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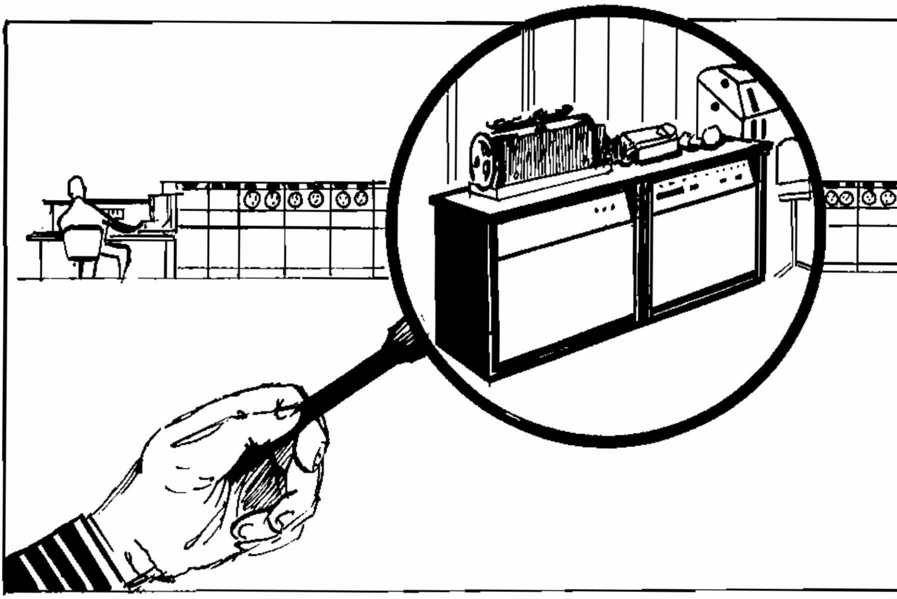

THE IMPACT OF ADP ON THE NAVAL STRATEGIC COMMAND AND CONTROL SYSTEM

A Research Paper prepared by
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INTRODUCTION

Military command of forces and military control of forces have been practiced by military organizations since the inception of organized warfare. Today, however, one essential difference is the split second requirement to assess the situation and act or react with precision. Marshall Andrews has stated in Bernard Fall's book about Vietnam:

Since World War II, war has assumed a new dimension. It is still the final expression of politics in the Clausewitzian sense, but it has become more than that. War is now an interim instrument of politics, to be applied and withdrawn at will. This modern use of military force has come to be known as "limited war," although wars of limited objectives with limited means are nothing new in the somber history of human conflict.[1]

The ability to apply and withdraw military force is heavily dependent on an existing command and control system. It is the purpose of this paper to examine the impact of recent technology in the form of digital computer systems on the Navy's strategic command and control system. The scope of the paper is limited to an analysis of the technical and organizational problems associated with efforts to improve Navy and Navy-supported command and control systems with the writer concentrating on major factors only.

After describing the general background of automatic data processing (ADP) in command and control, the associated problems are sorted into two groups: technical problems and organizational problems. This approach is used to allow the determination of fundamental difficulties and thereby allow the prescription of proper solutions. No attempt is made to educate the reader completely on ADP. A general knowledge of the principles involved and the included discussions of the particular technical subject in question should be sufficient. Command and control from a nontechnical standpoint is well covered in special annual issues of two periodicals: *Data* (January, February, or March) and *Armed Forces Management* in July. The reader is also directed to an Air University thesis by Maj. G. E. Breton, U.S. Air Force, for a related discussion of organizational problems in ADP on the Department of Defense level.[2] The technical aspect of ADP is covered in a myriad of books, periodicals, studies, reports, and conference proceedings. The four most consistently useful publications are Data Processing Management Association's *DPMA Quarterly; Communications of the ACM* (Association for Computing Machinery); *IEEE* (Institute of Electrical and Electronic Engineers) *Transactions on Electronic Computers;* and *Proceedings of the Spring* (or Fall) *Joint Computer Conference* by the American Federation of Information Processing Societies.

I — GENERAL BACKGROUND

Definition, Magic, and Presidential Attention. The title of this paper, "The Impact of ADP on the Naval Strategic Command and Control System," calls for some definition. Automatic Data Processing (ADP) as it applies to command and control may be divided into two major areas: first, fast and accurate information storage/retrieval, and, second, a collection of special purpose functional computer programs such as war game simulation, bomb damage assessment, unit scheduling, strike planning, counterinsurgency analysis, etc. The development of a vivid distinction between these two areas of ADP application by the reader is one of the objectives of this paper.

Another pertinent comment regarding the title is the converse, i.e., the impact of strategic command and control systems on ADP. The demands imposed by this application are having a significant impact on the development of ADP systems. It might also be noted that other parallel systems which, because of costs, can be expected to utilize the same ADP hardware and communications channels are having an impact on the development of ADP systems for command and control. These other parallel systems are concerned with the more mundane, but vital, subjects of supply, personnel, and general business management.

The military has control of its forces today just as it had control yesterday and the day before. The problem under consideration here in-

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A naval aviator, Commander Twite has served as Electronics Officer, Patrol Squadron 42; as Missile Officer, Guided Missile Unit 4; as Flag Lieutenant, Staff, Fleet Air Wings, Atlantic, and as Operations Officer, Helicopter Anti-Submarine Squadron 9. He was also the Military Head, Strategic Systems Department at the Naval Command System Support activity and Executive Officer of Helicopter Anti-Submarine Squadron 7.

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volves the application of recent computer technology to the perennial command and control problem in response to a more stringent need for detail and speed. With each advance in capability has come the need to modify existing systems in order to profit by the advance. For example, the introduction of radar into the Navy as a principal means of collecting tactical information created the need for a centralized organizational entity to coordinate data so received with that furnished from all other sources. Thus, the Combat Information Center (CIC) was developed.

The problems hindering the Navy now as it attempts to accommodate ADP into its command and control system are very much the same as those that hindered the development of CIC. Certainly not the least among these problems, now as then, is the lack of technical appreciation by sufficient numbers of naval personnel, both civilian and military. Since the introduction of radar and CIC into the fleet the Navy has developed a general expertise regarding radar and its use through experience and training. Also, there has developed an increased level of technical appreciation in the general public from which the Navy draws its personnel. However, after all these years, there still remains a degree of magic about radar. It is, therefore, not surprising to find this mystical factor so prevalent in the ADP field.

Sunday newspaper supplements which describe computers speak in terms of "machines that think." Articles regularly appear which lead the unindoctrinated to the conclusion that the purchase of a digital computer is the solution to all problems. The reader envisions a mysterious looking box which will somehow accept a statement of a problem and return an infallible solution. This picture is spiced with "gee-whiz" statistics regarding speeds in microseconds, capacities in millions of bits, and improvements over manual methods which shrink days of tedium into seconds of excitement. It is no wonder that the new "owner" of a computer or computer system is quickly disillusioned. Most of the old problems are retained for a period of time, and a few more are created by the presence of the machine.

Painful though it is, the Navy is going to be confronted with more and more of these "things" in the future. They represent a tremendous increase in capability after their use is learned. The President of the United States recently directed the heads of all Federal departments and agencies to ". . . give thorough study to new ways in which the electronic computer might be used to . . . provide better service to the public . . . improve agency performance . . . and reduce costs."[1] The Secretary of Defense quickly followed with a memorandum in which was expressed a ". . . desire that the Department of Defense not only concentrate its efforts on attainment of the President's objectives but provide an example for the rest of the Government to follow . . ."[2]

The desirability and feasibility of using digital computers in command and control have already been established. Undoubtedly the interest exhibited by the President and Secretary of Defense will spur digital computer development for command and control to an even faster pace.

The World-Wide Military Command and Control System (WWMCCS). Command and control is defined as "an arrangement of personnel, facilities, and the means for information acquisition, processing, and dissemination employed by a commander in planning, directing, and controlling operations."[3] Command and control applies to the entire spectrum of operations ranging from strategic to tactical. At one end of the spectrum there is concern with the employment of the Armed Forces of the United States to secure the objectives of national policy. At the other end, there is concern with the employment of tactical units in combat to secure much more limited objectives. The range of concern between these extremes runs parallel to the concerns of the various levels in the organizational hierarchy between the President and the smallest organizational unit. There is no sharp line of demarcation between strategic and tactical command and control. There is, rather, a continuous gradation as the various shades of grey change from black to white. However, it should be noted that in the Office of the Chief of Naval Operations there has been an arbitrary division as follows: "Tactical command and control systems are those systems in which combat direction, through direct control of tactical units, such as ships, aircraft, or transportable installations, is performed. Strategic systems are those which support a major shore based commander."[4]

"The World Wide Command and Control System (WWMCCS) is the total aggregate of all the means used to command and control the U.S. Armed Forces."[5] This aggregate includes the National Military Command System (NMCS), the systems of the commander-in-chief of unified and specified commands, the systems of the military departments and services, field and fleet operational command systems, and appropriate portions of other agencies and departments of the government. The first system mentioned, the NMCS, is further divided into several centers and command posts, i.e., the National Military Command Center (NMCC), the Alternate National Military Command Center (ANMCC), the National Emergency Command Post Afloat (NECPA), and the National Emergency Airborne Command Post (NEACP). The conglomerate is tied together with a survivable communications system. The communications system is considered an integral part of command and control as are the intelligence, surveillance and warning, and weapons control systems.[6] See figures 1, 2, and 3.

The Navy's portion of the WWMCCS may be seen to cover the entire command and control spectrum. However, there is a possible grouping depending on whether the Navy is supporting a unified commander or an element of its own department. This distinction is sometimes blurred in cases where both the unified commander and the service commander share the same computer complex.

The major divisions of the Navy command and control system are shown in figure 4. The Navy Information Center (NAVIC) is located at the Pentagon and serves the Chief of Naval Operations (CNO). The Major Operating Data Systems (MODS) and Subordinate Operating Data Systems (SODS) are located at the headquarters of the command supported. A comparison of figures 3 and 4 illustrates the close relationship between the command and control system of a service commander (CinCPacFlt) and a unified commander (CinCPac). "The Fleet Operations Control Center, Pacific, has a multicomputer installation which is so located that it can provide services to CinCPac and CinCPacFlt."[7] CinCPacFlt and his command and control system are at once independent of, and an integral part of, CinCPac's command and control system. This naturally follows the existing command relationships.

