have been advanced as good candidates for the ultra high speed storage registers. A new area referred to under micro-programmed computers in Section 4.4 is the read-only memory. The memory is only capable of being read and cannot be written it. This is an appropriate technique for implementing certain standardized computer control operations which need not be changed or need be changed only infrequently. A close relative of this technique might be referred to as the "read-favor" memory where the read cycle is far shorter than the total read write cycle, such as in the Biax memory used as the high speed memory of the PB400 computer.

7.1.2 Memory Operations

We have already referred in other sections to the interleaving of memory accesses between the main computer and the input/output devices. The data from the I/O device is therefore automatically multiplexed into the computer. Every modern computer uses or should make use of this feature.

Another interesting memory operation technique which has not seen extensive use, but is one in which interest is rapidly increasing, is the "overlapped accesses" technique. This technique allows a four micro-second cycle memory to be effectively a one microsecond memory by over-lapping the access of four independent memory devices, that is, where each one of the four has independent read-write circuitry. There are difficulties, of course, in programming, and there is some question of the total efficiency of such a system, since the four memories do not equal a one microsecond memory because the accesses cannot always be sequenced exactly. McGee (1) has made a very interesting study of this technique in a paper

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* Official designations CP642B/USQ-20(V) and CP-667(KN-1)UYK

7.1.2 Memory Operations (Continued)

presented verbally but not yet published. He arrives at an optimum degree of overlap of the memory based on a number of assumptions.

7.1.3 Addressing and Searching

Brooks (B2) has described the latest techniques for address specification. He describes truncation, indirection, indexing, and implication as being the four major techniques. Truncation gives an address only to a certain level, and the remaining bits are implicit within some hardware or software context. In indirection the address specifies the location of the full effective address. Indexing refers to augmenting the given address by the instruction counter content or by the contents of a special register. Push down store machines, such as the KDF9 and Burroughs B-5000, use the push down store technique which is an example of an implicated address.

Of very great interest to modern computer technology is the associative memory or content addressable memory*. Some of the earlier thinking on this type of memory accomplished by Newell, Shaw and Simon (3). In this paper, which was related to heuristic programming, list structures were developed which connected one memory cell to another. The first concept of associative memory was thereby developed. This technique will also see many uses in the future.

Another related technique is the content addressable memory. There are a number of conventional ferrite core memories now specifically designed to allow the searching of key bits of the memory in a short length of time -- in almost the same length of time required to give one specific word out of the memory. Also, cryogenic memory techniques lend themselves very readily to a very rapid search of a sizable memory to select out the cell or cells according to certain keys.

In general, it seems clear that in the future memory cells will

*Associative memories are discussed further in Section 7.2.

7.1.3 Addressing and Searching (Continued)

contain more information than simply the data information needed in the computation. Candidate information to be contained additionally in a memory cell are: type of data, priority of data, symbolic address of information and number of times the data has been used. Some of these techniques were described by Bauer (4) a number of years ago when he explained how advanced memory techniques could be used in a conceptual machine called Ultradatic.

Associative memory and list processing devices are now being considéred as building blocks for computers. In a recent paper Prywes (5) described a computer especially designed for multi-list processing and used the ideas of the associative memory. In still another paper Seeber and Lindquist (6) have described a highly parallel computer which utilizes the associative memory concepts.

7.2 MEMORY HARDWARE TECHNIQUES

Magnetic drums and magnetic core memories are firmly entrenched at present as the major forms of main internal storage. Magnetostrictive delay lines are used in at least two current machines. A number of new types of memories are being developed. The most promising appear to be thin-film memories and continuous-sheet cryogenic memories (7,8,9,10,11).

7.2.1 Thin Film and Cryogenic Memories

Magnetic thin films are one of the newer types of storage techniques that offer promise for the future and yet have been proved feasible and are in operation today. At least one commercial computer and several militarized computers available at this time use small thin film memories for high speed "scratch pad" type operation (11,13). The use of magnetic thin film memories in these machines is primarily to provide a small high-speed memory of a few hundred words or less to mechanize multiple high-speed registers requiring read-write cycle times of

7.2.1 Thin Film and Cryogenic Memories (Continued)

fractions of a microsecond. In one machine, a small magnetic thin film memory is used effectively to mechanize multiple arithmetic and control registers. In another, a magnetic thin film memory is used to provide a small high speed multiplexed input/output buffer that also serves as an internal "scratch pad" memory.

It is anticipated that the widespread use of magnetic thin film memories is approximately three to five years in the future. This, of course, would make them available at the right time for inclusion in the 1970-80 era Naval Tactical Data System. At present, the use of magnetic thin film memories is limited to high speed small capacity applications because of the cost of such memories and their present state of development. Magnetic thin-film memories will replace magnetic core memories in many operations where a linear select or word oriented type of core memory would be used because of the speed requirements. Magnetic core matrix memories are expected to continue their dominance of the applications requiring random access memories with cycle times of two to ten microseconds. However, it is believed that, in a few years, magnetic thin film memories will take over those applications requiring random-access with cycle times below one microsecond.

Improvements in the cost of magnetic thin-film memories are being made rapidly so that their cost can be expected to be competitive with linear-select or word-oriented core memories in the near future. It is believed that the selection between linear-select magnetic core memories and thin-film memories will be made primarily on a basis of speed vs cost. Because of the inherent magnetic and electronic techniques involved, there is little cost saving in slowing down a magnetic thin-film memory to operate at speeds slower than one microsecond cycle time. On the other hand, there are significant cost penalties in trying to operate magnetic core memories at one microsecond or less. As a result of these considerations, magnetic thin-film memories will be in widespread use during the time scale of the planned Navy Tactical Data System.

7.2.1 Thin Film and Cryogenic Memories (Continued)

Another attractive feature of thin-film memories and continuous-sheet cryogenic memories is that they are fabricated by batch fabrication techniques. That is, the memories are not fabricated and assembled element by element but rather groups of elements are fabricated in a batch type process. As a result, these types of memories are closely related to integrated circuits discussed in Section 6 which also makes use of a batched fabrication process. By the elimination of many manual operations, batch fabrication will significantly improve the reliability of thin film memories and continuous-sheet cryogenic memories in a manner similar to that in which the reliability of logic circuits has been improved by integrated circuit techniques.

It will be necessary to determine the appropriate criteria and trade-offs for selecting this type of memory rather than a magnetic core memory for certain applications. During this study, these factors and criteria will be determined, and magnetic thin film memories will be evaluated against other types of new high speed storage such as the continuous-sheet cryogenic memory. The magnetic thin-film memory appears the most promising and most immediate of the newer memory techniques, but the possibility that another technique such as the continuous sheet cryogenic memory will experience significant improvements and accomplishments at an early data cannot be ignored. Therefore, it will be necessary to consider and evaluate all of the new and proposed memory techniques on the basis of performance and cost on one hand and feasibility and availability on the other hand.

7.2.2 Associative Memories

Considerable effort has been expended in the last few years on associative memory techniques that permit locating information stored in a memory on the basis of a part of the contents rather than on a unique numeric address (14,15). For this reason, associative memories have

7.2.2 Associative Memories (Continued)

obvious advantages in certain functions such as table look up or indexing. However, there is a possibility that this type of memory may also lead to completely new and different forms of machine organization. If large scale, economic associative memories become available, we may find it advantageous to organize machines using the memories as the main internal memories in a completely different way from that in which machines with fixed address memories have been organized in the past. For example, a machine organization has been described by Davies (16) that achieves a dispersed and highly parallel type of arithmetic and control function as a result of the use of the logical properties inherent in associative memory cells.

A number of techniques have been proposed and investigated for achieving an associative content addressed memory. The two that have enjoyed the greatest interest and attention are those using multi-apertured magnetic core techniques (15) and those using cryogenic techniques (14). The major problem to date with this type of memory has been in achieving a large capacity memory at a reasonable cost. Small associative memories are now available, but a careful investigation would be required to determine whether associative memories of any significant size will be available within the time scale of the planned Naval Tactical Data System and at a price that would justify their use. At the same time, a thorough consideration is required to determine whether associative memories should be utilized in conjunction with more conventional type memories in a computer, or if associative memories should be utilized as the main internal memory, perhaps with a radically different form of internal machine organization.

Large associative memories will probably require batch fabrication techniques to permit reasonable cost per bit for the storage and logical capability inherent in each element of the memory.

7.2.3 Read-Only Memories

Read-only or non-destructive memories provide the ability to store certain data in a form in which it can be read very rapidly without danger of destroying the stored information. There is an increasing tendency to use a certain amount of read-only memory capacity in conjunction with the computer's main internal read/write memory. In read-only memories writing is slower and more difficult than reading. Usually, either the reading speed is much faster than in more conventional memories, or the read-only memory is cheaper than read/write memories with equivalent speeds. In many spaceborne systems, a large read-only memory (frequently a permanent store memory) is used for storing the program in conjunction with a small read/write scratchpad memory. This insures that the program will not be destroyed by malfunctions in other parts of the system and it reduces the weight and power consumption required for the total memory capacity. In some ground-based computers, a smaller read-only memory has been used in conjunction with a large read/write main internal memory. In this latter application, the read-only memory is used only to store constants, subroutines, or micro-instructions that are changed relatively infrequently to permit much faster access to this type of information than to information stored in the main memory.

Some of the major types of read-only memories that have been used are the Biax memory (18), transfluxor memories (19), and twistor memories (20). These three devices have been proved and are now operational. These and the newer types of read-only memories and their possible advantages and applications in Naval Tactical Data Systems should be evaluated. Although it may be determined later that read-only memories do not offer significant advantages in a Naval Tactical Data System. These memories should be considered and evaluated as the candidates for a possible component in the memory hierachy.

7.3 MASS MEMORY

Naval Tactical Command and Control Systems will require some form of on-line mass memory for storage. Some of the functions performed by such a mass memory are:

1. Storage of alternate programs and subroutines for handling interrupt conditions.
2. Storage of historical data and necessary programs to permit remaining machines in the multi-computer systems to take over the functions of the machine that has failed.
3. Storage of large volumes of data, each item of which may be used infrequently - - e.g., intelligence information, characteristics of enemy vehicles, etc.
4. Storage of short term historical information such as target track histories.
5. Storage of information for displays that are used relatively infrequently.

The major types of mass memory currently available are magnetic drums, magnetic disc files, and magnetic card memories (21). These three types provide the required combinations of large capacity, relatively fast semi-random access, fast data transfer rates, and eraseability and re-useability. They can be operated under direct on-line control of the computer and are addressable by the computer. Typical characteristics for these types of mass memories are summarized in Figure 7-1. The advantages and disadvantages of the major types of memories for commercial applications were summarized recently by Hobbs (22) as shown in Figure 7-2. Similar comparisons will be made with specific attention to military requirements.

