

A CONCEPT FOR NAVY COMMAND AND CONTROL IN THE YEAR 2000

A concept has been devised by APL that would lead to the development and deployment of an integrated Navy tactical command and control capability for the year 2000. A series of manual war games conducted at APL focusing on command and control resulted in the definition of a basic process that could be represented by a functional model. This led to a functional analysis and the formulation of a basic command and control structure. The selection of connectivities and interfaces defined an architecture that was then expanded into a conceptual Navy Command and Control System for the year 2000.

INTRODUCTION

In 1977, the Navy recognized that a concept for an integrated command and control system to support Naval warfare did not exist and requested that APL undertake a program to define an overall system to fulfill that requirement. Historically, Navy command and control systems had been developed for specific functional warfare areas (such as anti-air or anti-submarine) with little or no capability for interactive operation. Several factors drove the Navy to recognize the need for an integrated command and control (C^2) system. First, a sophisticated and complex threat to the Navy had developed, including supersonic bombers with antiship missiles. Such a threat forced the commander to make critical decisions and disseminate orders to his subordinate commanders in constantly shrinking time intervals. Second, new offensive Naval weapons scheduled for deployment in the 1980's, such as the Tomahawk cruise missile, projected Naval power to ranges beyond the horizon of the launch platform and thus required targeting data from remote sensors. Finally, defensive systems such as Aegis,¹ where a single ship may provide a major antimissile defensive capability for the entire battle group, placed stringent demands on command and control. The synergistic impact of these combat capabilities dictated a systematic development of a C^2 concept.

Our objective in this task was to define a concept for command and control, to identify a system architecture, and to develop a conceptual system that would support Naval warfare missions and lead to the design and deployment of an effective Navy command and control capability by the year 2000. This concept is defined in terms of the functions that must be performed so that the future system can operate in a projected threat environment and can accommodate new long range weapon systems currently under development. The architecture consists of (a) the functions that must be performed to achieve stated

objectives; (b) the structure within which these functions are performed; (c) connectivities within the structure to provide command, coordination, and information flow; and (d) interfaces with external entities.

The approach we followed to develop the architecture of the conceptual system is diagrammed in Fig. 1. The C^2 requirements were primarily dictated by stated Navy policies, plans, and missions; the projected threat; and the command- and control-oriented war games conducted at APL. The operational and functional requirements led us to identify the structure and needed connectivities of the architecture. We then defined a number of relevant selection criteria that allowed us to specify the functional connectivities and interfaces with higher commands, information sources, and weapons systems, thus completing a functional architecture. By mapping actual Navy commands and information sources on the architecture, a conceptual C^2 system was developed. The conceptual system addresses multiple operational commands, the different types of information sources associated with each command level, and processing operations related to surveillance and intelligence information. In addition, we established quantitative system characteristics by sizing information bases and computing information transfer rates; however, those characteristics are not presented in this paper because of security classification constraints.

THE COMMAND AND CONTROL PROCESS AND STRUCTURE

Initial effort to bound and define the Navy C^2 system revealed substantial difficulty in dealing with the many relationships of command and control in an analytical manner. Consequently, the need to represent command and control as a process of activities and events became an early objective. Drawing heavily on a series of war games conducted at APL, we de-