In addition to those commands which are obviously Navy and, therefore, Navy-supported, two of the unified commands have been designated

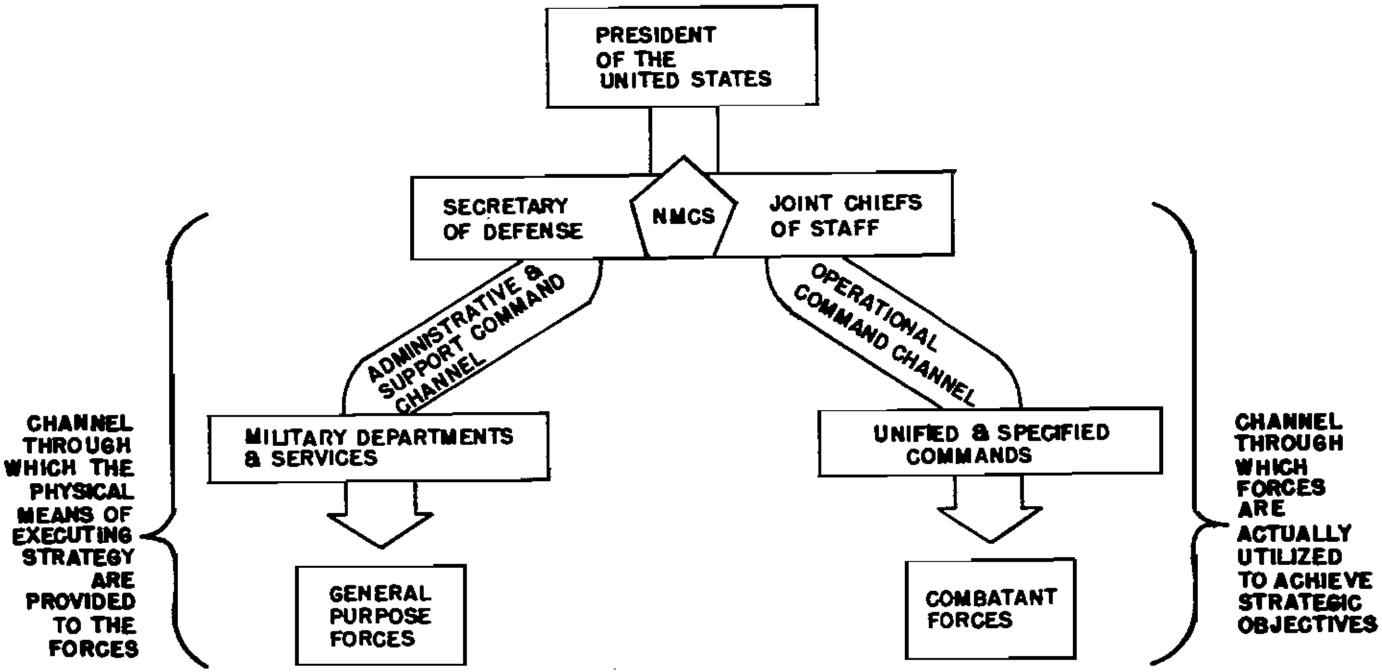


Figure 1 — The Two Channels of Authority for National Military Command & Control* Command & Control systems generally serve one or the other of two functional channels of authority — the administrative & support command channel or the operational command channel.

*Adapted from *Studies of Command & Control*, Study #1, The Strategic Direction of the Armed Forces, Institute for Defense Analysis, Tech Report 62-18, August, 1962.

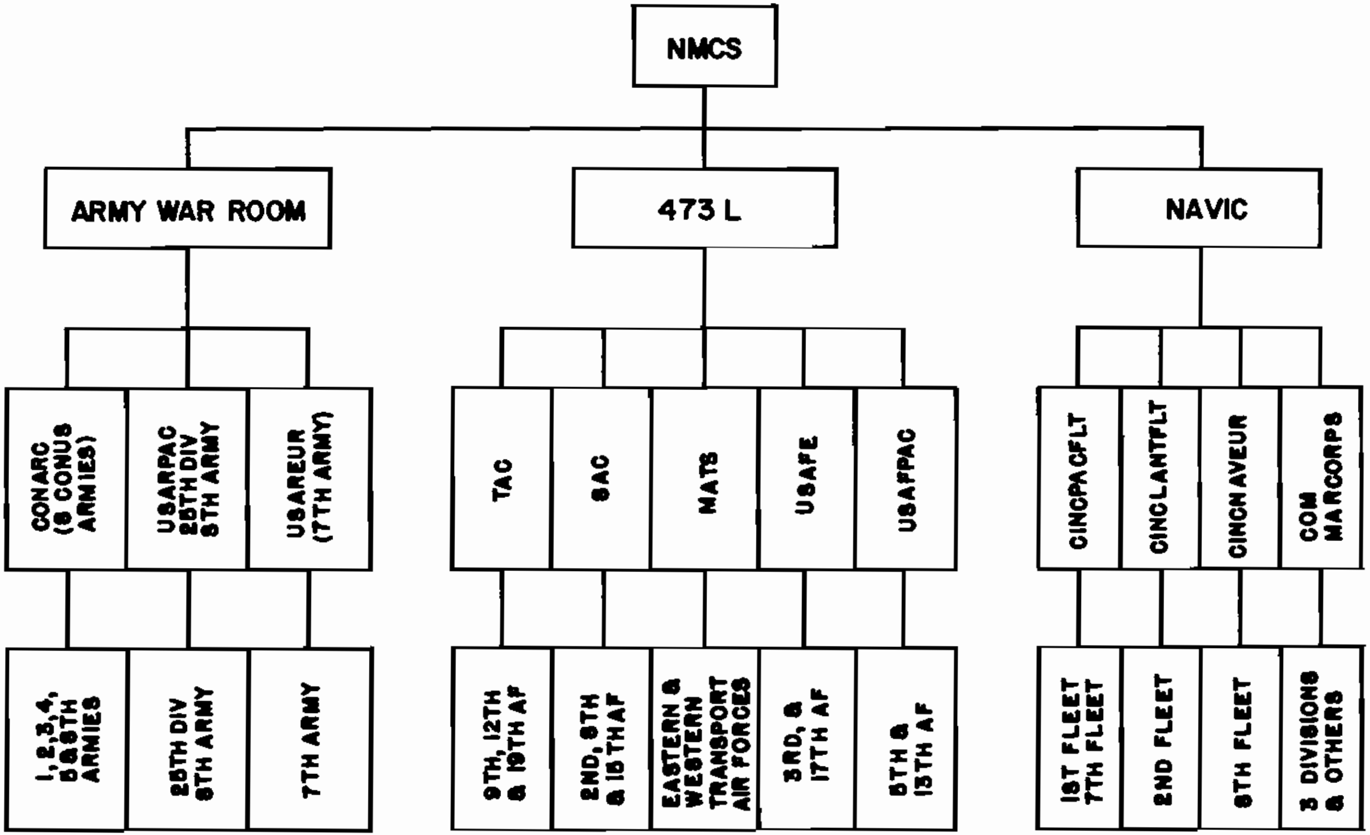


Figure 2 — The Administrative Command Network*

*Adapted from "National Military Command System: Decision Instrument for the Chief Executive," *Data*, March 1964, p. 11.

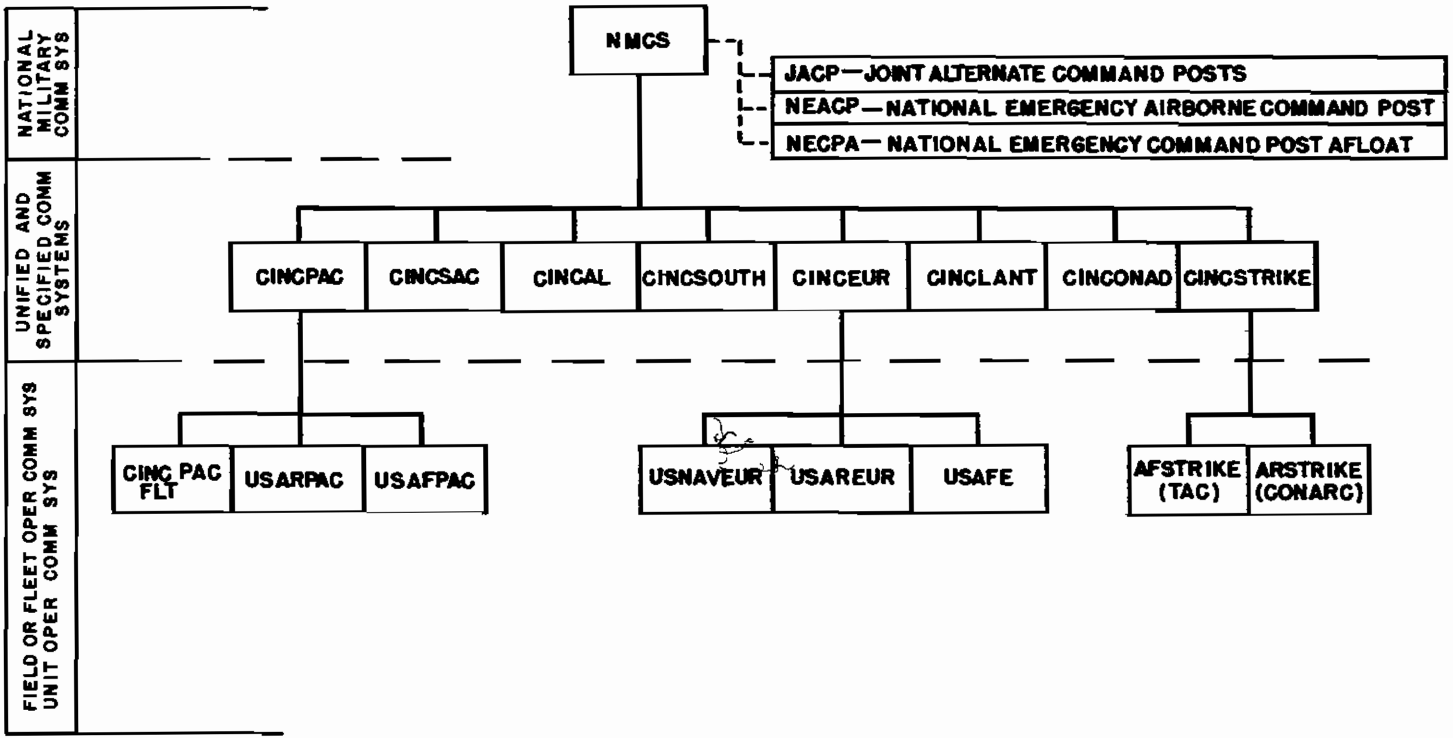


Figure 3 — The Operational Command Network*
*Adapted from "National Military Command System: Decision Instrument for the Chief Executive," *Data,* March 1964, p. 11.