In addition to these types of mass memories, certain bulk storage functions are commonly handled by high-speed magnetic tape units. Magnetic tape is cheaper for off-line storage than the mass memories discussed above. However, for on-line storage, where the tape reel is

TYPE OF DEVICE	ON-LINE CAPACITY PER-UNIT (CHAR.)	TYPICAL ON-LINE COSTS IN CHAR.	AVERAGE ACCESS TIME	DATA TRANSFER RATE IN CH/SEC.	REMOVABLE MEDIA	MULTIPLE ACCESS CAPABILITY	MAJOR ADVANTAGES	MAJOR DISADVANTAGES
MAGNETIC TAPE LOOPS	50×10^6 to 500×10^6	0.1	8 sec.	20,000 to 100,000	YES	NO	LOW COST	VERY SLOW ACCESS
LARGE FIXED-HEAD MAG. DRUMS	0.2×10^6 to 1.0×10^6	2.0	15 ms	100,000 to 200,000	NO	POSSIBLE	FAST ACCESS	HIGH COST-LOW CAPACITY
MOVING-HEAD MAGNETIC DRUMS	4.0×10^6 to 65×10^6	0.3	100 ms	50,000 to 150,000	NO	NO	LARGE CAPACITY, LOW COST	MEDIUM SPEED ACCESS
FIXED-HEAD MAGNETIC DISC FILE	10×10^6 to 25×10^6	0.6	20 ms	100,000 to 350,000	NO	POSSIBLE	FAST ACCESS	HIGH COST
1 DIMENSION MOVING-HEAD MAG. DISC.	10×10^6 to 150×10^6	0.2	100 ms	100,000 to 400,000	NO	POSSIBLE	LARGE CAPACITY, LOW COST	MEDIUM SPEED ACCESS
2 DIMENSION MOVING-HEAD MAG. DISC.	10×10^6 to 150×10^6	0.15	500 ms	50,000 to 100,000	NO	NO	LARGE CAPACITY, LOW COST	SLOW ACCESS
REMOVABLE-STACK DISC FILES	2.0×10^6	1.2 (on-line) 0.02(off-line)	150 ms	80,000	YES	POSSIBLE	LARGE OFF-LINE CAPACITY, LOW COST	SMALL ON-LINE CAPACITY
MAGNETIC CARD FILES	5.5×10^6	1.0 (on-line) 0.003 (off-line)	200 ms	100,000	YES	NO	LARGE OFF-LINE CAP., LOW COST, DISCRETE CARD	SMALL ON-LINE CAPACITY
* WOVEN SCREEN MEMORY	1.0×10^6 to 10×10^6	9.0	10 ms	100,000	NO	NO	FAST ACCESS, NON-MACH.	HIGH COST, NOT CURRENTLY AVAILABLE

FIGURE 7-1 SUMMARY OF CHARACTERISTICS OF MASS MEMORIES

* NOTE: All figures shown for Woven Screen Memory are estimates of future developments.

TYPE OF MASS MEMORY	ADVANTAGES	DISADVANTAGES
Fixed-Head Magnetic Drums	Fast access, no mechanical head motion, high continuous data transfer rate	Low capacity, high cost per bit, poorer volumetric efficiency, large electronic switching matrix, large number of heads
Moving-Head Magnetic Drums	Large capacity, low cost per bit, possibility of parallel reading or writing from multiple heads to greatly increase instantaneous data transfer rate	Poorer volumetric efficiency, relatively large number of heads for medium speed access or slower access if fewer heads
Fixed-Head Magnetic Discs	Fast access, medium capacity, no mechanical head motion, high continuous data transfer rate	High cost per bit of storage, large electronic switching matrix, large number of heads
Two-Dimension Moving-Head Magnetic Discs	Large capacity, minimum number of heads, low cost per bit	More complex positioning mechanism, slowest access, slow continuous data transfer rate
One-Dimension Moving-Head Magnetic Discs	Large capacity, possibility of multiple simultaneous accesses if heads are positioned independently, low cost per bit compared to fixed head units, possibility of parallel reading or writing from multiple heads to greatly increase instantaneous data transfer rate	Relatively large number of heads, somewhat higher cost per bit compared to two-dimension disc unit, medium speed access
Removable-Stack Discs	Large off-line capacity, low cost per bit of off-line storage, combines on-line random-access capability with large off-line capacity	Limited on-line capacity, higher cost per bit of on-line storage
Magnetic Card Memory	Large off-line capacity, low cost per bit of off-line storage, combines on-line random-access capability with large off-line capacity, individual cards can be copied, replaced, or inserted.	Limited on-line capacity, higher cost per bit of on-line storage
Woven Screen Memory	Fastest access, no mechanical motion	Lower capacity, higher cost per bit, not currently available

FIGURE 7-2

ADVANTAGES AND DISADVANTAGES OF TYPES OF MASS MEMORIES

7.3 MASS MEMORY (Continued)

kept on the tape unit, magnetic tape does not provide a significantly cheaper form of on-line storage than some of the mass memories listed (22). Magnetic tape suffers the severe disadvantage of slow serial access. Although magnetic tapes will continue to serve an important function as an input/output media and cheap large volume off-line bulk storage, most of the functions requiring on-line operation and fast access time are being taken over by large magnetic drums, magnetic disc files, and magnetic card memories.

Large fixed head magnetic drums provide storage capacity of 200,00 to 1,000,000 characters with average access times of 15 milliseconds. Larger magnetic drums with moving heads provide on-line capacity up to 65 million characters with approximately 100 milliseconds average access time (24).

Fixed head magnetic disc files provide on-line capacities of 10 to 50 million alpha-numeric characters with average access times of 20 to 40 milliseconds (25). Moving head magnetic disc files provide on-line capacities from 10 to 250 million alpha-numeric characters with average access times of 100 milliseconds. Some of these provide a simultaneous dual access capability (26).

A new type of magnetic disc file provides a removable disc stack with on-line capacity of two to three million alpha-numeric characters and average access times of 150 milliseconds (27). However, since the disc stacks can be removed, a large number of disc stacks can be stored off-line. This type of device provides a compromise between the advantages of magnetic disc files and magnetic tape-fast semi-random access to a limited amount of on-line storage combined with relatively cheap off-line storage of large volumes of data. Each disc stack has approximately 1/3 to 1/4 the capacity of a reel of magnetic tape but with about ten times higher cost.

7.3 MASS MEMORY (Continued)

Magnetic card mass memories provide on-line capacities of five to ten million alpha-numeric characters with an average access time of approximately 200 milliseconds (28). It is anticipated that this capacity can be significantly increased in the foreseeable future. The magnetic card files are similar to the removable stack disc files in that they combine a limited amount of fast access on-line capacity with an almost limitless amount of off-line storage capacity. An improved militarized magnetic card memory with increased capacity is now being developed under a Navy Contract.

Since all of these types of mass memories involve rather delicate and high precision electro-mechanical components, they are difficult to adapt to a tactical military environment. This is particularly true of magnetic disc files. Some work has been done in adapting militarized airborne magnetic drum techniques to mass memories. One company is now working on a large capacity militarized magnetic drum to provide capacities of approximately 15×10^6 alpha-numeric characters with an average access time of 8 milliseconds. Another company is developing a militarized flexible-disc file based on the Bernoulli principle. This unit will have a capacity of 20×10^6 characters and an average access time of 25 milliseconds. The magnetic card memory is less susceptible to problems of shock and vibration since the storage media is a stack of mylar cards with a magnetic coating rather than large precision discs. The fact that the mylar cards rather than the magnetic heads are moved in this type of device also causes it to be better suited to the environmental conditions of types of drums or discs that employ moving heads.

It is likely in the long run that a static magnetic and/or electronic mass memory will replace those involving mechanical motion. It does not appear that such mass memories will be economically competitive for commercial applications for a number of years. However, the advantages that they offer in military applications in terms of speed

7.3 MASS MEMORY (Continued)

and environmental characteristics may justify a cost premium that will expedite their use by military systems. One example of this type of memory is the woven screen magnetic memory being developed by at least one company (28). Other possible techniques not involving the motion of the storage media are magnetic thin-films, twistors, cryogenic, and photochromic techniques (30).

For a Naval Tactical Command and Control System for the 1970-80 era, it will be necessary to consider all possible techniques with particular emphasis on those that offer the greatest advantages in terms of environmental characteristics as well as performance. The ability to withstand shock, vibration, humidity and temperature condition characteristics of shipborne naval operation will be most significant. However, it will be important to make sure that techniques seriously considered to use in a tactical data system will not only be feasible but will also be developed to a proper point of performance, reliability and cost in time to be available for use in the planned system. During this study, techniques for obtaining mass storage will be studied and recommendations will be made concerning the feasibility and time scale for each and the areas where each type might be used to the greatest advantage.

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8. PROGRAMMING

8.1 ASSEMBLERS AND COMPILERS

8.1.1 Existing Structures and Programs

The task of programming command control to a great extent has become almost tradition bound to the use of assemblers and other systems which essentially use machine language. This tradition has arisen because of the tendency by government agencies to restrict the computer contract only to hardware items and perhaps include the implementation of an assembler. To complete the programming chore, a separate contract is usually let to implement the command control system in which the contractor, to minimize costs, accepts the existing program systems. The major exception to this philosophy has been contracts implemented by Systems Development Corporation in which they have recommended the use of JOVIAL first developed in connection with the Air Force 465L program. However, the Naval Tactical Data System has used CS-1 and NELIAC compilers, as discussed below.

The justification for the infrequent use of advanced compilers has been the judgment in the industry that only machine language coding is adequate to meet timing and space restraints. Hence, the recommendation of independent advisers has been to contract only for basic assemblers. Also, many programmers of on-line systems believe that only machine language programming can develop efficiently the codes for real-time functions.

This trend in the past has influenced most command control systems. However, the Navy, to a great extent, has taken the lead in stepping out of this tradition by the following major efforts:

1. Compiler System (CS-1) - This is a compiling system implemented for the Navy by UNIVAC to be used in the CP642A&B/USQ-20 computers. These computers have been, and will continue to be, important computers in Navy systems. The compile system provides a very large programming system in which many of the advantages of compiling have been realized. In addition, in recognition of

8.1.1 Existing Structures and Programs (Continued)

the characteristics of real-time command control systems, the compiler is oriented to preserve computer hardware characteristics in space and in instruction repertoire.

2. JOVIAL - The JOVIAL System has been designated by the CNO to be the preferred programming system for command control systems, much to the chagrin of the NELIAC touters. JOVIAL has been described as an ALGOL System that has been adopted to command control requirements. Its principal distinguishing feature has been the use of the Compool. The Compool has been implemented to provide communications between several major segments of command/control programs.

3. NELIAC - The NELIAC System has been sponsored by the Naval Electronics Laboratory. It has the advantage of rapid compilation. The system has proved its advantages to Army Fieldata personnel who have used NELIAC to obtain programs in Fieldata Computer BasicPac. The computer has the outstanding feature of tending to preserve hardware instruction repertoire. It is this feature that has also made the compiler subject to criticism because it limits the language power of the system.

4. ANUYK-1 Programming - The ANUYK-1 is an NTDS type computer used by the Navy and has featured micro-programming. As a practical solution to programming this system, a compiler of machine language type has been developed which allows macro as well as micro-programming.

Problem oriented languages such as FORTRAN, NELIAC, and the like, are efficiently used for general programs. A more difficult and serious problem is the language for use in coding the execution and master control parts discussed in Sections 7.2 and 7.3. These parts of the programs require critical space and time allocations that in the past have precluded the use of the problem oriented language. Considering the considerable amount of

8.1.1 Existing Structures and Programs (Continued)

effort expended in the systems enumerated above in preserving machine characteristics, it has become important to consider the use of problem oriented languages as candidates for coding the executive and master control programs. The successful use of these languages will provide quick progaam implementation that is flexible and easy to maintain.

8.1.2 List Processors

One of the new systems of programming has been the use of list processors, which received impetus when attempts were made to program systems that were designed to solve problems in which the handling of lists were required. In particular, the computer method for playing chess and for proving theorems in logic had this requirement. It has been proposed that if a language oriented for this problem were implemented, the programming costs could be reduced. The list processor has been adapted to the use of programs in which large search efforts were to be made. In command control there are several applications in identification and route selection that it is believed could be implemented quickly if a list processor were used.

The principal difficulty with list processors is that computer orgainzation at present is not designed to permit efficient utilization. List processing computers usually use associative memory techniques. There is increasing activity in the research of these techniques. They have been discussed briefly in Section 7.1.3 of this proposal.

8.2 EXECUTIVE AND MASTER CONTROL

8.2.1 On-Line Considerations

The executive and master control must specifically be structured within the framework of real-time and on-line requirements. In the context of this discussion, real-time refers to information handling which is constrained by either the interval between events or cycle time must be met if the data is not to be lost or the response time which is the allowable reaction time by the computer as a result of a stimulus. Two important

8.2.1 On-Line Considerations (Continued)

examples of such characteristics in the NTDS are the sampling of sensor data where the interval between events may be about 50 milliseconds, and the responses to man/machine query which are measured in seconds.

As a result of these requirements the system Executive will have to maintain control over the timing. This depends, of course, upon how much of the detailed bookkeeping and control is actually committed to hardware such as suitable interrupt priority control, active or passive clocks and sufficiently long buffers.