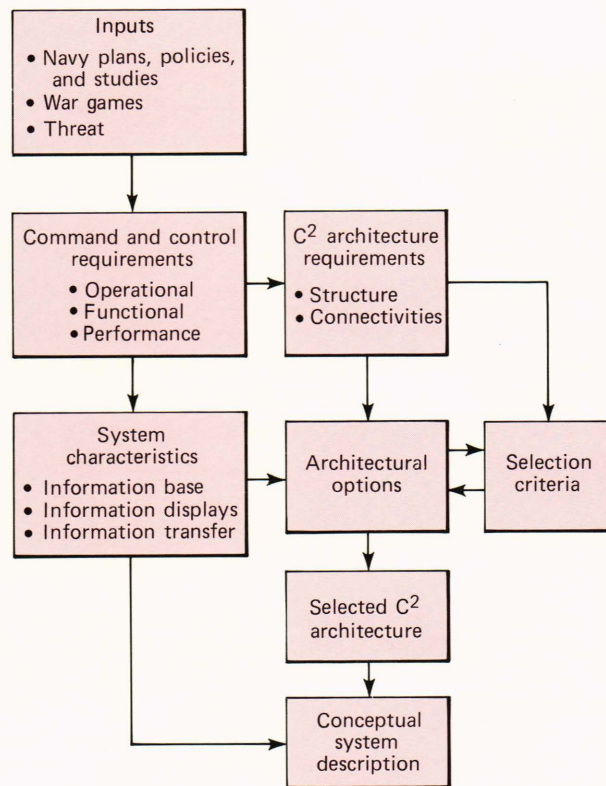


Figure 1 — Development of the architecture and the conceptual Navy command and control system.

vised such a process so that a systematic analysis of command and control could be accomplished. A functional model of the C² process is shown in Fig. 2.

Description of the Model

The process of command and control is exemplified by a set of functions at a particular command level. When we expand the model vertically, we encompass multiple echelons of command, although only three are shown in Fig. 2. The command levels are imbedded in the environment that is impacted by their decisions, but that also impacts these decisions. Each commander focuses on his domain of interest, which extends horizontally as well as downward. However, his domain of timely and accurate knowledge usually does not overlap his domain of interest, except at the lowest level. This mismatch between the two domains reflects present experience where, for a number of reasons (such as radio silence to avoid alerting the enemy), a subordinate commander may know more about certain events than his superior.

At any command level, friendly, neutral, and hostile events that occur in an environment are detected by sensors such as satellites, radio receivers, radars, sonars, and eyesight. The events are conveyed horizontally to manual- and computer-processing subsystems where they are internally labeled and, if possible, correlated with other events. These functions, in theory, could be performed nearly automatically

by the application of computer technology. The man-machine interface clearly must occur at the Evaluate function level (see Fig. 2), although some human intervention is likely at the Process and the Classify levels.

Planning, with doctrine as a major input, acts as a filter to reduce the decision-making burden on the commander. Anticipated events can be planned for, and appropriate responses can be promulgated by operation orders, contingency plans, and rules of engagement. Events that cannot be covered by planning require the commander's attention. He must select a course of action and, after deciding what response is appropriate, he has three options for implementing his decision: (a) he may choose to delegate authority to a subordinate commander, (b) he may decide to direct a subordinate commander to carry out a specified course of action via an operation order, or (c) he may decide to exercise direct control of a subordinate commander's assets, as in crisis management.

However the selected course of action is implemented, it affects the environment, generating events and responses to the events that are then sensed and processed. Clearly, command and control is a closed-loop process.

The model shows a need for the exchange of data at the Process level (see Fig. 2) in addition to the traditional links for information exchange among evaluators. The evaluator not only correlates and interprets information processed horizontally, but also may correlate information received from other levels, provided the communication link exists and the value of communicating outweighs possible penalties, as in the case of full emission control for impeding the detection of a battle group by the enemy.

Also, the model shows the connectivity with higher command levels (such as National Command Authorities and Unified/Specified Commands) as the establishment of doctrine promulgated in various plans, operation orders, other documents, and as direct orders. Doctrine is a predetermined means of achieving specified objectives. Thus, doctrine becomes a part of the planning function, and plans that can be delegated to a lower command level are sent to the evaluate function to be correlated and ranked with information derived horizontally at that command echelon.

Actions that can be delegated modify planning at a subordinate command level. Actions that a senior commander directs a subordinate commander to take either limit or expand the courses of action available to the subordinate commander. Actions that a senior commander chooses to control directly constrain the actions performed at the selected subordinate command level.