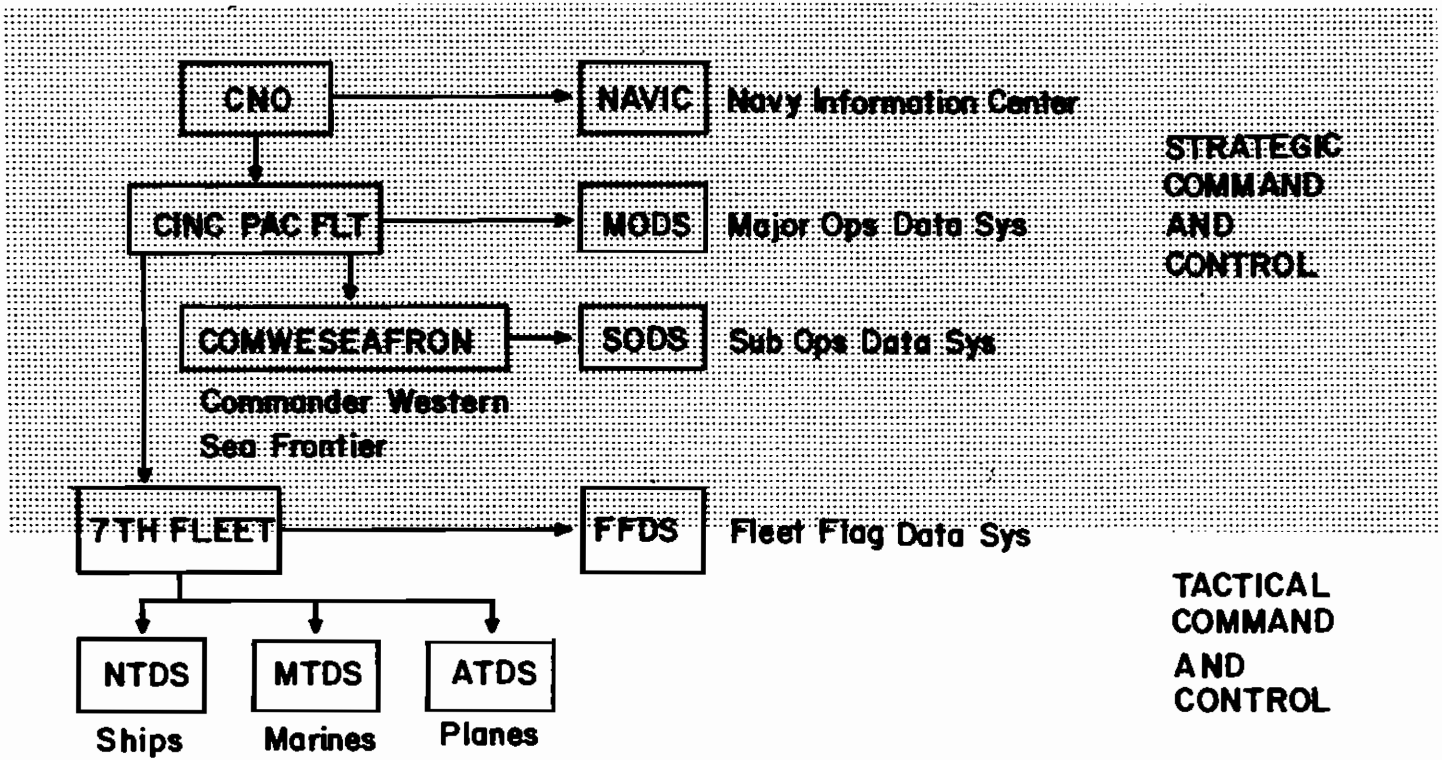


Figure 4 — **Example of Navy Strategic and Tactical Command Control***

*Adopted from "OpNav's Adm. Lambert Tells of Navy C-C Program Expansion," *Data,* February 1965, p. 17.

by the Secretary of Defense as Navy-supported. These are the Pacific Command and the Atlantic Command.[8, 9] The Navy started automating *strategic* command and control first with these commands and is now working its way further down the chain of command. This is *not* to say that the application of ADP to command and control at the commands first to receive digital computers is now complete. There is a need constantly to improve those installations by adopting an evolutionary approach to improvements in equipment and to modification of the command center arrangements. There is constant testing of newer equipments and procedures in day-to-day operation in a careful and prudent manner.[10]

The development of the WWMCCS to the stage outlined above has been in response to a need harbingered by the creation of the Department of Defense. The system has been created in order to provide the National Command Authority with the means for more accurate and timely operational direction of forces. The use of digital computers is merely the application of an available tool to an existing problem. This fact should be constantly kept in mind.

Symptoms and Needs. The United States is faced with many international issues which vitally affect its security. The nation has survived confrontations in Berlin, Cuba, and the Dominican Republic during recent years. It is now involved in Southeast Asia, and there are daily incidents elsewhere which foretell the future. The controlled application of America's power in response to these stimuli requires the provision of a much improved command and control system. Otherwise, there will be no foundation upon which to base timely political actions which involve the very existence of the nation and the preservation of peace.[11]

The need for detailed control of forces during crises was dramatically demonstrated during the Cuban blockade in 1962. Individuals on the highest level in the National Command Authority were in constant *and direct* radiotelephone contact with the commanding officers of Navy ships conducting the blockade.[12] More recently, the control of targeting for strikes into North Vietnam has been deemed a matter of exceptional political significance and is minutely controlled from Washington. It should be noted, however, that when reacting defensively to enemy-initiated actions such as the Tonkin Gulf incident, the United States does not have the luxury of time as that which obtains in offensive operations. The Tonkin Gulf incident is still highly sensitive among command and control experts.[13]

The fact that the usual chain of command has been, in effect, bypassed during crises is proof of the inadequacy of the existing command and control system. Responsible individuals in the National Command Authority are usually not well indoctrinated as to the merits of the chain of command principle; at least they do not feel constrained to observe it religiously. The Constitution itself dictates the ultimate control of the Armed Forces by a civilian, the President. The Secretary of Defense and the Secretaries of the three armed services and their staffs are civilian. The Armed Forces must, therefore, provide the means whereby the unindoctrinated civilian will be *encouraged* to proceed via appropriate military chains of command in the direction of military forces.

There is an immediately apparent danger in the continued deviation from standard military procedures. The danger lies in the reaction of the opposition. If the reaction is violent and massive, the military may find itself *in extremis*, with the major portion of the command hierarchy concerned unaware of the involvement until after the fact. The military hierarchy and its staff processes have been developed and proved through centuries. The ability of a commander in chief, as a result of long-range communications, personally to direct the actions of a tactical unit on the other side of the world does not invalidate the need for an organization. Direct control is convenient, response is immediate, but the pitfalls are many. Lack of knowledge of the local tactical situation makes the need for coordination with other friendly area and regional forces mandatory. Possible repercussions from a given tactical action may have strong effects on the bigger picture. Only when actions are properly staffed is there a reasonable assurance of avoiding the unexpected.

Organizational hierarchies exist because of the human inability effectively to comprehend and communicate more than a limited amount of information in a specified amount of time. The management principle of span of control is involved here. If the span of control, i.e., the number of people reporting directly to a single person or the amount of information to be processed by a single person, is too wide, the controller will not be capable of providing adequate direction or consideration. Therefore, the hierarchy must expand in the vertical direction, and the familiar organizational pyramid is formed. If the organization is not responsive enough, it must adjust its procedures accordingly, but the need for better response does not negate the original need for the organization.

Another very obvious factor which points to the need for a more responsive and reliable command and control system is the possible use of nuclear weapons by a third power, either against the United States (or Russia) or against a nation identified with U.S. interests. The United States is committed to a policy of retaliation and will use nuclear weapons only if attacked. But the question of "retaliate against whom?" is not so easily or quickly resolvable when more than one other nation has nuclear weapons.

The problem posed by a third power attack is related to that of system failure. American nuclear defense and offense are complex, and the number of people involved is large. The same is true in Russia. Regardless of the safeguards employed, there will someday be an accident. A nuclear weapon will inadvertently detonate or a rocket will be launched just as airplanes sometimes crash. A nuclear holocaust caused by a single accident is just as serious to the world as one caused by the political ambitions of an unscrupulous power. The ability to differentiate between accidental and intentional action places an extremely stringent requirement on the command and control function.

II — TECHNICAL PROBLEMS

The preceding chapter gives some of the more pressing and obvious factors which show the need of an improved command and control system. The techniques of automatic data processing in general, and electronic digital computers in particular, offer an opportunity for significant improvement in command and control capability. "No single technological advance in recent years has contributed more to effectiveness and efficiency in government operations than the development of electronic data processing equipment."[1] Since there is so little doubt as to the need, and since there is such an improvement possible, what, then, are the reasons for the less than rapid utilization of ADP?

Report to the President. The Bureau of the Budget, in a report to the President, listed a series of problems involving acquisition and utilization of computer systems.[2] The there may be summarized as follows:

(1) Questions caused by diversity prohlems and problem areas listed of ADP equipment versus the appropriateness of general management policies and guidelines.

(2) Need for a selection methodology to assist managers in deciding where to apply ADP.

(3) Need for means to assure high quality computer system design.

(4) Selection of equipment which requires extensive knowledge.

(5) High cost of equipment which dictates optimum utilization of existing equipment before acquiring additional equipment.

(6) Lack of standard equipment characteristics which make contracting difficult.

(7) Problems relative to prediction of useful equipment life which make rental versus purchase decisions inexact.

(8) Disposal of excess and surplus equipment which poses an increasing problem as existing machines become obsolete.

(9) Policies which must be developed for choosing between commercial and government equipment maintenance.

(10) Lack of standardization in practically every aspect which makes data transfer difficult.

(11) Need for coordinating research and dissemination of findings.

(12) Control of contractors to assure efficient use of ADP, particularly when working on a cost-reimbursement basis, is difficult.

(13) The effect of the computer on Federal employment, i.e., the demand for new skills, and the skills made obsolete. In connection with this, the Civil Service Commission has made a study of the subject.[3]

(14) The problem of improvement of the effectiveness and the economy of computer utilization without derogating the proper authorities and responsibilities of managers of the line.

The above-listed problem areas apply directly to ADP in command and control as utilized by the Department of Defense generally and to the Navy, and Navy-supported commands, specifically. A moment's reflection on them reveals two underlying factors. First, there is a need for, and there is presently a lack of, central direction in the management of ADP. Second, the complex technical nature of the subject demands the employment of technically competent people both regarding equipment (hardware) and programming (software). It is interesting to note that the authors themselves betray a certain lack of facility with the subject. This is evident by their "99 percent" concentration on ADP hardware with very little consideration and discussion of the equally important and expensive software.[4]

In addition to the problems identified above, a number of additional technical difficulties may be iterated.

Program Obsolescence with New Equipment Procurement. Related to item (10) above is the difficult problem of program obsolescence when new equipment is installed. The development of digital computers has been so rapid that computer manufacturers have not deemed it worthwhile to constrain the design of new models to allow using programs written for the earlier ones, even those of the same manufacturer. An exception to this dilemma is the latest IBM System/360 series of computers which will accept programs written for a few earlier models. However, this is made possible only through a special (extra) piece of hardware plus a special computer conversion program. Operated in this way the new computer is able to accept the previous computer's program but at a great sacrifice in speed.

"Computer programming costs have been major parts of total system costs for command data systems, accounting at times for as much as half the total cost."[5, 6] The Commauding General, Electronic Systems Directorate, Maj. Gen. C. H. Terhune, Jr., U. S. Air Force, has stated that the per instruction costs for the Semi-Automatic Ground Environment System (SAGE) program have varied from $32 to well over $100, depending upon whether they were included in regularly produced program models or were rush changes expedited into the field.[7] Programs written for command and control comprised of 50,000 to 100,000 instructions are commonplace, and some of the larger programs exceed 300,000 instructions. Therefore, it is evident that from both relative and absolute cost viewpoints installation of new equipment which also requires new programs requires a doubly difficult decision.

Rapid development of New Computers Overtakes System Implementation. The rapid development of electronic computers has been phenomenal. The initial development of an electron tube computing machine in the late 1940's established a basepoint from which continuous strides have since been made. The introduction of the transistor and the magnetic core memory during the mid-1950's was the principal factor toward major advances in the ability of computers to provide more and more computational capability. This increased-speed capability was further enhanced by increased sophistication in computing systems design.[8] Today, even as efforts are still going on to install and operate transistor/magnetic core "second generation" computers, manufacturers are marketing "third generation" computers utilizing integrated circuits. The improvements in capability are significant, and much of the second generaton hardware deficiency which had to be corrected by programming (software) has been eliminated. The question facing commanders now is whether to scrap several years of expensive effort and start over or to continue to struggle with the old system with its unnecessary problems.

Man-Computer Interface. As technology improved the speed, capacity, and flexibility of the computer itself, the ability of a human being to communicate and interact with the system has been comparatively reduced. There are nuts and bolts — the hardware — to build workable computerized command and control systems, with one glaring exception. This exception is the man-machine interface.[9] In the command and control environment there is a need for a direct user-computer dialogue. However, in most present command data systems command requests must be interpreted by a staff of specialists who operate a "closed shop" type computer system. Much time is lost and a user-data base diologue is impossible. Although not yet generally applied, methods and equipment have been developed to allow direct access to the computer by individuals via remote consoles. There are two basic approaches to this technique.

One approach is the provision of a flexible query language with dictionary and syntax rules similar to everyday English, allowing the user to make complex requests of the system. One advantage of such an approach is that a complex operator console is not required; usually an electric typewriter type input will suffice with the same typewriter acting as the output device. Operated in this manner, the console functions exactly like a send-receive teletype station. The user-operator in this type system must be skilled in the use of the language and have a considerable *a priori* knowledge of the data base content.