In the real world it is not always possible to schedule inputs so that each response is completed before a succeeding input is submitted. Many on-line systems, therefore, require a capability for scheduling of a queue. This queue may consist not only of task items generated by the inputs, but also of subtasks which are subordinate functions called out by an input. Thus, an input may require a response composed of a number of more or less independent I/O functions inter-mixed with computing functions. In addition certain tasks may be placed in the queue under internal scheduling as a function of counters or a real-time clock. In missions where several instruction sequences (threads) are being executed simultaneously on a time shared basis, the individual functions are scheduled as separate items in the queue so that they may be "sandwiched" in with each other, thus making more efficient use of both internal processor and I/O capacity.

A scheduling algorithm would be required for each application. This algorithm is a function of parameters such as:

1. priority of a task,
2. precedence rules, such as a completion of a prerequisite task,
3. deadline to meet,
4. available equipment,
5. pre-emption possibilities,
6. dumping, restoring and relocation economics.

8.2.1 On-Line Considerations (Continued)

Hence it will be important to point out various scheduling procedures and their characteristics by comparing their operation to a variety of real-time applications.

Another important consideration in real-time systems is that of error detection and system recovery. System requirements vary, but virtually all real-time systems require rollback procedures of one kind or another in case of failure. The Executive Control must be constantly cognizant of the status of the system and capable of initiating this rollback procedure.

It is impossible to discuss rollback and recovery procedures in general terms. Each individual application has different requirements. One missile range safety requirement is such that error determination and recovery must take place within 100 ms. Thus, when failure occurs, standby equipment must be alerted and placed in operation within 100 ms, precluding the use of auxiliary storage for programs. At the other extreme, whole operations may be repeated to recover from an error. At some point between these are systems which require that the status of the system be preserved at intervals - of say 15 minutes - and all subsequent inputs stored. If failure occurs during any period, recovery can be achieved by rolling back to the beginning of the interval and reprocessing the inputs. The latter examples may imply recovery in non-real time.

Although recovery after failure during a file updating process can be a serious problem, the most challenging recovery problems are those where rapid turnover to a standby computer is required. In at least one system, BMEWS, the error detection and recovery problem is solved by operating two computers in parallel. As each operation occurs, the answer is verified between the computers. If a deviation occurs, the operator is apprised of the fact and he decides which computer is producing the better data. Manual turnover is then instigated simply by switching to the trusted

8.2.1 On-Line Considerations (Continued)

computer. This system does not, of course, provide the reliability or the automaticity which would be provided by three computers where a majority decision could rule. However, its reliability could perhaps be improved by repeating steps when discrepancies occur and by automatic reasonableness checks on the computations.

Since parallel operation is very expensive, a more economic system is to have the standby system engaged in "production" type or "off-line" computing while in the standby state. In this arrangement a failure in the main computer must initiate standby programs in the standby computer. The amount of data which must be turned over to the standby computer depends on the application. Whether turnover can occur at all depends on the type of failure and the special features of the hardware which is available to make the turnover. Some of these features include timers which automatically set an interrupt or external signal if not periodically reset ("watchdog timers"), interrupts triggered by power failure which allow some 10 ms of computing time before complete failure, and interrupts (from special equipment) which require a predetermined response and which otherwise will indicate failure ("deadman"). Clearly the effectiveness of these hardware features depends on the kind of failure which takes place. A transient pulse, for example, could occur without triggering any of the above, but could nevertheless affect the accuracy of computation. As a matter of fact, the effect of transients may not be discovered until recovery is impossible.

The problem of program recovery and fault discovery are closely related. We have just considered recovery from computing errors which may be detected by examination of the output data. Some of these errors may be prevented by periodic health checks of the system. The amount of checking which can be done is, of course, a function of the time available between operational processes. In most systems, however, at least some time must be reserved for this checking. For this purpose a background diagnostic can be devised which, in effect, occupies the system completely during

8.2.1 On-Line Considerations (Continued)

what would otherwise be a period of idleness. On the other hand, it may be necessary to insure that sufficient diagnostic checking is done by giving the diagnostic program a priority and initiating it by an interrupt from the clock or special counter. In systems where the basic operational cycle is based on a well-defined programming loop, the diagnostic program must be handled just as any other function in the loop.

The scope of the diagnostics can vary considerably, but most often they may be confined to testing communications and status of peripheral devices. In multi-computer systems this may include cross-checking between the computers. Where multi-computer communications are involved, it is often useful to transmit data from a dummy calculation with each communication. Thus the transmitting computer might perform a carefully selected set of instructions which exercise all of the circuits and transfer a coded result along with the communication. The receiving computer performs the same exercise and compares this against the one received and the pattern which is prestored. A discrepancy indicates failure either in the transmission or in the computation unit of one of the computers. Further diagnostic checking is called for, and this might be handled in a special routine for the purpose.

The chief purpose of the diagnostic health check is to discover failure at the earliest possible time and,hopefully, to take corrective actions before any data is lost. Some failures may affect the data, but not the running programs. These failures are most likely to be discovered by reasonableness checks on the data. Other failures may cause certain elements of equipment to stall. These are most likely to be discovered by periodic health checks. Failures which cause the program to stall obviously cannot be discovered by programming methods. To overcome this contingency, hardware features such as the watchdog timers and deadman devices as discussed previously are employed.

8.2.1 On-Line Considerations (Continued)

The totality of the above considerations will be described and their implications be cited with respect to the design of the Advanced NTDS. A study point will be the present system which has many of these characteristics but lacks the automaticity which may be desired.

8.2.2 Executives for Multi-Computer Time Sharing

The recent trend toward on-line data processing systems operating in quasi-real-time has given rise to an increased emphasis on basic system organization. It has been recognized that careful consideration in the design of a suitable control system will frequently lead to more fruitful results in terms of speed and efficiency than will excessive expenditures for minor improvements in equipment.

Two originally distinct techniques have been proposed to improve computer organization and use. On the one hand there has been the concept of multi-programming or time sharing of a given computer by several programs which operate concurrently. On the other hand there has been the multi-processing concept in which true simultaneity of operation has been achieved through the use of distinct but inter-connected computers. Since command and control systems do involve multi-computers (NMCS, NTDS, OPCON future 473L and 465L) executive control of the system is important.

Historically speaking, the former approach has been adopted by those who have been concerned primarily with efficient use and servicing of human operators, and the latter approach by those more concerned with efficient use of system equipment. This had led to the emergence of divergent philosophies of executive control.

Modern usage, however, indicates that no fundamental incompatibility exists between the two techniques. A multi-processor installation in which individual computers are multi-programmed is now known to be feasible. It is still true that such systems are generally regarded as either a multi-programmed "computer" having more than one "logic unit" or as a multi-

8.2.2 Executives for Multi-Computer Time Sharing (Continued)

computer system in which one physical "shell" can contain more than one "computer".

This distinction, however, becomes entirely psychological once it is acknowledged that the true objective in either approach is optimization of the total man/machine system. The placing of emphasis is equivalent to defining "optimization", and is determined dynamically by the operational requirements of each individual job.

Informatics Inc. is currently engaged in the development of just such an Executive Control System under contract to the Information Processing Laboratory, Rome Air Development Center. The primary purpose is to develop techniques for command and control. In this particular project the situation is complicated by the fact that the equipment configuration on which the system is designed to operate consists of an assortment of devices produced by different manufacturers representing different periods in time. This configuration, moreover, is regarded as the first phase of an evolutionary installation. It is required, therefore, that the system should be, to the greatest extent practical, independent of the specific equipment and configuration.

To achieve this end, the Executive Control System (ECS) is divided into two major levels, as shown in Figure 8-1. An Administrative Control Program (ACP) is resident in the executive computer (a CDC 16-A). ACP is able to distinguish between various categories of equipment but is not concerned with their individual characteristics. A set of Local Control Programs (LCPs) are also provided, one for each programmable unit of the complex. The LCPs are responsible for requesting program and data transfers to and from the unit, but cannot initiate a data transfer to an external device.

LCP is also responsible for exercising any required control over purely internal functions of each computer. Every computer in the complex

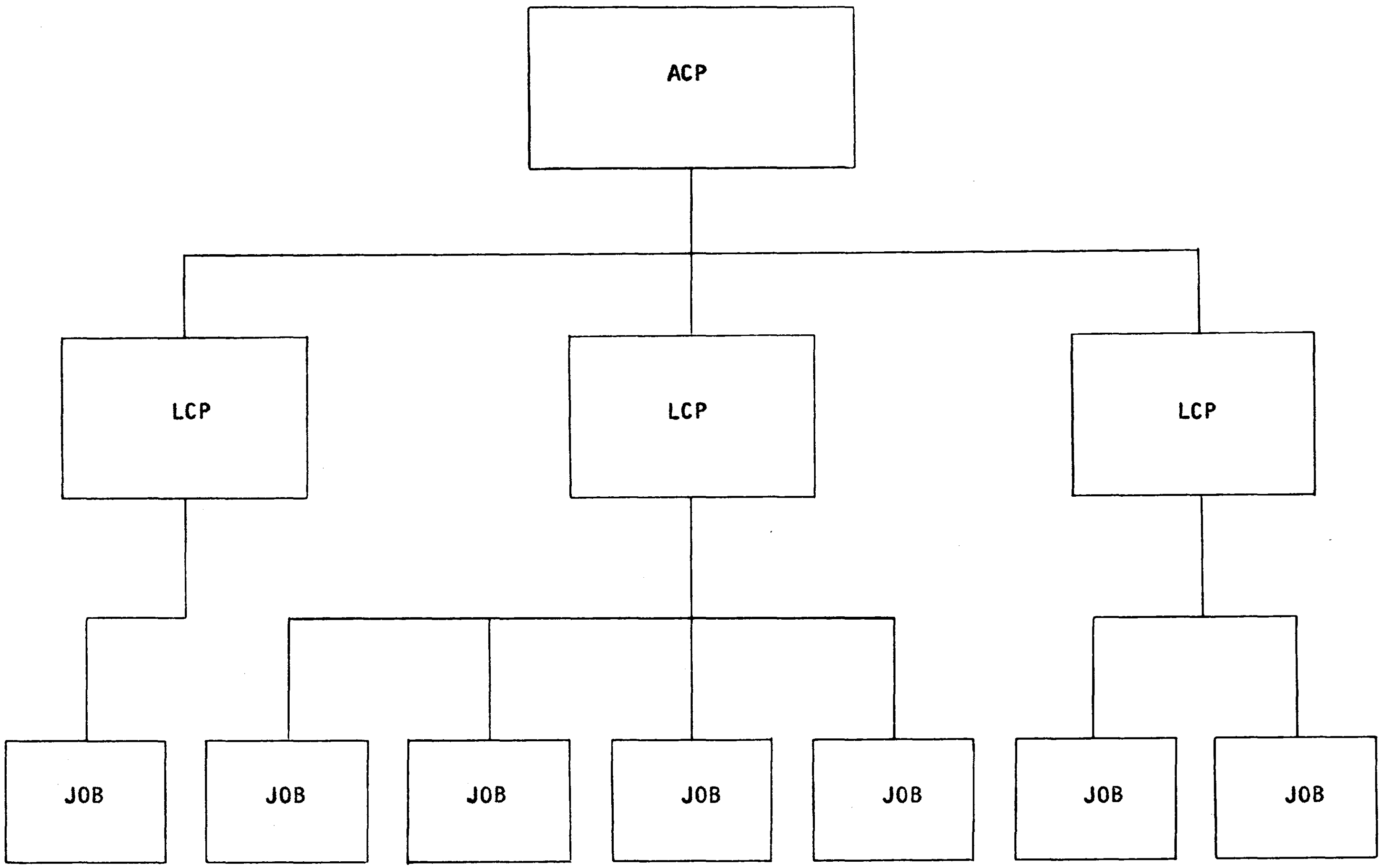

FIGURE 8-1

EXECUTIVE CONTROL SYSTEM HIERARCHY

8.2.2 Executives for Multi-Computer Time Sharing (Continued)

will be multi-programmed, at least to the extent of being time shared by one job program and its own LCP. Where more than one job program may be operating within a computer, the complexity of that LCP will be greater but the ACP will not be directly affected.