Functions and Functional Areas

The process represented by the model depicted in Fig. 2 was examined in another series of war games conducted at APL. As a result of those war games and of a detailed functional analysis of the process,

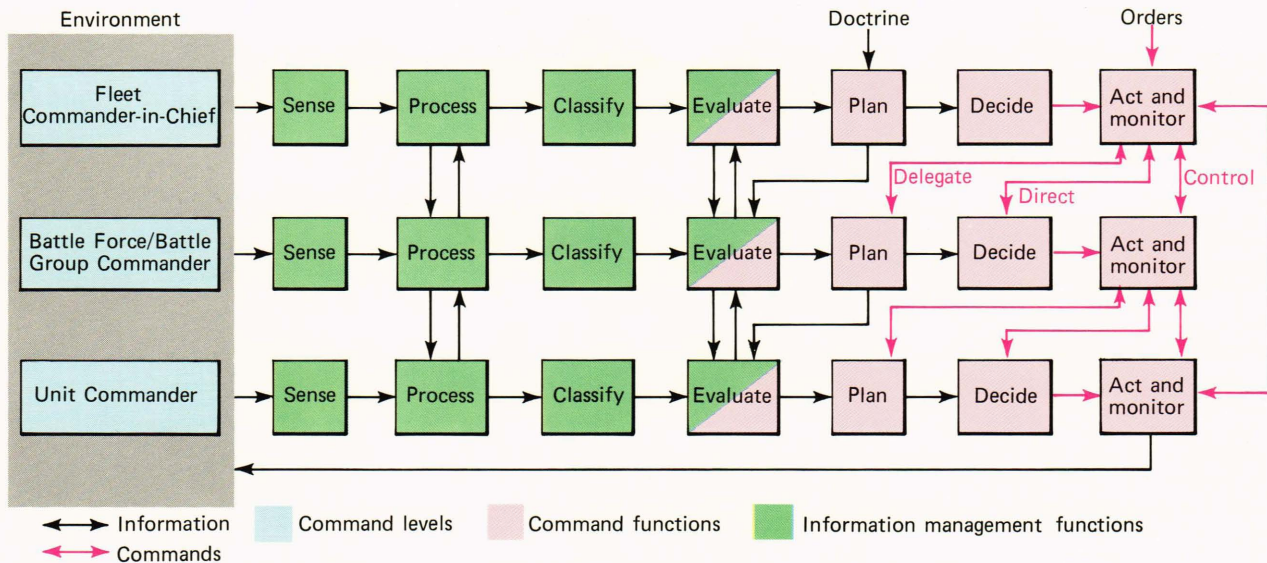


Figure 2 — The command and control process can be represented by this functional model. Each commander plans, decides, and acts on the basis of inputs from the Sense, Process, Classify, and Evaluate functions, from the existing plans, doctrine, and from the orders promulgated by higher level commanders. The decision of the commander may be either to delegate authority for a particular action to a subordinate commander (who can then do his own planning), to direct his activities using operational plans or orders, or to control his actions with specific orders. At the same time, the commander (or his staff) monitors the execution of the plans and orders. The actions taken at each level affect the environment, even though only one feedback loop is shown here for simplicity. The resulting events are sensed by the existing system, starting the new flow through the model. Thus C^2 is a closed-loop process with multiple tiers of interrelated functions and multiple feedback loops.

we identified a number of functions that a C^2 system must perform. The functions were aggregated into six “functional areas” of the C^2 architecture:

- Command
- Information management
- Engagement management
- Sensor management
- Communications management
- System management

The command functions include planning, directing, and assessing the operations of forces to achieve assigned mission objectives. Within a multiple-echelon command structure, it permits senior commanders to provide direction and guidance to subordinates who interpret, detail, and execute actions while providing their commanders with supportive information and plans. The three levels of functions comprising the command functional area are listed in Table 1.

The information management functions include acquiring, processing, and distributing data and information. The primary objective is to ensure the receipt of timely, accurate, and complete information by all users. This area provides information collection, processing, evaluation, and distribution services at each command node, resulting in an up-to-date tactical surveillance picture for the area of interest.

The engagement management functions include allocating, controlling, coordinating, and monitoring force assets that permit the execution of combat op-

erations to support the course of action selected to meet mission objectives. They coordinate the use of own-force weapons to maximize the destruction of enemy forces while minimizing the expenditure of resources in both offensive and defensive roles. This task requires that information, tactics, and the allocation of resources and responsibilities be coordinated among the various warfare areas, while an overall viewpoint of the engagement and its objectives is maintained.

The sensor management functions include allocating, controlling, coordinating, and monitoring sensor assets. They support command decision-making and weapons use (consistent with the constraints of the rules of engagement, emission control, and mutual interference with other sensor or communications assets by ensuring that surveillance information is provided to the information management functional area).