In the second approach, which may be referred to as the on-line display console technique, the computer guides the requester by cuing and monitoring him so that the permissible request is quickly generated. In this technique the display console, under computer control, helps the user formulate questions about the data base by focusing his attention on the types of answers available in the data base. For example, in response to a question about availability of transportation for an amphibious operation, the computer would direct the inquirer's attention to the classes of transportation, the specific types of transport, and their cargo-carrying capacities and types of cargo, in sequence of increasing detail. The requester can, at each stage, make selections from lists which the computer presents to him. The advantage of this approach lies in its basic simplicity in operation and training. The technique is easily learned and, perhaps more importantly, is more likely to be a reliable and error-free operation during periods of stress. The operator is less likely to make mistakes because the machine continuously cues him. However, in order to gain maximum benefit from such an approach, a rather complex console is required.

The problems involved in implementing either of these methods are much more fundamental than is at first apparent. He again the difficulties are divided into software and hardware. They are significant enough to warrant individual treatment and are discussed separately in the two succeeding sections. The specific subject of man-computer interface is the single most needful area for research and development.[10]

Information Processing System. The electronic digital computer may be used in several different ways. In the command and control environment the applications may be divided into one of two different categories. One category consists of independent *Special Purpose Functional* programs, and the other may be called *Generalized Information Processing* programs. The differences are as follows: (1) *Special Purpose Functional* programs are written to solve specific problems using data supplied for that specific purpose. Usually the program is written and stored externally to the computer until there is a need to use it. At that time, the program is read into the computer along with the necessary data for that particular instance. The computer then applies the program to the data and produces an answer which is presented to the user in some useful and/or comprehensible way. (2) *Generalized Information Processing* programs are different in that instead of *data* being supplied at the time of use, *descriptors or qualifiers of the desired answer* are supplied to the computer system in the form of a question or query. Usually, the data have been collected and stored as a general data base from which the program may extract specific bits in answer to a query. The procedure is exactly parallel to that used in a business office where a secretary (the computer and program) in response to a question (query) opens a file cabinet (computer memory or storage) and extracts information from the file (data base). The secretary then presents the information to her employer (user) in the format he prescribed. The procedure for storage of new information or updating information already stored is likewise exactly parallel to business secretary procedures.

A clear distinction between the different characteristics and uses of special purpose functional programs as opposed to generalized information processing programs is not apparent in the literature, even in quotations by those directly involved in adapting digital computers to command and control.

There have been many special purpose functional computer programs written for Navy and Navy-supported strategic command and control systems. On the other hand, there is only one generalized information processing system in use, and it has one major shortcoming, i.e., its design philosophy will not allow fast enough response to queries to make user-computer interactive processing feasible.[11] Much of the distress expressed about the inadequacies of ADP and Navy Strategic Command and Control by users and Navy Department planners alike stems from a failure to appreciate this fact.

In order to be of use to an individual in an interactive mode, a generalized information processing system must provide a response to a query within a reasonable amount of time. Exactly what this amount of time is, is a matter of definition. Usually the maximum is defined as 30 seconds, and the less time the better. The amount of time actually needed by the system to respond is determined by the manner in which the information is stored (structure) and the characteristics of the storage device.[12] The characteristics of storage devices and the manner in which they affect the system performance is discussed in the next section.

There is no computer-based, large-scale generalized information system which will allow interactive processing in existence at this time. At least, there is no instance where one has been applied to command and control. The most used systems at this time are the previously mentioned Information Processing System (IPS), developed by the Naval Command System Support Activity (Navcossact), and its less sophisticated predecessor, the Fixed File Formating System (FFFS). Both of these systems (really variations of the same system) suffer from a reaction time standpoint since they both are oriented for use on a serial type storage device, e.g., files written serially on reels of magnetic tape. In order to search the file, each record must be read sequentially and checked for the desired data. In IPS, information is structured into a file with each file divided into records, each record into sets, each set into items, and each item into subitems. For some complex queries the file must be completely read more than once. Therefore, the time required to answer a query depends on the size of the file (number of reels of magnetic tape in the file) and the complexity of the query. The time to search a single reel of tape at the fastest possible speed is approximately five minutes. If the time needed to locate and mount the tape reel on the proper machine is considered, it may be seen that this system is not amenable to a procedure that involves a question and answer dialogue. Even though the tape files are transferred onto (almost) random access storage devices such as disks and drums, there is no speed advantage other than the elimination of tape rewind time. The structure of the information does not allow utilization of random access features of these devices.

It has been stated above that there is no computer-based, large-scale generalized information processing system which will allow interactive processing in existence at this time; there are, however, several experimental systems in existence.[13] At least one major computer manufacturer has marketed a system to match its latest hardware line.[14] Also, the U. S. Navy Aviation Supply Office in Philadelphia has designed and installed a rapid-response computer system for inventory management which utilizes a list processing concept with generalized information storage and retrieval possibilities.

What remains is for the Navy to select one of these fast-response systems or system philosophies and begin immediate application to the command and control problem.

Computer Random Storage Devices. Storage devices are at the heart of every computer. They range in capacity from single bit, to single word (typically 6 to 64 bits long), to multimillions of words. Some are "read-only" and subject to change only by a maintenance technician, others are completely reusable, i.e., rewritable, under program control. Storage devices also vary in the amount of time necessary to access a word. Less than one-millionth of a second is necessary in some types, and several minutes are necessary in others. The types vary in capacity and time for access to form an entire array of combinations for choice.

As usual, economic considerations dictate a selection from this array such that a typical computer system will use several types depending on the needs for speed and capacity, as balanced against cost. Very high-speed memories with random access to each individual word are so expensive as to limit their use almost entirely to internal (to the computer) applications. For the purposes of command and control the desired characteristics for bulk storage are very large capacities with access to any portion of the data base in approximately one second. Information may be drawn from this large capacity, slow (and less expensive) storage, and the necessary manipulations may be performed using faster access (and more expensive) temporary work storage.

The great majority of external bulk storage in use today utilizes reels of magnetic tape similar to the familiar home tape recorder tape. The reels of tape are mounted on tape transports that control the passage of the magnetic tape over read-write heads in response to commands from the computer. The obvious problems associated with gaining access to information printed "somewhere" on the tape make its use unsatisfactory when speed of access is a primary criterion. The incompatibility of tape storage with interactive computer processing has been discussed above.

Filling the gap between "word-addressable" and "reel-addressable" storage are a series of pseudorandom access devices which divide the data into individually accessible segments. One such device is the drum which, as the name implies, is drumshaped and rotates rapidly on its axis. The outer cylindrical surface is coated with magnetic material, and information is magnetically printed on parallel tracks around the circumference from one end to the other. Each track usually has its own read-write head, and, therefore, the time to access any given track is dependent only on the speed of rotation of the drum.

A second pseudorandom device is the disk. The disk consists of a number of flat, circular plates coated on both sides with magnetic material. These plates are stacked on a single shaft with a slight space between each plate. The stack is rotated and comblike read-write heads with associated mounting arms access the disk surfaces by varying their in-and-out position. Here again the access time to any desired track is dependent on the speed of rotation of the stack of disks, but an additional amount of time is necessary for the in-and-out positioning of the comb.

A third pseudorandom access storage device is the data cell.[15] Here the storage medium is a flat piece of plastic coated with the usual magnetic material. The size and shape can vary considerably, but it is usually rectangular, about 3 inches by 14 inches. Thousands of these pieces of plastic (slabs) are code-mounted in such a way that any one of them can be pulled from its storage place, read (or written on), and returned automatically under computer control. Access time to any desired segment of information is considerably longer than for the disk or drum, but the feasible capacity is much larger, and the cost per bit stored is more attractive. Even though considered "slow" by comparison, a slab can be selected, retrieved, read, and returned to its storage in less than one second.[16]

The use of these three types of pseudorandom access storage devices — the drum, disk, and data cell — would greatly enhance the application of digital computers to command and control. But there is one important factor which must also be included. That is, there must be a computer program designed to take advantage of the improvement in access time over tape storage. Some computer systems now devoted to command and control already have disk storage installed and available. They do not, however, have a generalized information processing system (software) available to make use of the disk's pseudorandom access characteristics.

Random storage devices are discussed here not so much as a problem in themselves but rather as a problem relative to the information processing system in which they are used. The characteristics of available hardware must be included in any consideration of the development of a generalized information processing system as described above in providing for the user-computer interactive processing described previously.

It should be obvious from this discussion that the most desirable system would include completely random access to each word of information in storage within times compatible with the computer's central processor, i.e., times measured in millionths of a second. The development of a hierarchy of storage devices is the result of economic considerations. The near future promises economical new storage devices which will more closely approximate, or actually equal, the ultimate. However, systems must be designed for today's use with today's components.

Failure to Adhere to Standards. The most important step taken to date in strategic command and control standardization was the selection of JOVIAL (Jules' Own Version of the International Algorithmic Language) as the single strategic command and control language in 1961.[17] A JOVIAL compiler written for a given computer will allow (within certain limits) any program written in the JOVIAL language to run on that computer. An advantage of this standard would be that the agonizing problems associated with program obsolescence caused by procurement of new or different hardware would be nonexistent if the new hardware had a JOVIAL compiler. The decision to standardize was difficult, but the advantages were many.

However, after the establishment of the standard, ADP administrators were faced with other problems.

Should programming already started in another language be abandoned? Would it be allowable to program subroutines which were inefficiently handled by the existing JOVIAL compiler in machine language for that particular computer? If a programmer skilled in another language was available to start a priority project now, should the project be delayed and wait for another programmer? The problems were (and are) many, and exceptions were granted. The pressures of deadlines and workload have persisted; the ADP field is so fraught with other problems that the standard has been virtually ignored. The problems associated with a single language standard are not peculiar to JOVIAL. The same is true of other languages. A review by the writer of programs written in NELIAC, IPS, and JOVIAL by Navcossaet did not reveal a single example of a "pure" language program. Every program was tied to a particular computer due to the mixing of two or more languages, including machine language.

There are many other standards necessary to achieve compatibility in ADP and, although they are less significant than a language standard, taken as a group they become important. The Chief of Naval Operations has recognized this and issued an instruction whose purpose is to "delineate basic responsibilities for ensuring: a. standardization and compatibility within and between Naval Command and Control Systems; and, b. establishment of satisfactory interfaces of these systems within the World-Wide Military Command and Control System."[18]

By this instruction, the Naval Command and Control Systems Executive (OP-03C) is designated as the centralized authority in standardization and compatibility matters. The writer believes that the lack of success in fulfilling this responsibility is further indication of the need for adjusting the CNO organization which is discussed later.

One additional standard is sufficiently important to warrant separate treatment, i.e., the standard definition of data elements.

Data Element Definition. In any scheme for the storage of information for later recollection, an indexing system must be provided. Therefore, the information must be organized into a hierarchy of groups and subgroups, with keys provided to allow selective retrieval. The ultimate subgroups of information may be called data elements and data items. A data element has been defined as "a basic unit of information having a unique meaning and which has subcategories (data items) of distinct units and values. Examples of data elements are military personnel grade, sex, race, geographic location, and military unit." A data item has been similarly defined as "a subunit of descriptive information of value classified under a data element.[19, 20, 21, 22] For example, the data element "military personnel grade" contains data items such as "sergeant, captain, and colonel."