Executive programs for multi-computer systems have been developed for the RW-400 computer originally intended for the Air Force 117L program, and for the OPCON Center for CINCPAC. The latter utilizes approximately five CDC-1604 and two CDC-160 computers.

One of the most prominent executive control programs for time sharing has been that developed by SDC on the ARPA project. It emphasizes the use of the computer "simultaneously" by many analysts on an on-line basis.

8.3 PROGRAMMING MANAGEMENT

Utility and executive functions were discussed in the first three parts of Section 8. It will also be pertinent to this study project to structure the programming environment within which large real-time systems evolve, and to supply an insight into the problems that must be considered. Also it will be of help to system planners to have at their disposal some yardsticks by which measurements can be made regarding size and time requirements of the job itself.

Examples of large systems which apply to such a consideration are 473L, 465L, SAGE, NTDS, OPCON and NMCS. Hence, it will be desirable to discuss the programming management with such groups. A consequence of this investigation will be management recommendations, examples of which are (2) and (3).

In addition, tables will be supplied reflecting pertinent parameters measuring the programming process. A start has been made in doing this and it is possible to obtain data for large systems such as shown in Figure 8-2. It is from this kind of information that guidelines can be deduced. For example, figures relating to the cost per checked-

8.3 PROGRAMMING MANAGEMENT (Continued)

out instruction are useful. These figures generally range in the $10-$15 range but this depends on the amount of system design and analysis included. Maj. Gen. Terhune, Commander of ESD, USAF, recently made statements that Air Force L programs costs for programming is $32 per instruction. He also said that costs increase according to the square of the number of instructions.

Calendar Period - 24 months

Total Technical Personnel, Man/Month	2,032
Total Computer Hours	6,010
No. Instructions Developed	373,500
Pages of Final Documentation	4,500
Computer Time Used/Programmed Instruction	.965 min.
Computer Time Used/Man Months	2.96 hours
Programmed Instructions Yielding One Page of Final Documentation	85.6
Prog. Instruction Yield per Man/Month	184.0
Final Documentation Pages/Man/Month	2.1
No. of Basic Program Systems	13.0
No. of Major Computer Installations Used	14.0
No. of Geographic Locations Used	8.0

Computers Used . . . 7090, 1604, 1401, 160

Program Language Used . . . JOVIAL and Machine Language

Total Pages of Interim Documentation	20,000

FIGURE 8-2

STATISTICS FOR IMPLEMENTING ONE COMMAND AND CONTROL SYSTEM

REFERENCES TO SECTION 8

1. "An Approach to On-Line Processing", S. Blumenthal, DATAMATION, June 1961.

2. "Management Techniques for Real-Time Computer Programming" T. Holdiman, JOURNAL OF THE ACM, July 1962.

3. "Programming On-Line Systems", W. L. Frank, et al., DATAMATION, May and June 1963.

9. ADVANCED USAGE TECHNIQUES

A number of interesting and promising techniques of computer usage are, as yet, in the experimental stage. Certain of these, while showing no current applicability to command and control technology, are promising for future use.

9.1 LEARNING AND SELF-DIAGNOSING TECHNIQUES

The techniques of learning and self-diagnosis, which are related, can be said to be in the experimental stage today. Two approaches distinguish the attempts in this direction: first is the building of special-purpose machines aimed at having learning capabilities. Such machines fall more or less in the classical category of "robots" (1). Second are attempts to program general purpose machines to exhibit structures of learning (2).

In particular the work of Newell, Shaw, and Simon at the RAND Corporation, Minsky, Selfridge, and others at MIT, and of investigators at the Bell Laboratories and the System Development Corporation has received notice in the technical and secular press. Most work of investigators seeking to build or to program a machine exhibiting learning has been addressed to the limited areas of game playing and theory, pattern and sound (visual and audio) recognition, including speech, and simulation of various simple kinds of human or animal behavior.

It is well to distinguish between those devices which are essentially sensors (such as the IBM "Shoebox," designed to translate the spoken Arabic numerals zero through nine into unique bit patterns) and those which involve self-generation of response patterns. The latter are intended to be the "learning" elements in the system.

Wooldridge (5) has suggested that the establishment

9.1 LEARNING AND SELF-DIAGNOSING TECHNIQUES (Continued)

of permanent, closed neuron chains or loops in the human brain is the basic mechanism of pattern recognition, memory, and, hence, of learning. He further suggests that such mechanisms are constructible in electronic machinery, but that the complexity of such circuits is beyond present-day technology and economy. Some of the attempts to build special-purpose machinery make use of analogs of the neuron chain, while others do not. The structure of simulation programs on general purpose machines, however, does not follow such a pattern, due to the basic structure of the digital computer.

The ultimate usefulness of simple learning has obvious future application in command and control systems, since the command problem is greatly simplified by ability to command a system with learning abilities.

9.2 HEURISTIC PROBLEM SOLVING

Heuristic problem solving is concerned with the information processes of complex intellectual behavior-thinking. Various attempts have been made to program certain of these processes on digital computers. To do such programming, much thought has been addressed to understanding this type of behavior-thinking process in human thinking. To date the understanding is incomplete and disjointed.

So far, no programs have been developed which give the machine a capability to handle problems of significant intellectual content.

One key concept in heuristic programming is effective search reduction. Hence such concepts as the content-addressable memory are central to heuristic problem solving. The solution spaces for any but the most trivial of such problems are extremely large, and solution algorithms are not known for most problems of intellectual interest.

Heuristics are rule-of-thumb tricks and strategies which may guide search of the solution space into areas fertile with potential

9.2 HEURISTIC PROBLEM SOLVING (Continued)

solutions, ignoring areas which are relatively sterile.

In spite of the magnitude of the general task, heuristic programs have been written for many tasks on general-purpose computers. These include: programs which prove theorems in Euclidean geometry and symbolic logic, which do indefinite integration of complex integrands, which play checkers, chess, and other games, balance assembly lines, select stock portfolios, and so on.

Certain of the approaches of applied mathematics have Heuristic content, such as the Newton-Raphson and related iteration methods, approximate solutions of various kinds, relaxation methods of solution, and other related search-reducing approaches.

The application of Heuristic problem-solving methods to command and control systems will undoubtedly be of importance in the future.

9.3 LANGUAGE TRANSLATION

The applicability of language translation to command and control systems is difficult to foresee. However, some of the work involved in computer-programmed language translation is closely related to the two previous subjects, so that the inclusion of the topic here is not unrelated. Further, some techniques involved in programs related to language translation are useful in command and control systems (7).

While language translation efforts using computers have shown remarkable successes, they are by no means economical. The cost of preparing input for computer translation still exceeds the total cost of first-rate professional translation by people. Computers will begin to match the costs of human translation only with the development of a successful high-speed optical print reader.

The machine approach to language translation varies, but most programs are constructed to operate somewhat in the following order:

9.3 LANGUAGE TRANSLATION (Continued)

1. Read a block of input text.
2. Dictionary look-up of each word.
3. List homographs and words missing from dictionary.
4. Assign grammar code to above words where possible.
5. Syntactic analysis of sentences.
6. Resolve multiple meanings, choosing correct equivalents.
7. Output translated text.

While machine translations are, by and large, not elegant at the present state of the art, they often yield a surprisingly complete translation.

It is in the areas of those routines which perform the dictionary function and the syntetic analysis, and those which resolve multiple meanings that one may expect to find techniques applicable in command and control.

Work in translation of languages, notable Russian to English, is being done at a number of locations, and is quite fully reported in the technical literature.

9.4 APPLICATIONS IN FUTURE COMMAND AND CONTROL SYSTEMS

It will be many years before most of the learning, heuristic, and language translation techniques are useful in everyday command and control problems; they are essentially research techniques at present, with limited practical usage. However, it is important for the work proposed to understand these techniques and extrapolate them 2-5 years in the future or longer. Also, it is important to realize that many aspects of these systems can become important for practical systems even though the technique as now conceived and developed cannot be. For example, elaborate diagnostic programs, assemblers, compilers, etc. in the future may well be based on the idea that the program performs a self-improvement function or is to a degree introspective. These capabilities, while modest by research standards, may be efficient and practical.

REFERENCES TO SECTION 9

1. The Perceptron - An Experiment in Learning, W. E. Bushor, ELECTRONICS, 33, pp 56-59, July 22, 1960.
2. A Pattern Recognition Program that Generates, Evaluates, and Adjusts its Own Operators, L. Uhr and C. Vossler, PROCEEDINGS, W.J.C.C., Los Angeles, 1961.
3. Advanced Computer Applications, W. F. Bauer, D. L. Gerlogh, and J. W. Hranholm, PROCEEDINGS of the IRE, 49,1, January 1961.
4. Principes d'Incertitude de la Perception et Machines Philosophiques, A. A. Moles, CYBERNETICS, 2,1, pp 51-57, 1959.
5. The Machinery of the Brain, D. Wooldridge, McGraw-Hill Book Co., New York, 1963.
6. Attitudes Toward Intelligent Machines, P. Armer, The Rand Corporation, Santa Monica, P-2114, September 30, 1960.
7. 705 Indexes Dead Sea Scrolls, COMPUTING NEWS 66,3, April 15, 1958.

10. COMMENTS ON TWO NAVY SYSTEMS

10.1 FUNCTIONS AND REQUIREMENTS FOR NAVAL TACTICAL DATA SYSTEMS

The existing Naval Tactical Data System is the most sophisticated Tactical Command and Control System in operation today. It includes not only a multi-computer system with associated displays, storage, and input/output equipment, but also an integrated multi-ship communication system providing automatic digital data transmission of information stored in the computers on one ship to those of another ship. In addition the system is closely integrated with the Air Tactical Data System and the Marine Tactical Data System to provide an integrated command capability for ground, sea, and air forces. It is essential that future Naval Tactical Data Systems of the 1970 and 1980 era maintain these capabilities for a multi-computer and multi-unit operation. The use of a multi-computer system on each ship helps alleviate the logistic problem and provides a much greater assurance of the proper functioning of critical operations if one machine fails or malfunctions. With the proper programming precautions and an adequate back-up, the remaining computers can assume the critical tasks previously being handled by any computer if that computer fails. A multi-computer system also permits adjusting the computer capability to the requirements of any size or category of vessel. The ability of different ships, aircraft, and ground forces to interchange tactical data is essential to the proper operation of large combined task forces. This problem is more critical to the Navy than to any other service because of its wide diveristy of responsibilities and types of forces.

The present Naval Tactical Data System has been programmed primarily to handle air defense operations to date. However, program modules are being proposed for ASW operations. The operations and functions required in executing most of the tactical responsibilities of naval forces will be proved by operational experiance on the present NTDS system, prior to the completion of the planning of the 1970 - 1980 tactical data system.

10.1 FUNCTIONS AND REQUIREMENTS FOR NAVAL TACTICAL DATA SYSTEMS (Cont'd)

The future Naval Tactical Data System should handle all the operations and functions planned for the current NTDS system, but with a greater capability and flexibility and with reduced equipment size and weight. On many classes of ships, the available space limits the amount of equipment of existing types that can be used. Integrated circuits and other microminiaturization techniques will permit far greater capability in a less space to greatly enhance the overall tactical data system - particularly on the smaller ships such as destroyers and destroyer escorts. Reliability, maintainability, and serviceability will be extremely important in future naval tactical data systems because of the critical operational requirements imposed on the system and the difficulty of training and maintaining competent technicians. With the increasing use of atomic power on naval vessels, and the consequent significant extensions in the time away from home bases, reductions in logistics support requirements will be of crucial importance.