The communications management functions include allocating, controlling, coordinating, and monitoring communications assets. They provide the connectivity needed to implement the exchange of commands and information between or among designated force elements to allow the most effective direction of dispersed force elements.

The system management functions include allocating, controlling, coordinating, and monitoring force assets that comprise the C^2 system, with the exception of the communications assets. The C^2 system assets include information-handling systems, dis-

Table 1 — A set of command and control functions.

<i>Top-Level Function: Command Assigned Forces</i>	
<i>Second-Level Functions</i>	<i>Third-Level Functions</i>
Assess the tactical situation	Determine mission objectives Review the operational situation Establish rules of engagement Review enemy location, composition, and capabilities Postulate alternative enemy courses of action Develop own alternative COA's
Select the course of action (COA)	Review assigned forces for adequacy, strengths, and weaknesses Determine the requirements for, and limitations to, each COA Test the COA's for suitability, feasibility, and acceptability Choose the COA to meet mission objectives
Plan the employment of forces	Prepare the C ² system to support the COA Establish and rank the tasks to carry out the COA Coordinate support plans Identify and request nonorganic needs of operations Assign forces to tasks
Implement the COA	Prepare directives for resource allocation and force movements Issue orders

This example of three levels of functions that must be performed as part of the C² process lists the top-level function “command assigned forces” and its subsidiary second- and third-level functions. These functions are performed by each commander at any command level, though not necessarily at all times or to the same extent.

plays, and decision aids, among others. System management allows a commander to establish and adjust the C² system state, measure and assess its status, and develop options and timing for system reconfiguration or reconstitution in the event of disruption while maintaining system stability.

Basic Structure and Connectivities

A generic building block of the C² architecture consisting of the six functional areas and the functional connectivities among them is shown in Fig. 3. We believe that this building block is a reasonable representation of the functions, structure, and connectivities present at each command level, even though the scope and depth of the specific functions will vary between command levels.

The connectivities among the six functional areas have been defined as follows:

1. *Command*—The connectivity that allows a commander to direct and control his forces;
2. *Coordination*—The connectivity between functional areas required to ensure that assets are employed in accordance with command guidance;
3. *Information Exchange*—The transfer of data and information items among the various areas to support the needs of the six functional areas.

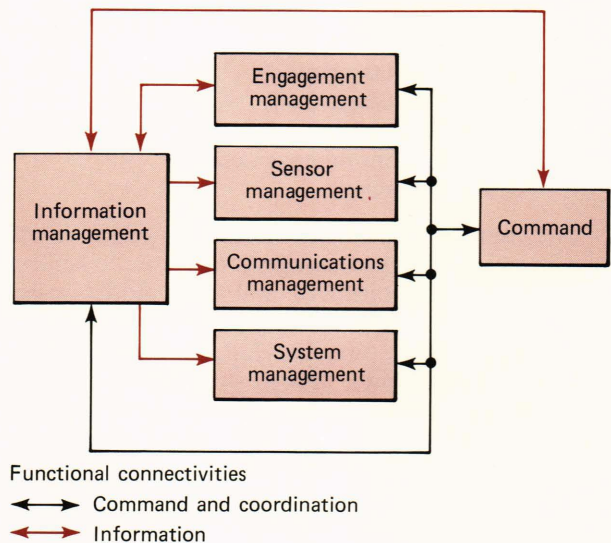


Figure 3 — All of the functions identified in the command and control process and its functional model shown in Fig. 2 were aggregated into the six functional areas shown in this figure. These functional areas, together with the functional connectivities, constitute the basic C² structure – a building block of the C² architecture.

The command portion of the command and coordination connectivities allows a commander to exercise his authority and the functional areas to respond

to his direction. The coordination portion allows engagement, sensor, communications, and system management areas (the implementation arms of command) to interface with one another (in accordance with the guidelines established by command) and with command during the planning and implementation process. Two-way information flow connects each functional area with information management. That information flow provides for the transfer of data and information within the command level, allowing an information base to be developed and maintained and its contents disseminated.