An earlier section, which describes a generalized information processing system, addresses the subject of information storage and retrieval from the standpoint of capability: primarily speed of response to a query. The point here is that regardless of the structure employed and regardless of the purpose of that structure, the stored information will always have small groupings which may be called data elements, and there is an absolute necessity to provide a set of well-defined descriptors for use as indexing keys.

One of the characteristics of any computer-based system is its comparative inflexibility. This inflexibility is partly due to the completely literalmindedness of the computer. The level of sophistication of even the most complex computer system is such that all programming must be very precise. There is no ability inherent in a computer to read contextual implications into communications with the computer. Therefore, when structuring information for computer storage and retrieval, it is necessary to do so in a very precise and unambiguous way. The computer system "knows" about the scheme of storage by way of the resident storage and retrieval program. The system will perform properly as long as the computer system is presented with a set of unambiguous descriptors of the data elements and items to be retrieved. It will not, however, be able to handle synonyms of descriptors not used at the time of storage. In order to assure retrieval, there obviously must be a set of commonly understood terms for use as keywords or descriptors by both the storer and the retriever.

The problem of definition is neither new or confined to computer systems. For instance, the Joint Chiefs of Staff have recognized that the standard definition of a term is essential to effective communication:

Much confusion is caused by several different terms being used when the same definition is intended. For example, "central war," and "general war," "unlimited war," "all out war," "total war," have all been used to define the same conditions. The use of different terms which mean the same thing must be avoided. The problem is particularly applicable to the areas of strategy, forces, and arms control, but, in general, applies to all fields.[23]

There is no need to elaborate further on this point. The need for standard definitions in any field where common understanding is essential is obvious. But, it should be emphasized that this need is even more acute in dealings with an inflexible and literal minded machine.

It has heen previously pointed out that in the design of computer-based systems there is a natural tendency to concentrate too much on the tangible hardware and to neglect the equally important intangible software. Software standards in the form of standard data elements and items are no exception to this assertion. Considering the fact that ADP systems in strategic command and control have been under development with an integrated system as an objective for at least 10 years, it is symptomatic that the first DOD directive regarding data element standardization is dated December 1964, just over two years ago.[24] As it now stands, the establishment of a centralized master file of all standard data elements and related codes has been assigned to the Assistant Secretary of Defense (Comptroller.)[25] The Assistant Secretary is also assigned a delegable responsibility to publish standard data elements and codes as identified and developed.[26] As of March 1967, over two years later, nothing has been published. The Secretary of the Navy has assigned responsibilities for implementation of a data element and data code standardization program to the Office of Management Information and the components of the Navy Department.[27]

The Joint Chiefs of Staff have addressed the problem of standard data elements in their publication on national military command system standards. That publication is used in the preparation of data for exchange within the National Military Command System (NMCS) and by elements of the World-Wide Military Command and Control System in all reports submitted to the NMCS. Approved NMCS standards which normally are published in other publications of the Joint Chiefs of Staff, the Department of Defense, or the Executive Branch of the Government are not repeated. Codes for geographic areas, logistics planning and reporting, unit identification, information interchange, and punched cards are currently included.[28]

III — ORGANIZATIONAL PROBLEMS

"Brook Bill." The application of digital computers to government processes has been generally uncoordinated.[1] This circumstance has led to duplication of effort, inefficiencies, and unwise equipment procurement. The Comptroller General of the United States made more than 60 audit reports to Congress over a seven year period, 1958-65, which indicated wastes in excess of $100 million dollars per year.[2]

An outgrowth of the obvious need for coordination within the Federal Government is Public Law 89-306, 89th Congress, dated 30 October 1965, popularly known as the "Brook Bill." It is an act "to provide for the economic and efficient purchase, lease, maintenance, operation, and utilization of automatic data processing equipment by Federal departments and agencies." It provides for administration by the Administrator of the General Services Administration, for scientific and advisory services, including the establishment of standards by the Secretary of Commerce (primarily through the National Bureau of Standards), and for fiscal and policy control by the Bureau of the Budget. An additional feature is the establishment of an ADP fund "which shall be available without fiscal year limitation for . . . the procurement . . . of equipment, maintenance, and repair of such equipment . . . necessary for the efficient coordination, operation, utilization of such equipment by and for Federal agencies." The Administrator of the General Services Administration shall not "impair or interfere with the determination by agencies of their individual automatic data processing equipment requirements, including the development of specifications for and the selection of the types and configurations of equipment needed. The Administrator shall not interfere with, or attempt to control in any way, the use made of automatic data processing equipment or components thereof by any agency."

Department of Defense. The functions assigned to the General Services Administration, the Secretary of Commerce (National Bureau of Standards), and the Bureau of the Budget apply with some exceptions within the Department of Defense. The Secretary of Defense has assigned responsibility within the Department as follows:

a. The Director, Defense Research and Engineering validates plans for the acquisition of ADPE in support of the World-Wide Military Command and Control System, . . .

b. The Assistant Secretary of Defense [Comptroller] is responsible for ADP oriented standard data elements and associated codes.

c. The Assistant Secretary of Defense [Installations and Logistics] is responsible for the Department of Defense ADP Program and has promulgated policies on the selection, acquisition, sharing, re-use, release, and transfer of ADPE.

d. The Defense Intelligence Agency validates ADPE used for intelligence processing.

e. The Defense Supply Agency coordinates transfer of ADPE among Department of Defense components and with the General Services Administration.[3]

The above listing of responsibilities as they are assigned in the Defense Department is the latest available summary (March 1967). It represents the current phase in a series of adjustments which commenced with the establishment of the Department of Defense in 1947. The National Security Act of 1947, as amended, placed special emphasis on the management of research and development activities within the Defense Department by vesting its overall direction and control in the Secretary of Defense. The basic policy behind this move was, as described in the Act, "to eliminate unnecessary duplication in the Department of Defense, and particularly in the field of research and engineering."[4]

The Defense Reorganization Act of 1958 increased still further the responsibilities of the Secretary of Defense, particularly in the operational direction of research and development activities. Pursuant to the Reorganization Act of 1958, a new position of Director of Defense Research and Engineering was established to supervise all activities in this area. Under the provisions of the Reorganization Act, the Director's responsibilities encompass both executive as well as staff functions, including the supervision of all research and engineering activities in the Department of Defense. The Director also acts as the principal adviser to the Secretary of Defense on scientific and technological matters and directs and controls research and engineering activities that require centralized management.[5] It may be seen, therefore, that most of the basic decisions affecting the development of command and control systems have been made at the Defense Department level.

Until late 1963 the individual services remained almost completely responsible for defining command and control requirements on an individual basis. As a result, most of the command and control systems have been service-oriented. This arrangement was not completely compatible with the command and control system concept.

In mid-1961 the Advance Research Projects Agency (ARPA) assigned a "Digital Computer Application Study" to the Institute for Defense Analysis.[6] Carried out by computer and technical experts across the country, the study reported a great deal on the proper role of computers in command and control. One of the most significant findings was that command personuel must be involved intimately in the design and development of their computer-aided command information system.

The Secretary of Defense took action by issuing a memorandum in October 1963 which charged the unified and specified commanders to:

Establish and submit to the Joint Chiefs of Staff and the Secretary of Defense for approval the operational requirements, and any major modifications thereto, for his C&C system; participate in the formulation of system design and system performance and design specifications for his C&C system; participate in the formulation of engineering, management, procurement, facility construction and installation plans, developed to satisfy his C&C requirements . . . establish procedures which regulate (a) management arrangements for operating C&C facilities; (b) input/output formats, schedules, and priorities for communications links, computers and displays; (c) information and documentation formats; (d) content of computer programs and data base, and (e) development of computer programs.[7]

Therefore, for the past three and one half years, the unified/specified commander has been the dominant figure in command and control. However, it probably is better to say that the unified/specified commander should have been the dominant figure. There are indications that this approach is not working much better than its predecessor. The primary reasons given are a lack of information processing experience and expertise on the part of the operational commanders and a serious dilution of the reservoirs of technical talent which do exist.[8]

The Joint Chiefs of Staff have been given the responsibility for providing guidance and direction to the unified and specified commanders in the development and acquisition of their systems. The organizational entity through which this is supposed to be accomplished is called the Joint Command and Control Requirements Group (JCCRG). The Chief of the JCCRG has been assigned functions relating to functional and technical system design of the NMCS, to apprising the JCS on needs or changes in present or future command and control requirements, and to developing guidance for the unified and specified commanders.

The organizational problems associated with ADP and command and control on the DOD level are thoroughly analyzed in an Air University thesis by Maj. G. E. Breton, U. S. Air Force. Major Breton concludes that there is an urgent need for the DOD to provide a greater degree of unified guidance and direction, that increased centralized management control be exercised over the many independent DOD programs, and that techniques and procedures for the development of command and control systems should be standardized wherever possible.

Department of the Navy. The Special Assistant to the Secretary of the Navy is responsible for all Navy matters related to ADP systems and equipment and is designated as the Navy Automatic Data Processing Policy official.[9] The Office of Management Information is supervised by him and has as one of its functions the provision of staff support to the Special Assistant.[10]

Within the Office of the Chief of Naval Operations, the responsibility for command and control ADP is divided several ways. The Assistant Chief of Naval Operations for Communications (OP-94) is logically responsible for communications links which will someday tie the various Navy automated command and control systems into a single network. This is a closely related subject worthy of another entire paper and will not be covered here. The Command, Control, and Electronics Division (OP-35) under the Deputy Chief of Naval Operations for Fleet Operations and Readiness (OP-03) is responsible for establishing operational command and control requirements. The Command Systems Branch (OP-724) of the Development Programs Division (OP-72) under the Deputy Chief of Naval Operations for Development (OP-07) is responsible for directing the actual development of equipment to meet these requirements. In actuality, a close working relationship exists between these two groups in all stages of the program from the development of operational concepts and requirements through to the preparation of a development plan. This approach tends to temper the establishment of requirements to conform to the technical state-of-the-art.[11]

The Deputy Chief of Naval Operations (Fleet Ops and Readiness) also has assigned to him a Naval Command and Control Systems Executive (OP-03C) whose mission is "to insure the expeditious achievement of effective strategic and tactical systems, facilities, and related means for command and control of naval forces, and for naval support of unified and specified commanders and higher authorities in command and control, and to coordinate matters related thereto."[12]

The Operations Evaluation Group (OEG), which functions under the Center for Naval Analysis, also plays an important role in the Navy Command and Control effort. This group analyzes operational problems concerning the actual operation of forces and material afloat. Their analysis is used as the basis for further exploration prior to establishing a specific operation requirement.[13] For longer range, more conceptual analysis, problems are referred to the Institute for Naval Analysis.

The problems, confusion, and uncoordinated ADP development experienced by the Navy in the past, still being experienced today, and/or to a certain extent as they will be experienced in the future are due to many factors. Primary among those problems identified are the following:

(1) Parallel but independent ADP development in the command/control, business/logistics, and scientific areas. Navy directives and regulations were (and are) inadequate and have all but completely neglected software.

(2) The organization of OPNAV is logically incorrect.

(3) Two different commands are involved in the design and specification of strategic data systems.

(4) Tortuous administrative procedures are incompatible with evolutionary system development.

Each of these problem areas will be discussed individually.