Finally, it is very likely that the future Naval Tactical Data System for the 1970 - 1980 era will be the center of a completely integrated computer and data processing system. The various electronic subsystems, such as fire control, search radar, sonar, and communications, will be integrated under control direction of the ships offices through the tactical data system. Integrated circuits, sophisticated interrupt techniques, high-speed large-capacity internal storage and mass memories will permit tieing computers in the individual subsystems directly into the central tactical data system and into other subsystems, with the necessary digital data being transferred automatically from one to another. With this type of system, routine manual operations that are error-prone will be minimized, and the necessary digital data will be provided automatically and in a timely manner for support of the human decision-making function.

To realize these requirements and capabilities in a future naval tactical data system will require the use of many of the new components

10.1 FUNCTIONS AND REQUIREMENTS FOR NAVAL TACTICAL DATA SYSTEMS (Cont'd)

and techniques described in other sections of this proposal. However, it is most important that only those techniques and components be used that will be both feasible and available in the required time frame with proved performance, reliability, and maintainability. Therefore, it is essential not only that the results of this study should provide sufficient information and insight into the different components and techniques to permit a determination of their feasibility and timeliness, but also that proper criteria be developed to aid in the selection of optimum components, techniques or processes for each given function or requirement. It will be necessary to provide the Navy planners with adequate guidelines and criteria to aid them in determining which components, techniques, or processes will provide the best performance and reliability for the permissable costs, size, and weight. These guidelines or criteria should permit the proper tradeoffs to be determined between speed and cost and between performance characteristics (e.g. storage capacity, speed, logical operations, etc.) and operational characteristics (e.g. ruggedness, maintainability, reliability, etc.).

10.2 NATIONAL EMERGENCY COMMAND POST AFLOAT (NECPA)

The NECPA is a command control system application that is of primary interest to the Navy. It is to provide certain national command post capabilities for the President and the Joint Chiefs of Staff on an emergency basis. The functional requirements of this mission have already been refined by the Joint Cheifs of Staff and have been partially implemented for other emergency sites. However, it is clear that the equipment and programming of these tasks has to be modified to meet NECPA environmental conditions. A major problem is the preparation of programs existing on the CDC 1604A computer for operation on the NTDS computer such as CP667, CP642B, UNIVAC 1218, or TRW-130 (AN/UYK-1).

There are essentially two aspects to this problem. The first is the brute force translation from one computer program to the same program

10.2 NATIONAL EMERGENCY COMMAND POST AFLOAT (NECPA) (Continued)

on another computer. The solution is not easy because JOVIAL has been used to implement part of the sites and there is no equivalent system for programming the tasks on the NTDS computers. The NTDS languages of CS-1 and NELIAC are not directly related to JOVIAL.

The second aspect of the problem is a study of the NTDS standards that have to be met to determine which standards should be modified or at least extended to meet mission requirements. The best illustration of this problem is in the inter-computer communication which utilize two interfaces. The "slow interface" is the NTDS interface which is slow by current standards for this function. Also available is the "fast interface" which is non-NTDS and is available at no extra cost. There is a difference in speed of approximately 4 to 1 between the two interfaces. In addition, new equipment has to be developed to meet other NECPA requirements, and the problem arises as to whether NTDS interface standards should be recommended for these new equipments. Implicit in the revision of functional NTDS standards would be the cost and maintanance aspects which are not trivial.

11. PROJECT PLAN

This section of our proposal includes the work statement, the program schedule, the program organization and management.

11.1 WORK STATEMENT AND DELIVERY SCHEDULE

Informatics Inc. proposes to supply the following services to implement the subtasks 2 and 3 of the project to provide guidance to planners of advanced Navy Command and Control Systems. The items marked with an asterisk will be excluded if awarded subtask 2 only.

1. Participate with other subtask personnel in the development of a Study Approach Plan. Informatics personnel will travel to and remain in Washington, D. C. to accomplish this task.
2. Prepare an interim Project Plan to briefly describe the initial work, followed by a comprehensive Project Plan describing the technical job to be performed and flagging technical and administrative problems. Tasks will be described and detailed milestones will be established and schedules developed. The contents of interim documentation will be described. The Project Plan will be updated on a monthly basis.
3. Identify, analyze and evaluate current and projected technology applicable to future Navy command and control systems in order to provide Navy planners with a comprehensive documentation of information on available technology to form a basis for their planning decisions. Technical areas covered will include:

a.) Input/output and displays,
b.) Memory techniques,
c.) Computer organization,
d.) Hardware techniques,
e.) Programming,
f.) Advanced Usage techniques,
g.) Miscellaneous areas of importance to data processing in command and control systems.

11.1 WORK STATEMENT AND DELIVERY SCHEDULE

Items 3 a.) and 3 b.) will cover both uses and systems, and hardware. A list of criteria will be developed to measure the applicability of the new developments to requirements of the system.

** 4. Insure study integration by:

a.) Appropriately communicating with project members of other subtasks to insure integration of tasks with the total project effort.

* b.) Taking into consideration the various technical data developed in subtasks 1 and 2 (viz, Development of General Systems Requirements and Evaluation of Applicability and Availability of Current and Projected Technology) concerning various approaches to the system design.

In this study integration, alternate approaches will be identified, analyzed, evaluated, and documented for use in command and control system design. The relative merits of the approaches will be assessed, to guide the planner on several approaches that he can further develop and select from in preparing the system's Technical Development Plan.

* 5. Develop a system design methodology for command and control systems appropriate to this project. Identify, analyze, and evaluate various techniques in system design methodology and make appropriate recommendation and develop suitable documentation. Discuss system simulation and methods of determining trade-offs.

6. Develop and produce presentations and documentation on an interim basis as well as for the completion of the project. These efforts will include:

a.) Monthly typewritten progress reports in 25 copies of each.

b.) Midway subtask reports covering work completed and including an outline of planned future work. These reports will be supplied for subtasks 2 and *3 approximately 6 months after authority to proceed is given. They will be submitted in 15 copies.

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* See Note at beginning of Work Statement.

**In the event of an award for subtask 2 only, this work statement item refers to coordination only, not the formal Study Integration task of the Request for Proposal.

11.1 WORK STATEMENT AND DELIVERY SCHEDULE

(Methodology Report)

c.) Final subtask report/covering the work performed in the evaluation of applicability and availability of current and projected technology, will be prepared in a draft form of 15 copies three weeks before the end of the contract. After approval by the Scientific Officer a final report will be prepared and submitted in 50 copies at the end of the contract.

* d.) Final Integrated Study Report in draft form in 15 copies 3 weeks prior to the end of the contract.

e.) Progress reports to document the effort in each technical area as that work is completed.

f.) Presentation of a final report material at least 2 weeks prior to the end of the contract, to consist of an oral briefing accomplished by visual material such as slides/filmstrip, or flip charts depending upon the size of audience.

g.) Presentations to planners groups to show the information of the Midway Subtask Report and three additional briefings. These will consist of oral presentations accompanied by visual material appropriate to the size of the audience. Informatics personnel will travel to Washington, D. C. to make these presentations and the presentation of 6 f.) above.

Informatics Inc. will assign suitable qualified personnel to this project as listed in Section 11.3. Substitutions by equally qualified personnel will only be made on agreement with the Scientific Officer.

11.2 WORK PLAN, MILESTONES AND SCHEDULES

Figure 11-1 shows the approach by Informatics Inc. and its subcontractor Hobbs Associates, to scheduling the tasks of the project. More detailed project plans will be generated shortly after the initiation of the project as shown on the chart. The Project Control System used by Informatics Inc is discussed in Section 11-2.

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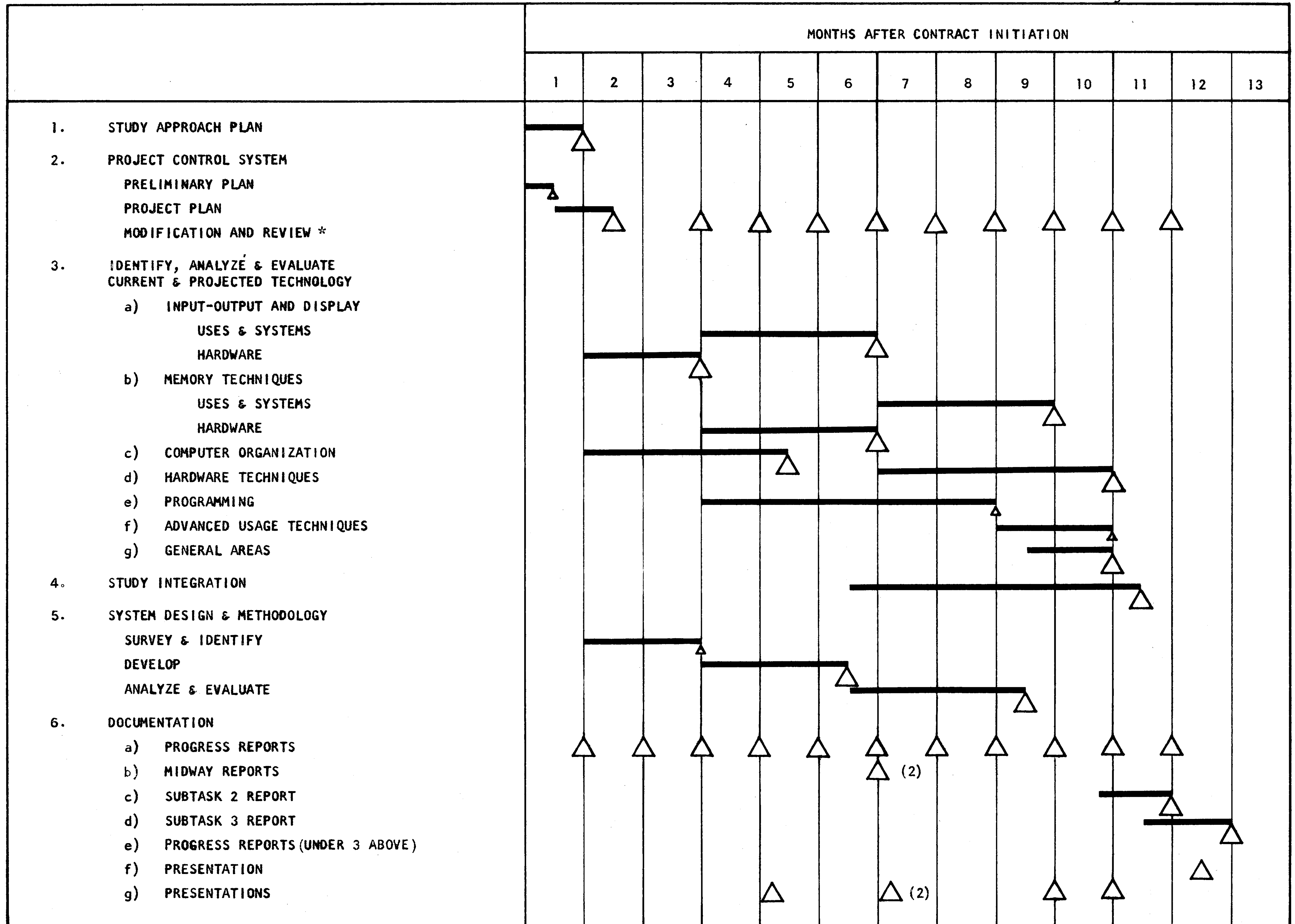
* See Note at beginning of Work Statement.



* Internal Control Report

△ Documentation Report

FIGURE 11-1

PROJECT SCHEDULE

11.2 WORK PLAN, MILESTONES AND SCHEDULES (Continued)

Referring to Figure 11-1 the first item to be accomplished is the participation with other subtask personnel in the development of a study approach plan. This work will take place in Washington, D. C. as specified in the RFQ and will occupy the efforts of the key members of the project team. Also, as mentioned above, one of the first tasks is to develop a Project Plan.

Following this, the main technical effort of the project begins. Each bar, representing an area of technical activity, will consist normally of the following efforts:

1. Technologies and techniques will be identified by literature survey and by discussions with individuals.
2. The various technologies and techniques will be analyzed and fully understood to develop the appropriate facts for evaluation.
3. The technical factor will then be evaluated and their applicability determined and recommendations made.
4. The technical area will be documented.