Parallel but Independent Development. The parallel but independent (from command and control) development of ADP in business/logistics and scientific applications areas has led to some confusion. Also, the available guidance in the form of directives and regulations is primarily hardware-oriented. The passage of the "Brook Bill" and the resolution of responsibility in the Navy Department regarding ADP and ADPE as set forth in SECNAV Instruction 10462.7B (commonly referred to as the "blue book") has done much to clarify the situation. However, this instruction still leaves several questions unanswered regarding policy and procedures in the overall Navy ADP program versus ADP in command and control. It also needs to provide clearer guidance in the differentiation between ADP and ADPE policies. It might be noted as an indication that the table of contents of this instruction alternately uses the terms ADP and ADPE. The predecessor instruction, 10462.7A of 26 February 1964, was titled "Navy Data Processing Equipment Program" and dealt exclusively with ADPE. It is obvious that the newly established Office of Management Information (OMI) used the former ADPE instruction as a point of departure in expanding to the overall ADP program.

Distribution of SECNAV Instruction 10462.7B was made only to the Navy Department. Appropriate bureaus and offices must forward the instruction to the Operating Forces and Shore Establishment as necessary or write their own in consonance with it. At the time of this writing (February 1967), the CNO (OP-354) had forwarded the instruction to the various OpCon (Operations Control) centers unofficially for use until official action could be taken. Hopefully some of the unanswered questions will be covered at that time. The SECNAV instruction does apply to operational command and control, including associated intelligence, so far as the management and control of the ADPE is concerned. It does not apply regarding the development and use of ADPE in command and control[14] or regarding ADPE resource sharing.[15]

The writer attended a briefing in Washington in November 1966 in which the Office of Management Information (OMI) was proposing an adjustment to the CNO organization which would provide the means to bring some order out of the existing chaos. The most striking feature of the proposal is the combining of the Command and Control (C^2) and the Management Information Systems (MIS) management. Basically the proposal would centralize control of all Navy information systems including audit and cost-analysis at the Special Assistant to the Secretary level; delegate control planning, FYDP (Five-Year Defense Plan) programming, systems design, and computer programming to the CNO/CMC level; establish a new Assistant Chief of Naval Operations to centralize CNO's information system functions; and expand the functions of the Naval Command System Support Activity (Navcossaet — a field activity of CNO) to include analysis, design, and programming for both C^2 and MIS throughout the Navy.

On 4 February 1967 the Secretary of the Navy announced the "implementation of a long-range plan for the orderly improvement of computer-based information systems and automatic data processing capabilities within the Department of the Navy."[16] This is the start of the development of a Department of the Navy Management Information and Control System (MICS) designed to meet total information and control requirements except those integral to operational and strategic command and control; development and processing of weather, warning, and intelligence data; and scientific and engineering processes. The establishment of a MICS would provide the centralized control and overall coordination of ADP in areas other than those excepted above.

Dating from the time when intra-Defense Department discussions led to the promulgation of DOD Directive S-5100.30, the Navy has been trying to provide similar centralized control and coordination to ADP in C^2.[17] The results have not been too impressive, but there is some accrued benefit. The next step beyond the establishment of a MICS is the establishment of the means to relate the MICS to the other areas, i.e., C^2, weather, warning, intelligence, and engineering. The danger to C^2 from all this is that the already strained ADP resources developed in C^2 may be further diluted by other demands.

Office of the Chief of Naval Operations Organization. A specific curiosity regarding the present OPNAV organization is apparent from the organizational diagram for OP-03. Six of the seven OP-3X's have a naturally-grouped function. The exception is OP-35 with Command and Control somehow grouped with Electronics. It is true that ADPE used in command and control is primarily electronic in nature but ADPE is only part of ADP. The software is certainly not electronic, and software has been previously shown to account for more than half of the cost in an ADP system. The systems analysis effort that must be expended before a system can be properly designed is not electronic either. And, even if the strong electronic flavor of ADP is granted, the facet of electronics handled by the other branches within the OP-35 Division bears no relation whatsoever to ADPE.

Strategic command and control more or less grew up in OP-35 and was placed there originally at the same time NTDS (Naval Tactical Data System) was moved from OP-36 in 1961. NTDS was correctly considered at that time to be a close relative to automated strategic command and control, so it seemed logical to consolidate control of both systems to provide for a common denominator of standardization, compatibility, and interface.

The briefing given by the Office of Management Information, referenced above, had as one of its main points the establishment of a new Assistant Chief of Naval Operations (ACNO) as a means of coordinating and controlling ADP in the Navy. It has recently been learned unofficially that this portion of the proposal will probably be modified and accomplished through the expansion of the General Planning and Programming Office (OP-90), i.e., the formation of an OP-90X. It is believed that there is a danger to command and control inherent in the organizational adjustments being proposed. Automated command and control has serious problems and certainly cannot be held up as an example of organized development. However, when compared to the completely unregulated development of ADP in other areas, command and control ADP is considerably ahead. If MIS and C^2 development are lumped together and, in addition, if control of C^2 ADP is vested in a part of OPNAV which is by past association and function more closely identified with management, then C^2 ADP assets will be diluted by MIS requirements. This can only happen to the detriment of C^2.

Coordination between BuShips and Navcossact. One of the peculiarities in the division of responsibilities that evolved during the past five or six years is that between the Bureau of Ships (BuShips) and the Naval Command Systems Support Activity (Navcossact — a field activity of CNO).[18] The main problem associated with the division of responsibility is apparent in an article which quoted the former Commanding Officer of Navcossact:

> *As stated earlier, Navcossact concerns itself primarily with software development while working closely with BuShips which is usually designated as the lead Bureau in systems development. As such, BuShips provides the hardware and an associated systems software package (executive system) along with a test functional program: to demonstrate the operational capability of the system . . .*[19]

A test functional program must, in fact, be considerably more than a test. In order to be meaningful, it must be an actual program entailing a large amount of effort and expense to design and program. The test functional program ends up as the initial ADP system capability.

Navcossact is charged with the responsibility for providing centralized and coordinated technical support to evolving Naval and National Command and Control Systems.[20] It is primarily a software development organization, but it is also regularly called upon by OPNAV to analyze commands in order to prescribe their ADP systems. The provision of an ADP system by BuShips should therefore be in accordance with Navcossact analysis. Under existing procedures there is no regulation which compels BuShips (and now the Electronic Systems Command) to coordinate.

The Navy Department reorganization which places the Chief of Naval Material and the Electronic Systems Command in the chain of command under CNO should alleviate future problems — i.e., if OPNAV is able to provide firm direction in ADP development.

Evolutionary Development. It has been stated that the Defense Department is improving its command and control systems by adopting an evolutionary approach.[21] However, the procedures used for obtaining the required improvement approvals within the Navy Department and the Department of Defense do not lend themselves to this.[22] A literal interpretation of the instructions covering the preparation of the Specific Operational Requirements (SOR) and Technical Development Plans (TDP) under General Operational Requirement 31 (GOR-31, Command and Control) is that each incremental improvement would have to proceed through unnecessarily tortuous procedural plans.[23, 24, 25, 26, 27] (See figure 5 for the required procedure.) The required procedures are oriented toward large-scale systems and revolutionary changes rather than evolutionary implementation. As the Navy works from both ends of the command and control spectrum toward the middle, its progress should be in accordance with a single master plan but with sufficient latitude in noncritical features to allow for the desired system evolution. Paradoxically, the requirement for detailed formal planning and approval for each step leads in this case to piecemeal development of the whole.

IV — CONCLUSIONS AND RECOMMENDATIONS

This paper has concerned itself with the technical and organizational problems caused by the impact of ADP on the Naval Strategic Command and Control system. It was shown in Chapter I that the President of the United States himself has directed the increased use of ADP in Government operations. The Secretary of Defense further directed his department to provide an example in ADP for the rest of the Government to follow. The Navy's responsibility in supporting portions of the WWMCCS and the need to improve the response of command and control systems were discussed.

Chapter II covered some of the major technical problems confronting ADP in command and control. Chapter III also covered problems but sorted out those primarily organizational in nature.

It would be entirely possible to write the concluding chapter by matching conclusions and/or recommendations on a one-to-one basis with the technical and organizational problems listed in Chapters II and III. However, solutions to the problems as iterated are, for the most part, straightforward and obvious. It is considered better at this point to attempt to distill the essence of the paper into an easily remembered picture and to limit recommendations to the correction of the more fundamental problems.

Conclusions. It is concluded that the problems discussed indicate three broad areas of concern. These are a need for standardization, a need for a fast-response, generalized information processing system, and a need for an adjustment in Navy Department organization, particularly OPNAV.

Standardization. The problems of program obsolescence with new equipment procurement and of new computer development overtaking system implementation would be eliminated if there was rigid adherence to a machine independent programming language, e.g., a compiler language such as the so-called present standard, JOVIAL. The Government can reasonably make the provision of a standard compiler a condition to the acquisition of new computers.

The problems associated with the lagging development of standard data elements will not be fully apparent

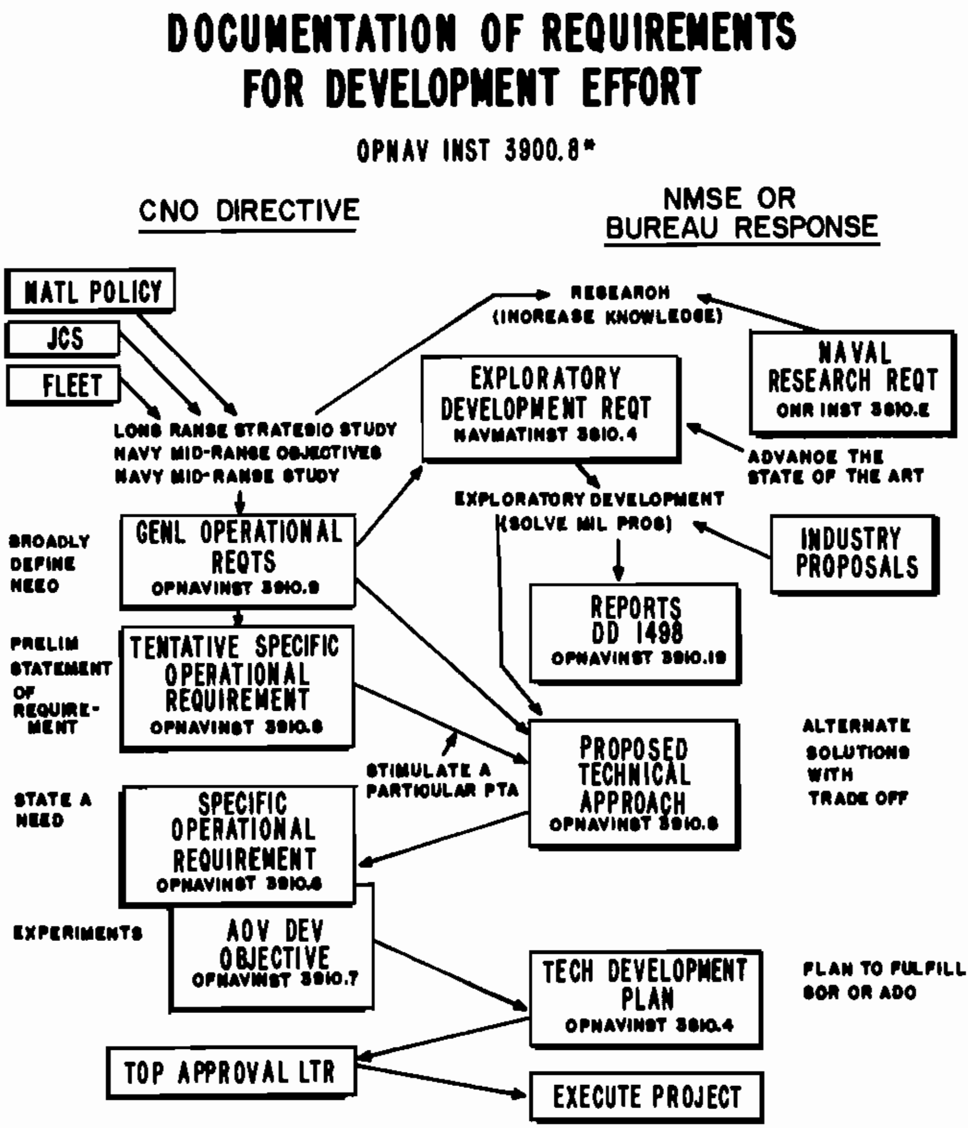


Figure 5[1] — Documentation of Requirements for Development Effort
OpNav Inst 3900.8*

*All instruction numbers are shown without revision letters. Latest revisions apply.

[1]U.S. Office of Naval Operations, "Planning Procedures for the Navy Research, Development Test and Evaluation (RDT&E) Program," OPNAV Instruction 3900.8C (Washington: 17 January 1966), Encl. (1).

until after computer systems are interconnected and there is a daily need for data exchange. Much can be done now to preclude overwhelming problems in the future.

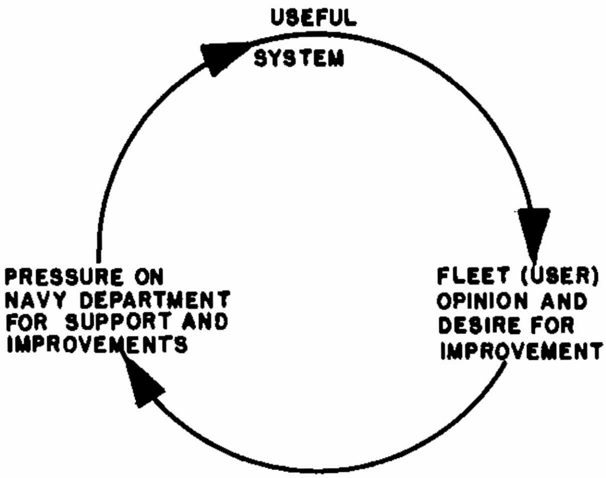
Fast-response, Generalized Information Processing System. The development and application of a fast-response, generalized information processing system is the key to major breakthrough in the use of ADP in strategic command and control. It is neither possible nor desirable to automate staff processes. It is possible and desirable to automate the routine and time consuming collection, storage, retrieval, correlation, collation, and formulating of information needed by the staff officer in the performance of his duties. The requirements for such a system, both software and hardware, are available now. All that is required is a clear recognition of the need and of the subsequent steps necessary to develop the system.

Navy Department Organization. The techniques of ADP are comparatively new and are very complex. It is therefore not surprising to find dislocations in its application to command and control, as elsewhere. Two organizational elements are particularly well located and have the charter to provide the needed direction and guidance. These are the Joint Command and Control Requirements Group (JCCRG) on the DOD level and the Naval Command and Control Systems Executive (OP-03C) on the OPNAV level. An assessment of the present state of affairs forces the conclusion that these two organizational elements have almost completely failed in their purposes. Specifics regarding DOD-level problems are outside the scope of this paper.

Usually, when a particular organizational element fails to perform its assigned function some other element senses the failure and corrective action quickly follows. Since ADP in command and control is the application of new technology to fleet requirements, the usual feedback is not present. One of the fundamental difficulties is that there is no present system in the hands of the user from which he can extrapolate requirements for a better future system. Potential users of ADP are at a loss to respond to the question, "What are your requirements?" The process may be viewed as cyclical:

Recommendations. There is an urgent need to adjust the organization of the Navy Department, particularly OPNAV, thereby enabling the necessary planning and direction to preclude the generation of additional problems. This change should be designed to get the fleet feedback cycle started and allow the concentration of talent to deal with technical problems such as those listed in Chapter II. The subject of organization is being considered at this time at the SECNAV level in connection with the establishment of a MICS. The Navy should take advantage of the opportunity presented by this renewed interest and organize to improve command and control in addition to combining direction of command/control and business/logistics ADP.

Looking back over the effort already expended in applying ADP to command and control, it may be wondered why the cyclic process has not been made self-sustaining through the sheer magnitude of the man-years and money lavished upon it. It is believed that this is primarily the result of the failure of responsible persons to appreciate the need for a fast-response, generalized information processing system. The staff officer in the fleet will continue to view ADP as a special purpose "gimmick" rather than an everyday utility until the means to interact personally with the system are pro-



vided. The necessary means to do this include both the hardware interface, which should be on his desk (and as familiar to him as a telephone), and the system hardware/software to provide practically instantaneous response. When the ADP system becomes a useful utility the enthusiasm and desire for improvement will follow, and the cycle will sustain itself.

The key to resolution of the fundamental problem of fleet feedback is the extraordinary concentration of talent in order to get the cycle started. This has been done in the past in special programs such as Polaris. It is recommended that a Project Manager for ADP Applications be established in the Naval Material Command to provide intensified ADP systems management. This Project Manager should provide the necessary coordination for all ADP application areas thereby removing the semantic and artificial distinction between command/control and other applications. Coupled with effective SECNAV and OPNAV direction, this Project Manager would enable concurrent improvement in both command/control and other applications.

As soon as the Navy seriously addresses the problems and concentrates technically competent personnel to adapting ADP to command and control, the development and application of a fast-response, generalized information processing system will naturally follow. Likewise, the advantages of standardization will be more fully appreciated.

It is hoped that whatever is done to improve ADP throughout the Navy is not done at the expense of what assets have been accrued by command and control. The current interest in ADP applications has received very high-level encouragement. However, the importance of a responsive command and control system far outweighs other considerations.

FOOTNOTES

INTRODUCTION

1. Bernard B. Fall, *Street without Joy* (Harrisburg, Pa.: Stackpole, 1961), p. 1.
2. George E. Breton, "The Development and Acquisition of Military Command and Control Systems: a Need for More Centralized Management," Unpublished Thesis, U.S. Air University. Maxwell Air Force Base, Ala.: 1965.

I — GENERAL BACKGROUND

1. Presidential Memorandum of 28 June 1966.
2. Secretary of Defense Memorandum of 29 July 1966.
3. U.S. Joint Chiefs of Staff, *Dictionary of United States Military Terms for Joint Usage,* 3d rev. JCS Pub. 1 (Washington: U.S. Govt. Print. Off., 1964), p. 32.
4. William LaLiberte, and John B. Shea, "OPNAV C/C Execs Take a Forward Look at Strategic and Tactical Systems," *Data,* January 1966, p. 41.
5. John B. Bestic, "National Command System: Decision Instrument for the Chief Executive," *Data,* March 1964, p. 9.
6. *Ibid.,* p. 11.
7. "OPNav's Adm. Lambert Tells of Navy C-C Program Expansion," *Data,* February 1965, p. 15.
8. U.S. Dept. of Defense, "Responsibility for the Support of the Headquarters of Unified and Specified Commands," DOD Directive 5100.3 (Washington: 21 February 1964).
9. U.S. Secretary of the Navy, "Responsibility for the Support of Unified and Specified Commands," SECNAV Instruction 5410.4C (Washington: 4 March 1964).
10. Thomas F. Rogers, "C^2 System Development: a Shared Responsibility," *Data,* January 1966, p. 9.
11. Princeton University, Econometric Research Program, *The Command and Control Structure* (Princeton: 1962), p. 1.
12. Theodore C. Sorensen, *Kennedy* (New York: Harper & Row, 1965) p. 708, 710, 713.
13. "Effectiveness, Responsiveness of National Command System Vital to U.S. Security," *Armed Forces Management,* July 1966, p. 43.

II — TECHNICAL PROBLEMS

1. U.S. Bureau of the Budget, *Report to the President on the Management of Automatic Data Processing in the Federal Government* (Washington: U.S. Govt. Print. Off., 1965), p. 1.
2. *Ibid.,* p. 2-4.
3. U.S. Civil Service Commission, *A Study of the Impact of Automation on Federal Employees* (Washington: U.S. Govt. Print Off., 1964).
4. Hal Bamford, "Software Is the Greater of the Two 'Wares' Problem," *Armed Forces Management,* July 1963, p. 55.
5. *Ibid.*
6. Informatics, Inc., *Advanced Naval Tactical Command and Control Study, Methodology* (Sherman Oaks, Calif.: 15 January 1965), v. IV, p. IV-2-141.
7. *Ibid.*
8. Honeywell Electronic Data Processing, *Mildata Study,* Final Report (Wellesley Hills, Mass.: 1964), v. II, p. E-2.
9. "A Systematic Approach to Command/Control," *Data,* January 1966, p. 13.
10. *Ibid.*
11. The system is called Information Processing System (IPS) and it has been implemented on several different computers, e.g. CDC-1604, IBM-7090, and USQ-20, by the Naval Command Systems Support Activity (NAVCOSSACT).
12. Martin J. Twite, Jr., "Organization of Structured Information for Mechanized Retrieval Operations and Some Related Efficiency Considerations," Unpublished Thesis, U.S. Naval Postgraduate School, Monterey, Calif.: 1964.

13. For instance, Project MAC at MIT, the Systems Development Corporation SDC time sharing system, the COLINGO System by MITRE Corporation.
14. "GE Studies Retrieval Problems," *Electronic News*, 7 November 1966, sec. 2, p. 28.
15. "Data Cell" is actually the name of the IBM product which is representative of this type of pseudo-random access device.
16. T. H. Bonn, "Mass Storage: a Broad Review," *Proceedings of the IEEE*, December 1966, p. 1861.
17. David Lambert, "Naval Command/Control Offers Growth Potential," *Data*, March 1964, p. 18.
18. U.S. Office of Naval Operations, "Standardization and Compatibility of Naval Command and Control Systems," OPNAV Instruction 5230.2A (Washington: 7 April 1965).
19. U.S. Dept. of Defense, "Data Elements and Data Codes Standardization Program," DOD Directive 5000.11 (Washington: 7 December 1964).
20. U.S. Dept. of Defense, "Data Elements and Data Codes Standardization Procedures," DOD Instruction 5000.12 (Washington: 27 April 1965).
21. U.S. Secretary of the Navy, "Data Elements and Data Codes Standardization Program," SECNAV Instruction 10462.11A (Washington: 29 April 1966).
22. U.S. Navy Office of Management Information, "Data Elements and Data Codes Standardization Program," OMI Instruction 10462.1 (Washington: 30 April 1966).
23. U.S. Joint Chiefs of Staff, Dictionary, JCS Pub. 1, p. i.
24. DOD Directive 5000.11.
25. *Ibid.*, par. IV.A.3.
26. *Ibid.*, par. IV.B.1.
27. SECNAV Instruction 10462.11A, par. 6.
28. U.S. Joint Chiefs of Staff, *National Military Command System Standards*, JCS Pub. 7 (Washington: U.S. Govt. Print. Off., 1964).