We would like to stress the last point -- the fact that following each effort in a technical area the work is documented so that there is a continuity of documentation throughout the project and no vital information is delayed. This further enables project personnel to maintain a continuous focus on the principal end product -- the final documentation for the system designers' use.

Each of the task efforts as shown in the chart will be manned by 2 - 4 project personnel. Rather than have one person worry about memory techniques, for example, for an 11 month period, it will be advantageous to work in teams of 2 - 4 people to appropriately exchange ideas and to coordinate efforts.

In general, the Project Plan calls for the examination of certain hardware techniques, the integration of these hardware techniques into systems, and then a full examination of their potential usefulness. The

11.2 WORK PLAN, MILESTONES AND SCHEDULES (Continued)

hardware activities, it will be noted, are spaced throughout the project so that the project team members emphasizing hardware can go from one technical area to the next.

11.3 PROJECT CONTROL SYSTEM

Informatics Inc. utilizes a comprehensive Project Control System as a strict policy. The Project Manager must, after no longer than 6 weeks following the initiation of a project, develop a comprehensive Project Plan. Prior to this, to insure efficient work in the early weeks of the project, a temporary Project Plan is issued, briefly describing the work.

The Project Plan presents briefly the technical job to be performed and specifically refers to any technical or administrative problems which are likely to arise. Tasks are described and teams and project personnel are assigned to the task. Detailed milestones and schedules are developed. Contents of interim documentation are described. Dollar expenditures are planned for each task and subtask. Charts are presented showing the rate of direct labor expenditure and the rate of other direct cost expenditure. The Project Plan is a deliverable contract item but the cost information will be omitted.

Throughout the life of the project the Project Plan is updated on a monthly basis. The actual expenditures are presented on the charts and compared with the planned expenditures. Each month the Project Manager and key project personnel make a verbal presentation to Informatics management on the progress of the work.

The Project Control System, carefully conceived and diligently carried out, insures that project efforts will be efficient and economical. There is no substitute to this approach.

11.4 THE PROJECT TEAM

The project team members and their technical areas of contribution to the project are as shown in Figure 11-2. Dr. Walter F. Bauer is

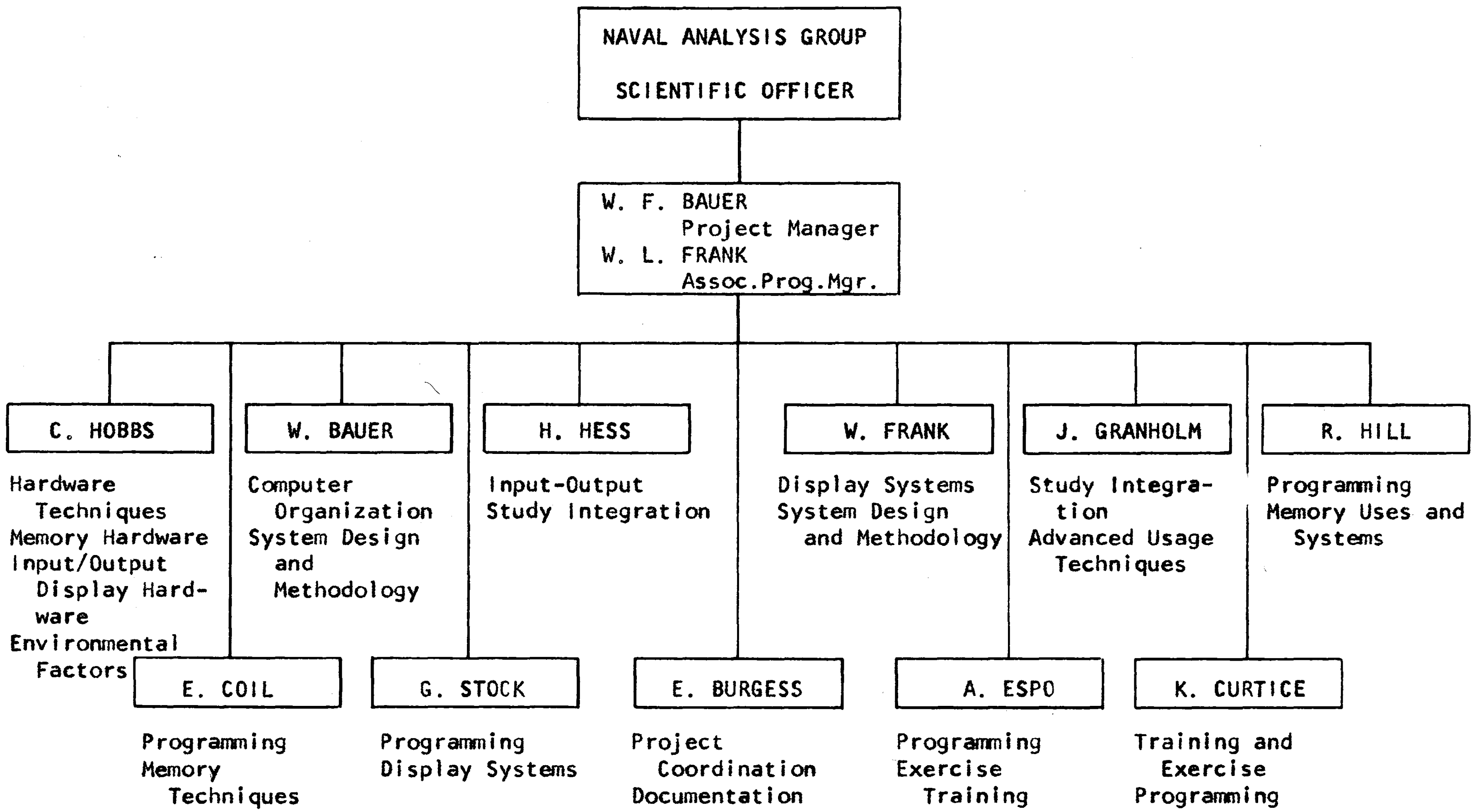


FIGURE 11-2

PROJECT ORGANIZATION

11.4 THE PROJECT TEAM (Continued)

designated the Project Manager. We recognize the unusualness of this approach since he is the President of Informatics Inc. However, the project is of great interest to him professionally and we believe that this assignment will insure the best administratively and technically coordinated approach. Dr. Bauer has a long list of qualifications for this job as described in Section 12.

Mr. Werner L. Frank is designated the Associate Project Manager, He likewise has had extensive experience which directly qualifies him for this task. For example, he was the Project Manager on a $500,000 System Design project for DODDAC which is now the National Military Command Support Center. His list of qualifications is likewise recorded in Section 12.

The chart shows proposed members including Dr. Bauer and Mr. Frank. It illustrates certain technical areas in which the personnel have special qualifications. These areas are the likely ones for assignment.

Of the group of 11 personnel shown, 6 have had over 12 years experience, each, in modern electronic computer systems, most of it advanced military weapons records experience. (Experience in punched card areas or general technical work is not counted.) The remaining 5 have had 4 - 10 years experience in modern large scale computer systems.

The proposed assignments and an estimate of the amount of time it is planned the project personnel will work on the study are as follows:

Dr. W. F. Bauer, Project Manager *	30%
Werner L. Frank, Associate Project Manager	100%
L. C. Hobbs, Hardware Techniques, Memory Hardware, Input/Output and Display Hardware, Environmental Factors	100%
H. Hess, Input/Output, Study Integration	100%
J. W. Granholm, Study Integration, Advanced Usage Techniques	70%

11.4 THE PROJECT TEAM (Continued)

R. H. Hill, Programming, Memory Uses and Systems	100%
E. A. Coil, Programming, Memory Techniques	100%
G. Stock, Programming, Display Systems	100%
E. Burgess, Project Coordination, Documentation, Presentations	70%
A. Espo, Programming, Training, Exercise	100%
K. Curtice, Training and Exercise, Programming	100%

* Note: If we are awarded Subtask 2 only, the percentage of time for Dr. Bauer will be negotiated.

12.0 CONTRACTOR QUALIFICATIONS

This section describes the qualifications of the companies involved, the qualifications of the project team as a group, and the qualifications of the individuals. It includes an extensive bibliography of the project team members as well as their formal biographical sketches.

12.1 INFORMATICS INC. AND HOBBS ASSOCIATES

Informatics Inc. was organized to provide systems design and analysis, consulting, and programming for systems involving stored program electronic digital computers. The background of the individuals and the current projects is such that the work is almost exclusively military. Advanced on-line, or real time, computer systems is the specialty.

Current total head count of Informatics Inc. is 45. Approximately 95% of the work is involved with the design and programming of on-line systems for military applications. This represents projects at the Goldstone Tracking Station, Jet Propulsion Laboratory, Pacific Missile Range, Manned Space Craft Center - Houston, National Military Command System Support Center - Washington, and the Rome Air Development Center as major efforts. The remaining projects are in programming systems work and diagnostic programs for computers. The background of key Informatics' personnel as well as these specific projects explains the interest and qualifications of the company for this project.

Hobbs Associates is a hardware and systems engineering firm devoted to the study, evaluation, and design of digital equipment and systems. Hobbs Associates has two employees and three professional affiliates. Specific areas of interest, experience, and capability include:

12.1 INFORMATICS INC. AND HOBBS ASSOCIATES (Continued)

Digital equipment and systems,
Special purpose and general purpose computer organization and design,
Data acquisition systems,
Input and output subsystems
Message composers and data editing equipment
Display subsystems
Mass Storage
Digital hardware techniques, and
Command and Control Systems.

Since Hobbs Associates does not manufacture equipment, they are in a unique position to make technical studies and provide recommendations without the danger of their being influenced by vested interest in specific techniques or types of hardware.

12.2 TEAM QUALIFICATIONS

As mentioned in Section 11.3, of the 11 proposed members of the project team, 6 have over 12 years experience, each, in modern electronic computer systems. The remaining have had 4 - 10 years experience. The group has the following qualifications:

1. They are experts in on-line computer systems -- computer systems which interface with extensive instrumentation on a real time basis.
2. They have extensive experience with military systems especially command and control.
3. They know technology and techniques and are acquainted in detail with the data processing industry, its products and its people.
4. They have published and presented numerous papers in the technical areas of interest. The bibliographic list for the project team is presented at the end of this section (Section 12.4).

12.2 TEAM QUALIFICATIONS (Continued)

5. They have established an approach to the various task areas as shown by this technical proposal.

Figure 12-1 shows the specific contact which team members have had with large scale military systems related to or similar to the Navy Tactical Command and Control Systems. The following is a very brief description of each of these systems.

NMCSSC - DODDAC. NMCSSC (National Military Command System Support Center, successor to DODDAC) is responsible for providing basic information on damage assessment and the status of forces and resources during peace time as well as during war time for friendly, enemy and neutral forces. It is the highest level command and control system being planned in the country.

NTDS. The Naval Tactical Data System is the present system for tactical command and control. It complements or is related to many other systems such as the Marine Tactical Data System and other airborne and shipborne systems.

PMR - RTDHS. The PMR Real Time Data Handling System is an important system for consideration here since it employs the NTDS computers and handles sensor information on real time basis. It therefore includes many of the technologies of interest in command and control.

ARTOC. The Army Tactical Operations Center is the central command post of the U. S. Field Army which will be implemented by communications, computers and displays.

FIELDATA. This is the general system of communications and computing facilities for the Field Army and includes such functions as intelligence data handling, weapon control, command, and battlefield surveillance.

	NMCS-DODDAC	NTDS	PMR-RTDHS	FIELDATA	ARTOC	SSI of 117L	AJCC	NECPA	ASW	473L	496L	SAGE	NAVIGATIONAL SATELLITE
BAUER	x		x			x	x			x			x
FRANK	x					x	x	x		x			
HOBBS		x			x	x			x	x	x		
GRANHOLM													x
HILL			x			x							
HESS	x		x	x			x	x					
COIL										x			
STOCK	x					x				x			
ESPO			x									x	
CURTICE	x											x	
BURGESS						x*							

* SS E, F, G & I

FIGURE 12-1

CONTACT OF TEAM MEMBERS WITH LARGE-SCALE MILITARY SYSTEMS

12.2 TEAM QUALIFICATIONS (Continued)

SS1 - 117L. Subsystem 1 of Air Force System 117L was a very large scale ground-based data handling system. It was designed to extensively process photographic and electro magnetic intelligence data with the use of computers and advanced man/machine communication techniques.