III — ORGANIZATIONAL PROBLEMS

1. U.S. Congress, House, Committee on Government Operations, *Automatic Data Processing Equipment*, Hearings (Washington: U.S. Govt. Print. Off., 1965), p. 1-2.
2. *Ibid.*, p. 247-269.
3. U.S. Secretary of the Navy, "Department of the Navy Automatic Data Processing Program," SECNAV Instruction 10462.7B (Washington: 11 March 1966), par. II.E.
4. U.S. Dept. of Defense, "Functions of the Department of Defense and Its Major Components," DOD Directive 5100.1 (Washington: 31 December 1958), p. 1.
5. U.S. Dept. of Defense, "Director of Research and Engineering," DOD Directive 5129.1 (Washington: 10 February 1959), p. 1-2.
6. "Where the Computer Fits in Command and Control," *Armed Forces Management*, July 1962, p. 22.
7. "How Not to Build C&C Systems Is Still an Unanswered Question in Defense," *Armed Forces Management*, July 1966, p. 109.
8. *Ibid.*
9. U.S. Secretary of the Navy, "Assignment of Responsibilities to and Among the Civilian Executive Assistants to the Secretary of the Navy," SECNAV Instruction 5430.7G (Washington: 14 February 1966).
10. U.S. Secretary of the Navy, "Establishment of the Office of Management Information," SECNAV Instruction 5430.71 (Washington: 11 December 1964).
11. Lambert, "Naval Command/Control Offers Growth Potential," p. 16.
12. U.S. Office of Naval Operations, *Organization Manual* (Washington: 1962), p. 03-4.
13. Lambert, "Naval Command/Control Offers Growth Potential," p. 17.
14. SECNAV Instruction 10462.7B, chap. I, par. C.3, p.I-1.
15. *Ibid.*, Appendix C, par. 3, p. C-1.
16. U.S. Secretary of the Navy, "Improved Information and Control Systems and ADP Management," SECNAV Notice 5200 (Washington: 4 February 1967).
17. U.S. Dept. of Defense, "Concept of Operation of the World-Wide Military Command and

Twelve: Alfred Thayer Mahan: The Impact of ADP on the Naval Strategic

Control System (WWMCCS), (U)," DOD Directive S-5100.30 (Washington: October 1962). SECRET

18. The Navy Department was reorganized in the spring of 1966 and the functions of the Bureau of Ships addressed here have since been assimilated by the new Electronics Systems Command.
19. "Capt. Stan Foote at NAVCOSSACT Details Navy C-C Projects," *Data,* February 1965, p. 25.
20. U.S. Office of Naval Operations, "Submission and Processing of Project Requests and the Prosecution of Projects for Command Systems Support," OPNAV Instruction 5230.1A (Washington: 1 October 1964), par. 4.a.
21. Rogers, p. 9.
22. Informatics, Inc., p. IV-1-5.
23. U.S. Office of Naval Operations, "Planning Procedures for the Navy Research, Development Test and Evaluation (RDT&E) Program," OPNAV Instruction 3900.80 (Washington: 17 January 1966).
24. U.S. Office of Naval Operations, "General Operational Requirements," OPNAV Instruction 3910.9A (Washington: 11 August 1965).
25. U.S. Office of Naval Operations, "Instructions for the Preparation of Specific Operational Requirements (SOR) and Tentative Specific Operational Requirements (TSOR)," OPNAV Instruction 3910.6B (Washington: 11 June 1964).
26. U.S. Office of Naval Operations, "Monthly Project Evaluation," OPNAV Instruction 3910.12A (Washington: 19 August 1965).
27. U.S. Office of Naval Operations, "Technical Development Plan," OPNAV Instruction 3910.4B (Washington: 24 June 1964).

BIBLIOGRAPHY

Bamford, Hal. "Software Is the Greater of the Two 'Wares' Problem." *Armed Forces Management,* July 1963, p. 52-55.

Bestic, John B. "National Command System: Decision Instrument for the Chief Executive." *Data,* March 1964, p. 7-13.

Bonn, T. H. "Mass Storage: a Broad Review." *Proceedings of the IEEE,* December 1966, p. 1861.

Booda, Larry, "Command, Control Procurement Shifted." *Aviation Week,* 25 November 1963, p. 33-34.

Breton, George E. "The Development and Acquisition of Military Command and Control Systems: a need for more Centralized Management." Unpublished Thesis. U.S. Air University, Maxwell Air Force Base, Ala.: 1965.

Callan, Robert W. and Kinsella, W. T. *The Structure and Operation of Top-Level Military Command.* Santa Barbara, Calif.: General Electric Co., 1962.

Callan, Robert W. and Thompson, Frederick B. *Concept for the Navy Operational Control Complex of the Future.* Santa Barbara, Calif.: General Electric Co., 1962.

"Capt. Stan Foote at NAVCOSSACT Details Navy C-C Projects." *Data,* February 1965, p. 23-26.

Cullins, Peter K. "Command and Automation." Unpublished Thesis. U.S. Naval War College, Newport, R.I.: 1964.

"Effectiveness, Responsiveness of National Command System Vital to U.S. Security." *Armed Forces Management,* July 1966, p. 43-46.

Fall, Bernard B. *Street without Joy.* Harrisburg, Pa.: Stackpole, 1961.

"For the Sea-Going Services, the Naval and Marine Tactical Data Systems Are 'the Best since Radar.'" *Armed Forces Management,* July 1966, p. 78-81.

"GE Studies Retrieval Problems." *Electronics News,* 7 November 1966, sec. 2, p. 28.

Honeywell Electronic Data Processing. *Mildata Study.* Final Report. Wellesley Hills, Mass.: 1964. v. II.

"How Not to Build C & C Systems Is Still an Unanswered Question in Defense." *Armed Forces Management,* July 1966, p. 109-112.

Informatics, Inc. *Advanced Naval Tactical Command and Control Study; Methodology.* Sherman Oaks, Calif.: 15 January 1965, v. IV.

Kochen, M., et al. *Computers and Comprehension.* Santa Monica, Calif.: Rand, 1964.

LaLiberte, William and Shea, John B. "OPNAV C/C Execs Take a Forward Look at Strategic and Tactical Systems." *Data,* January 1966, p. 39-41.

Lambert, David. "Naval Command/Control Offers Growth Potential." *Data,* March 1964, p. 15-18.

Levien, Roger E. *National Strategy Implications for Command and Control.* Santa Monica, Calif.: Rand, 1963.

"Op Nav's Adm. Lambert Tells of Navy C-C Program Expansion." *Data,* February 1965, p. 15-19.

Orwell, George. *Nineteen Eighty-Four.* New York: Harcourt, Brace, 1949.

Patrick, Robert L. *A Technique for Improving the Management of a Computer Installation.* Santa Monica, Calif.: Rand, 1964.

Princeton University. Econometric Research Program. *The Command and Control Structure.* Princeton: 1962.

Read, Thornton. *Command and Control.* Princeton: Princeton University, Center of International Studies, 1961.

Rogers, Thomas F. "C[4] System Development: a Shared Responsibility." *Data,* January 1966, p. 8-9.

Schlesinger, James R. *The Political Economy of National Security.* New York: Praeger, 1960.

Slaughter, Lawrence H. "Computers in the Department's Future." *Department of State Newsletter,* no. 66, October 1966.

Sorensen, Theodore C. *Kennedy.* New York: Harper & Row, 1965.

"A Systematic Approach to Command/Control." *Data,* January 1966, p. 12-15.

Tate, Lester K. "The National Military Command System and National Strategy." Unpublished Thesis. U.S. Naval War College, Newport, R.I.: 1965.

Twite, Martin J., Jr. "Organization of Structured Information for Mechanized Retrieval Operations and Some Related Efficiency Considerations." Unpublished Thesis. U.S. Naval Postgraduate School, Monterey, Calif.: 1964.

U.S. Bureau of the Budget. *Report to the President on the Management of Automatic Data Processing in the Federal Government.* Washington: U.S. Govt. Print. Off., 1965.

U.S. Civil Service Commission. *A Study of the Impact of Automation on Federal Employees.* Washington: U.S. Govt. Print. Off., 1964.

U.S. Congress. House. Committee on Government Operations. *Automatic Data Processing Equipment.* Hearings. Washington: U.S. Govt. Print. Off., 1965.

________. ________. ________. *The Computer and Invasion of Privacy.* Hearings. Washington: U.S. Govt. Print. Off., 1966.

U.S. Dept. of Defense. "Concept of Operation of the World-Wide Military Command and Control System (WWMCCS) (U)." DOD Directive S-5100.30. Washington: October 1962. SECRET

________. "Data Elements and Data Codes Standardization Procedures." DOD Instruction 5000.12. Washington: 27 April 1965.

________. "Data Elements and Data Codes Standardization Program." DOD Directive 5000.11. Washington: 7 December 1964.

________. "Director of Research and Engineering." DOD Directive 5129.1. Washington: 10 February 1959.

________. "Functions of the Department of Defense and Its Major Components." DOD Directive 5100.1. Washington: 3 December 1958.

________. "Responsibility for the Support of the Headquarters of Unified and Specified Commands." DOD Directive 5100.3. Washington: 21 February 1964.

U.S. Joint Chiefs of Staff. *Dictionary of United States Military Terms for Joint Usage.* 3d rev. JCS Pub. 1. Washington: U.S. Govt. Print. Off., 1964.

________. *National Military Command System Standards.* JCS Pub. 7. Washington: U.S. Govt. Print. Off., 1964.

________. *Organization and Functions of the Joint Chiefs of Staff.* rev. JCS Pub. 4. Washington: 1966.

U.S. Navy. New Developments Research Dept. Personnel Research Activity. *Impact of Senior Command and Control Billets on Officer Qualifications.* Washington: 1964.

________. Office of Management Information. "Data Elements and Data Codes Standardization Program." OMI Instruction 10462.1. Washington: 30 April 1966.

U.S. Office of Naval Operations. "General Operational Requirements." OPNAV Instruction 3910.9A. Washington: 11 August 1965.

________. "Instructions for the Preparation of Specific Operational Requirements (SOR) and Tentative Specific Operational Requirements (TSOR)." OPNAV Instruction 3910.6B. Washington: 11 June 1964.

________. "Monthly Project Evaluation." OPNAV Instruction 3910.12A. Washington: 19 August 1965.

________. *Organization Manual.* Washington: 1962.

________. "Planning Procedures for the Navy Research, Development Test and Evaluation (RDT&E) Program." OPNAV Instruction 3900.8C. Washington: 17 January 1966.

________. "Standardization and Compatibility of Naval Command and Control Systems." OPNAV Instruction 5230.2A. Washington: 7 April 1965.

________. "Submission and Processing of Project Requests and the Prosecution of Projects for Command Systems Support." OPNAV Instruction 5230.1A. Washington: 1 October 1964.

________. "Technical Development Plan." OPNAV Instruction 3910.4B. Washington: 24 June 1964.

U.S. President. "Memorandum for Heads of Departments and Agencies . . . to Use the Electronic Computer . . . ." Washington: 28 June 1966.

U.S. Secretary of Defense. "Management and Use of the Electronic Computer." Washington: 29 July 1966.

U.S. Secretary of the Navy. "Assignment of Responsibilities to and among the Civilian Executive Assistants to the Secretary of the Navy." SECNAV Instruction 5430.7G. Washington: 14 February 1966.

————. "Data Elements and Data Codes Standardization Program." SECNAV Instruction 10462.11A. Washington: 29 April 1966.

————. "Department of the Navy Automatic Data Processing Program." SECNAV Instruction 10462.7B. Washington: 11 March 1966.

————. "Establishment of the Office of Management Information." SECNAV Instruction 5430.71. Washington: 11 December 1964.

————. "Improved Information and Control Systems and ADP Management." SECNAV Notice 5200. Washington: 4 February 1967.

————. "Responsibility for the Support of the Headquarters of Unified and Specified Commands." SECNAV Instruction 5410.4C. Washington: 4 March 1964.

"Where the Computer Fits in Command and Control." *Armed Forces Management*, July 1962, p. 22-24.

Wisman, W. W. "NMCS: the National Voice of Command." *Data*, January 1966, p. 16-25.

The time for taking all measures for a ship's safety is while still able to do so.

Fleet Admiral Chester W. Nimitz, in a letter to the Pacific Fleet, 18 February 1945.

When the necessity for arms ceases, armaments will disappear. The basic causes of war are not armaments, but in human minds.

Mahan, 1840-1914, Armaments and Arbitration