AJCC. The Alternate Joint Command Center (old name) is the hardened installation which provides the alternate command area for the Joint Chiefs of Staff. In other words, it is a national emergency command post. Project personnel have been present in this location during atomic coordination exercises.

NECPA. The National Emergency Command Post Afloat is another national emergency operation for the Joint Chiefs of Staff and the President. It is a shipborne system.

ASW. Anti-submarine Warfare System for Seahawk Destroyer class is the area referred to. This includes surveillance and weapons control functions.

473L. This is the system for the Air Force Command Post. This is currently implemented by 1401 computers and extensive console displays.

496L. This is the Air Force system frequently referred to as "Spacetrack." It is an on-line surveillance system to keep track, in real time, of the many objects orbiting in space to determine whether a threat exists and the nature of the threat.

SAGE. This was the nation's first extensive computerized Air Defense System.

Navigational Satellite. This is the system which utilizes the measurement of doppler signals from an orbiting satellite to determine position. It is planned for extensive use on all combat ships of the U. S. Navy. It is an extensive on-line, computerized

12.2 TEAM QUALIFICATIONS (Continued)

system which involves processing of information from sensors and inertial navigation systems as well as the satellite information to obtain highly accurate positional information.

12.3 INDIVIDUAL QUALIFICATIONS

The individual qualifications of the team members are summarized in Figure 12-2. Various technical areas are listed there which are of importance to the project work.

The following paragraphs describe in more detail the qualifications of the various individual project team members.

W. F. Bauer

1. Dr. Bauer has been an invited speaker on advanced computer organizations at the 1959 and 1961 Joint Computer Conferences. He has given an invited address on "Military Command: A Challenge for Information Processing" at the 1962 National meeting of the Association for Computing Machinery and has given a similar talk at a meeting of the American Ordnance Association in the Pentagon to a number of high ranking officers. This paper was published on Computers and Automation in April, 1963.

2. He has organized a Symposium on Advanced Computer Organization for the IFIP-62 Conference in Munich, Germany, in 1962. His trip there was sponsored by the Office of Naval Research.

3. He has published a large number of papers in the fields of computer design, computer organization and military systems. These papers are listed in the bibliography.

4. He has been the Project Manager of a $2,000,000 project involving computers and on-line displays for DODDAC (NMCSSC). This involved systems work as well as hardware efforts.

	SYSTEM MANAGEMENT	INTELLIGENCE DATA HANDLING	COMMAND AND CONTROL FUNCTIONS & REQUIREMENTS	QUERY TECHNIQUES	SENSORS AND VEHICLE TRACKING	FILE STORAGE AND DESIGN	ON-LINE PROGRAMMING	COMMUNICATIONS	SYSTEM DESIGN	SYSTEM OPERATION AND ENVIRONMENT	DISPLAYS
BAUER	x	x	x		x			x	x		x
FRANK	x	x	x	x	x	x	x	x	x	x	x
HOBBS	x	x	x			x			x		x
GRANHOLM	x				x		x	x	x		
HILL		x			x	x	x	x		x	
HESS		x	x		x	x	x	x		x	x
COIL			x	x			x				
STOCK		x	x	x		x	x				x
ESPO							x	x			
CURTICE							x				
BURGESS		x	x		x						

FIGURE 12-2

SUMMARY OF QUALIFICATIONS OF PROJECT TEAM MEMBERS

12.3 INDIVIDUAL QUALIFICATIONS (Continued)

5. He has supervised projects such as a radar data handling system at the Atlantic Missile Range, instrumentation data handling system at the Pacific Missile Range, analysis and programming for navigational satellite systems, real time computer for automobile traffic control, and on-line monitoring system for Goldstone Tracking Station.

W. L. Frank

1. Mr. Frank was the Project Manager on the $500,000 System Design project for the NMCSSC (formerly DODDAC). This involved aspects of hardware design, system usage and systems analysis for a large-scale system involving communications, mass memory file storage, multi-computers and on-line displays.

2. He has been a Project Manager on a number of display activities for the NMCSSC and DODDAC. These include such areas as the development of a programming system for the displays. It also includes assistance to NMCSSC on an evaluation of a large number of on-line displays for potential use and recommendations to NMCSSC.

3. He is familiar in detail with such systems and technical areas as the following: NMCSSC, NECPA, AJCC, Intelligence Data Handling, and Air Force system 473L.

4. He recently lead a team of Informatics personnel in the organization and writing of a paper on "Programming an On-Line System", one of the first definitive papers on the subject.

5. He is thoroughly grounded in advanced programming techniques, numerical analysis and military system functions and requirements.

L. C. Hobbs

1. Mr. Hobbs has 15 years experience in systems engineering, digital computers and data processing.

12.3 INDIVIDUAL QUALIFICATIONS (Continued)

2. He was manager of Data Processing Engineering at the Aeronutronic Division of Ford Motor Co. which included responsibility for parts of the Army Tactical Operations Center program.

3. He has headed groups responsible for programming, systems analysis and systems specifications for small and medium data processing systems and was in charge of the logical design part of the first BIZMAC system.

4. Recent work has included a study of the Tactical Imagery Interpretation Facility, a study of the requirements for a central data processor for an ASW Data System for the SEAHAWK class destroyer, a study of the use of automatic data processing equipment for the prediction and recognition of potential tactical nuclear targets, a survey of the magnetic thin film memory field, the evaluation and selection of computers, and a study of mass memory requirements, devices and techniques.

5. He is a Lecturer in Engineering at UCLA having taught a course in Digital Computer and Systems Design, and is extremely active in the professional computing and data processing societies having been chairman of many technical committees in this field.

<u>H. Hess</u>

1. Mr. Hess was a key member of the DODDAC System Design team which is described above under W. L. Frank's qualifications. One of the assignments included requirements and systems analysis for the NECPA.

2. For the FIELDATA System of the U. S. Army he was a principal investigator and designer of the Intelligence Data Handling System portion. This included experience in communications and tactical data processing.

12.3 INDIVIDUAL QUALIFICATIONS (Continued)

3. He is one of the key members of a current project team at the Pacific Missile Range which involves the Q20B and 1218 computers of the NTDS type. It is an on-line system involving communications, multi-computers and displays for real time instrumentation data handling.

4. For the SATURN Stage 2 Automatic Checkout System he has been a principal consultant and contributed directly to the design of the on-line programming system for this project. In this role he was the consultant directly to the Project Manager of the 25 man team designing and programming the system.

5. His early experience dates back to 1949 when he was one of the first programmers in the country, at the Bureau of Census.

J. W. Granholm

1. Mr. Granholm's early experience dates back to the late 40s and early 50s when he was doing computation work with BOMARC and its predecessor, the GAPA Project.

2. He was the Project Manager on the extensive ground data handling system for jet aircraft data reduction. This included design and selection of the equipments, programming and operating the system.

3. He has been a principal consultant over a one-year period on the U. S. Navy Navigational Satellite program. This involved work at Ramo Wooldridge on systems design, systems analysis, selection of equipments, etc., to accomplish the navigational satellite data processing for shipboard work.

4. As a private consultant he has done extensive work on product design, product analysis and systems design for a large number of contracts and projects in the Los Angeles area.

R. H. Hill

1. Mr. Hill was Assistant Director of the Western Data

12.3 INDIVIDUAL QUALIFICATIONS (Continued)

Processing Center of UCLA. This was the organization that obtained the country's first IBM-709 computer. He was responsible for programming systems and taught courses in programming.

2. He has been a Project Manager at Informatics Inc. for programming and systems design work for the Goldstone Tracking Station multi-computer programming system and for the systems design and programming specification work for the extensive PMR-TRDHS instrumentation data handling system.

3. At Ramo-Wooldridge he supervised a number of programming groups in the design and implementation of diagnostic programs and conventional computer software.

4. He performed consulting work on computer design for two computers during their development and definition stage before the computers were announced. The two computers were the PB-400 of Packard Bell and a new computer by National Cash Register which is still not announced.

5. He was one of the three principal designers of a large scale computer at Ramo Wooldridge designated the RW-403, the design of which was completed but the project was shelved owing to realignment of the company.

E. Burgess

1. Mr. Burgess is an internationally known space technology and missile author responsible for some of the earliest technical papers on comsats and planetary probes.

2. He was responsible for clarifying concepts and preparing many presentations on the data handling systems of 117L with particular reference to control center operations and tracking station operations for both reconnaissance and early warning. He prepared a report on the effect of placing man in space and the development of spaceborne

12.3 INDIVIDUAL QUALIFICATIONS (Continued)

reconnaissance systems in the next 25 years.

3. He conceived and prepared for a major aerospace company a technical briefing to the Air Force ESD to outline the next 25 years in the aerospace control environment with particular emphasis on the problems of command and control and data handling.

4. At the request of the Air Force he conceived and produced a long technical presentation on the need for research and development in command and control systems.

5. As a consultant he surveyed the Deep Space Instrumentation Facility of the Jet Propulsion Laboratory with respect to operational requirements and instrumentation, and he prepared specifications for a deep space mission monitor console.

6. At a major aerospace company he was a proposal planning manager for space surveillance systems and multiple re-entry systems.

E. Coil

1. Mr. Coil's experience dates back to the National Security Agency and programming for those computers in 1951.

2. He has had extensive experience in designing diagnostic programs and in supervising groups preparing software for the Librascope computers.

3. He has had experience in matching computers and computer designs to various military command and control areas such as 473L.

4. He has been Project Manager of an Executive Control project for a multi-computer system for the Rome Air Development Center used to investigate software systems for command and control systems.

G. Stock

1. Mr. Stock has had experience in designing the programming

12.3 INDIVIDUAL QUALIFICATIONS (Continued)

system for the display system for DODDAC and NMCSSC. He is thoroughly grounded in all of the techniques of on-line consoles and of on-line group displays of the automatic film slide variety.

2. He had programming experience with the handling of intelligence data from photographic and electromagnetic sources.

3. He was one of the consultants to IBM on the work involved in the programming system for 473L Air Force Command Post displays.

4. He was an author, with W. L. Frank, of the paper "Programming On-Line Systems."

A. Espo

1. Mr. Espo has had extensive programming experience on SAGE and was responsible for the hardware simulation program involving 40,000 operating instructions.

2. He was also responsible for other programs for the control and auto recovery of the SAGE system.

3. He has been one of the key analysts on the PMR Real Time Data Handling System. He is thoroughly familiar, as a result, with the on-line systems programming efforts for the NTDS computers involved there.

K. Curtice

1. Mr. Curtice was a programmer-analyst and instructor on the SAGE system. He is familiar with the operation and maintenance of the programming system and became well grounded in the problems of displays and man/machine systems.

2. He has had recent experience in the display system usage and programming systems for the NMCSSC.

NOTE: Formal and detailed biographies and selection of papers published appear in subsequent sections.

12.4 BIBLIOGRAPHY OF TEAM MEMBERS

The following is a selection of the published papers and books by members of the project team.

W. F. Bauer

"An Introduction to High-Speed Computation"
W. F. Bauer
INDUSTRIAL MATHEMATICS SOCIETY JOURNAL
March 1952

"High-Speed Digital Computation in the Guidance Studies of an Automatic Interceptor"
W. F. Bauer and R. A. Beach
Symposium III on Simulation and Computing - Project Typhoon, Phil. Pa.
October 12, 1953

"Integrated Computation System for ERA-1103"
W. F. Bauer
ACM JOURNAL, Vol. 3, pp 181-185
1956

"Modern Large-Scale Computer Design"
W. F. Bauer
COMPUTERS AND AUTOMATION
January, 1957

"New Digital Computer Trends"
W. F. Bauer
ELECTRONIC DESIGN
December 1956

"Input-Output Equipment"
W. F. Bauer
AUTOMATION IN BUSINESS AND INDUSTRY, Chapter X, John Wiley, New York
1957

12.4 BIBLIOGRAPHY OF TEAM MEMBERS (Continued)

"Modern Large-Scale Computer System Design"
W. F. Bauer
COMPUTERS AND AUTOMATION
January 1957

"A System for General Purpose Analog-Digital Computation"
W. F. Bauer and G. West
ACM JOURNAL, Vol. 4, pp 12-17
1957

"Aspects of Real-Time Simulation"
W. F. Bauer
IRE TRANSACTIONS ON ELECTRONIC COMPUTERS, Vol. EC-7, 2
June 1958

"The Monte Carlo Method"
W. F. Bauer
JOURNAL OF SIAM
December 1958

"Advanced Computer Applications"
W. F. Bauer, D. L. Gerlough and J. W. Granholm
Special Computer Issue of IRE PROCEEDINGS
January 1961

"DODDAC - An Integrated System for Data Processing, Interrogation and Display"
W. F. Bauer and W. L. Frank
PROCEEDINGS OF EASTERN JOINT COMPUTER CONFERENCE
December 12, 1961

"Why Multi-Computers?"
W. F. Bauer
DATAMATION
August 1962

12.4 BIBLIOGRAPHY OF TEAM MEMBERS (Continued)

"Information Processing in Military Command"
W. F. Bauer
PROCEEDINGS OF ACM NATIONAL CONFERENCE
1962

"Military Command; A Challenge for Information Processing"
W. F. Bauer
COMPUTERS AND AUTOMATION
April 1963

"PMR Real-Time Data Handling System"
W. F. Bauer and Sheldon Simmons
To be published in DATAMATION

<u>E. A. Coil</u>

"A Multi-Addressable Random Access File System"
Emory A. Coil
IRE WESCON Convention Record
1960

"Librascope Mass Memory - A "Working" Storage System"
Emory A. Coil and Simon A. Goodman
Disc File Symposium
March 1963

"Executive Control in a Heterogeneous System"
E. A. Coil and R. E. Kaylor
Submitted for publication

<u>W. L. Frank</u>

"The Organization of a Program Library For a Digital Computer Center"
W. L. Frank
COMPUTERS AND AUTOMATION
March 1956

12.4 BIBLIOGRAPHY OF TEAM MEMBERS (Continued)

"How to Hire a Programmer"
J. W. Granholm
DATAMATION
July 1962

"ALGOL on the 7090"
J. W. Granholm
DATAMATION

L. C. Hobbs

"Review and Survey of Mass Memories"
L. C. Hobbs
PROCEEDINGS, Fall Joint Computers Conference 1963

"The Specification and Selection of Military Information Systems"
L. C. Hobbs
Accepted for the Winter MIL-E-CON, 1964

H. Hess

"A Comparison of Discs and Tapes"
Herman Hess
COMMUNICATIONS OF THE ACM, Vol. 6, No. 10
October 1963

R. H. Hill

"Stored Logic Revisited"
Richard H. Hill
To be published

"Programming Design for a Large-Scale Real-Time Processing System
Richard H. Hill
To be published.

12.4 BIBLIOGRAPHY OF TEAM MEMBERS (Continued)

"Mathematical Subroutines for the UNIVAC Scientific Computer - A Survey"
W. L. Frank
COMPUTERS AND AUTOMATION
September 1957

"Computing Eigenvalues of Complex Matrixes by Determinent Evaluation and by Methods of Danilewski and Wielandt"
W. L. Frank
JOURNAL OF SOCIETY FOR INDUSTRIAL AND APPLIED MATHEMATICS, Vol. 6, No. 4
December 1958

"Solution of Linear Systems by Richardson's Method"
W. L. Frank
JOURNAL OF THE ASSOCIATION FOR COMPUTING MACHINERY, Vol. 7, No. 3
July, 1960

"Programming On-Line Systems"
W. L. Frank, W. H. Gardner, and G. L. Stock
DATAMATION
May 1963

J. W. Granholm

"Programming Leads the Way for Computer Design"
J. W. Granholm
ELECTRONIC EQUIPMENT ENGINEERING
December 1955

"Magnetic Tape is Key to Flight Test System"
J. W. Granholm
AVIATION AGE
June 1956

"Advanced Computer Applications"
J. W. Granholm, W. F. Bauer, D. L. Gerlough
PROCEEDINGS OF THE IRE, Vol. 49, No. 1
January 1961

12.4 BIBLIOGRAPHY OF TEAM MEMBERS (Continued)

E. Burgess

"Establishment and Use of Artificial Satellites"
E. Burgess
AERONAUTICS
September 1949

"High Altitude Research"
E. Burgess
THE ENGINEER
September 12, September 19, 1952

"Anti ICBM, Myth or Method?"
E. Burgess
MISSILE DESIGN AND DEVELOPMENT
January 1958

"Role of Undersea Warfare in the Space Age"
E. Burgess
AIRCRAFT
February 1959

Note the above are examples out of over one-hundred papers and articles.

FRONTIER TO SPACE
Eric Burgess
Chapman and Hall Ltd., London, 1955
Revised 2nd Edition 1956
Macmillan Co., New York, 1955
Library of Science Selection, 1956
Collier Paper Back Edition 1962
Translated into Russian, German, Swedish & Polish

12.4 BIBLIOGRAPHY OF TEAM MEMBERS (Continued)

SATELLITES & SPACEFLIGHT
Eric Burgess
Chapman & Hall Ltd., London, 1957
Scientific Book Club, London, 1958
Macmillan Co., New York, 1957
Reprinted, 1958, 1958
Translated into Swedish

LONG RANGE BALLISTIC MISSILES
Eric Burgess
Chapman & Hall Ltd., London, 1961
The Macmillan Co., New York, 1962

<u>Note</u> the above are examples out of seven books.

12.5 RESUMES OF PERSONNEL

The following pages contain formal resumes of the personnel assigned to this project. They are arranged in the following order:

W. F. Bauer, Project Manager
W. L. Frank, Associate Project Manager
L. C. Hobbs
H. Hess
J. W. Granholm
R. H. Hill
E. A. Coll
G. J. Stock
E. Burgess
A. H. Espo
K. E. Curtice

HOBBS ASSOCIATES

Linder C. Hobbs

Mr. Hobbs received the BS degree in Electrical Engineering from the Georgia Institute of Technology and the MS degree in Electrical Engineering and the MBA degree in Statistics and Industrial Management from the University of Pennsylvania.

Mr. Hobbs has had fifteen years experience in the fields of systems engineering, digital computers, and data processing. His most recent prior experience was with the Aeronutronic Division of the Ford Motor Company where he served as Manager of Data Processing Engineering. He was responsible for the analysis, specifications, design, and development of all types of digital equipment and systems including special purpose computers, data entry equipment, data editing and display equipment, memories, parts and several of command and control systems. This included responsibility for parts of the Army Tactical Operations Center program.

At the Remington Rand Univac Division of Sperry Rand Corporation, Mr. Hobbs was in charge of a group responsible for the programming, systems analysis, and systems specifications for small and medium scale data processing systems.

At the Radio Corporation of America, Mr. Hobbs was in charge of the logical design of parts of the first BIZMAC system. He later directed several system studies of military and special purpose systems utilizing digital computers.

At Hobbs Associates, his work has included a study of the Tactical Imagery Interpretation Facility, a study of the requirements for a central data processor for an ASW Tactical Data System for the SEAHAWK class destroyer, a brief study of the use of automatic data processing equipment in the prediction and recognition of potential tactical nuclear targets, a brief survey of the magnetic thin film memory field, the evaluation and selection of computers, and a study of mass memory requirements, devices and techniques.

Mr. Hobbs has had five patents granted and has ten patent applications pending. He is a Lecturer in Engineering at UCLA having taught a course in Digital Computer and Systems Design for the past seven years. Mr. Hobbs is also editing a text book in Digital Systems Design. He was chairman of the Los Angeles IEEE symposium on Tactical Command and Control Systems held September 16, 1963. He presented a paper, "Review and Survey of Mass Memories" at the 1963 FJCC and has prepared and submitted a paper for presentation at the 1964 Winter MIL-E-CON entitled, "The Specification and Selection of Military Information Processing Systems". Mr. Hobbs has organized and moderated panel discussions on "Computer Generated Displays" and "New Developments and Trends in Computers and Digital Systems".

Mr. Hobbs is a member of Tau Beta Pi, Eta Kappa Nu, the American Ordnance Association, the Association for Computing Machinery, the Institute of Electrical and Electronic Engineers, and the IEEE Professional Technical Groups on Electronic Computers, Military Electronics, and Engineering Management. He is a Past Chairman of both the Philadelphia and Orange County chapters of IEEE PTGEC, a Past Chairman of the IRE Computer Definitions Subcommittee, Chairman of the IEEE Electronic Computers Technical Committee, a member of the IEEE Standards Committee, and Chairman of the Technical Operations Committee of the Los Angeles Section of IEEE.

<u>Albert H. Espo</u>, Member of Technical Staff

Mr. Espo was educated at Los Angeles City College and has completed special training courses in computer languages, programming techniques and computer-based command and control systems at Systems Development Corporation.

Following early experience in the Flight Test Data Reduction Section of Lockheed Aircraft Corporation, he became, in 1956, an analyst lead-man at Rocketdyne where he trained technical computer and data reduction personnel in the use of facilities and equipment. He was responsible for the presentation of test data on the ATLAS missile project.

As a Senior Programming Analyst with the Systems Development Corporation from 1958-1961, he was responsible for maintenance and modification of a hardware simulation program of the SAGE Air Defense System. He was also responsible for the development of the control, auto-recovery, and instrumentation complex of programs for the operational SAGE system which involved the manipulation of approximately one-quarter million operating instructions. He also designed, developed, and implemented the tools for a running, timing, and reliability study of the various models of the SAGE system.

From 1961-1962, Mr. Espo was a Senior Member of the Engineering Staff of the Radio Corporation of America Data Systems Division where he was responsible for the development of a programmed capability for the RCA 4100 series product line. He also developed and implemented a CDC-1604 computer program to remotely command and maintain the attitude of an orbiting vehicle.

From 1962 until he joined Informatics technical staff in mid-1963, he was with Aerospace Corporation where he was engaged in programming PERT-cost for the IBM 7090.

Mr. Espo has a total of 8 years experience with computer applications in the IBM 700 series, CDC-1604, AN FSQ-7 special purpose computers, various special purpose devices, and the RCA 4100 series product line.

He is a member of the Association for Computing Machinery.

Keith E. Curtice, Member of Technical Staff

Mr. Curtice began his studies in engineering at the University of California at Berkeley, prior to military service. He completed his degree in Political Science, receiving his bachelor's in 1960 from the University of California at Los Angeles. The latter interest developed during two years service as Czech interpreter/interrogater for the Military Intelligence.

Upon leaving the service in 1955, he joined the Missile Division of North American Aviation. There he performed routine calculations on wind analysis for missile launch feasibility, reduction and analysis of wind tunnel data and computer simulated data on the serodynamics and performance of Navajo and Hound Dog missiles.

In 1958 he joined the Thompson Ramo Wooldridge Corporation. As a programmer for the RW 300 process control computer he wrote several input-output utility routines, aided in checkout of the assembler-compiler, and wrote and used special programs to aid in checking the reliability and performance of newly manufactured computers and tape units. As well, he worked on the team that wrote the process control program system to blend elemental ores to produce optimum mix for cement manufacture. Also he operated the system for the cement company on the in-house computor prior to installation of their own computer.

After time out to complete his studies, he joined the System Development Corporation in 1960. There, as programmer-analyst and instructor, he was concerned with the operation and maintenance of the program system for the SAGE Air Defense System on the AN/ESQ7. He became well grounded in the space-time problems of a large real time system and the communication problems of a man/machine system. His particular areas of concern were the executive control and timing programs, and the automatic recovery program and procedures to provide continuous operation. He gave instruction on those and other areas of the system, programming for the AN/FSQ7, and in JOVIAL, the procedure-oriented language developed by System Development Corporation.