DEVELOPMENT OF THE ARCHITECTURE

An architecture is composed of functions, structure, connectivities, and interfaces. The functions were discussed earlier. The set of six functional areas, when expanded to cover all command levels, becomes the structure of the architecture. We examined the command levels that represent the operational commands of the Navy directly involved in tactical C², namely

- Fleet Commander-in-Chief
- Numbered Fleet Commander
- Battle Force/Battle Group Commander
- Unit Commander
- Platform Commander

To complete the development of the architecture, we needed to specify the connectivities and interfaces.

Selection of Connectivities and Interfaces

Connectivities are the means for command, coordination, and information flow within the C² system. Similar flow to and from external entities occurs via interfaces. We identified three sets of connectivities among functional areas at different command levels and three types of interfaces (external command, systems, and information sources) that are significant to the development of the C² system. The connectivities and interfaces are listed below in a functional order:

1. The connectivity among command functional areas;
2. The interfaces between command and the National Command Authorities, Unified, and Allied commands;
3. The interfaces among information sources and information management functional areas at various command levels;
4. The connectivity among information management functional areas at all command levels;
5. The connectivities among the engagement, sensor, communications, and system management functional areas at different command levels;
6. The interface between weapon systems and the information and engagement management functional areas.

Earlier in this study, we determined that an “adaptive hybrid control” is necessary for the connectivi-

ties among commands. It is hybrid in that it combines three possible forms of control: hierarchical (normal chain of command), virtual (skip-echelon), and independent. It is adaptive in that the system must be capable of reconfiguring its connectivities without loss of control or information. This form of control applies equally to the interfaces with external commands. A number of options (listed in Table 2) characterize the remaining four connectivities. Those options represent logically possible ways of providing functional connections without considering implementability, efficiency, or effectiveness. Some options were subject to various operational constraints and were eliminated. The surviving ones were then evaluated by the application of four selection criteria. The criteria and the rules for application are listed and defined in Table 3.

Table 2 — Options for connectivities and interfaces.

<i>Connectivities and Interfaces</i>	<i>Options</i>
Information source to information management area interface	Centralized: Numbered Fleet Commander (NFC) Centralized: Battle Force/Battle Group Commander (BF/BG) Same level dissemination Limited downward dissemination Parallel downward dissemination Full dissemination
Information management area connectivity	Centralized: NFC Centralized: BF/BG Hierarchical Parallel Combined parallel-hierarchical Indirect
Asset management area connectivity	Hierarchical Parallel Mixed Indirect
Weapon system interface	Platform level BF/BG and lower levels Single level other than platform

The functional connectivities that tie the C² system together and the interfaces with external systems are listed in this table. The options are the various alternative means of accomplishing the connectivities and interfaces.

Selected Architecture

As a result of the evaluation, we selected the following options for the four types of connectivities and interfaces:

Table 3 — Selection criteria.

<i>Criterion</i>	<i>Definition</i>	<i>Rule of Application</i>
Performance	The ability of an option associated with a particular connectivity to provide timely, accurate, and adequate information to, or effective coordination with, appropriate elements of the system.	Estimate the effect of the number of intermediate steps from source to user on the ability of the option to deliver timely, accurate, and adequate information or to coordinate effectively. (A connectivity or interface is considered to perform effectively if the number of intermediate nodes separating information transfer end points or coordinating elements is minimized.)
Survivability	The ability of an option to perform its indicated functions (with minimal degradation) when the loss of one or more nodes or links occurs.	Estimate the effect of losing a node or link on the ability of the option to perform its functions.
Flexibility	The ability of an option to operate in the mode of other options associated with that connectivity, if so required.	Estimate the ability of the nodes and links of the option to allow for the operation of the connectivity in the different modes.
Support	The ability of an option associated with a connectivity to operate with minimal demands on communications and/or processing support.	Estimate the ability of the option to operate without placing significant demands on communications and/or processing support.

We determined that these four selection criteria, as defined, were both necessary and sufficient to permit us the selection of one option for each connectivity and interface. We applied the selection criteria in accordance with these rules and used a numerical score to rate the options.

1. Parallel downward dissemination for the interface between information sources and the information management areas;
2. Parallel connectivity between the information management areas at all command levels;
3. Hierarchical connectivity (adjacent levels only) between asset management areas;
4. Interface between weapon systems and the information management area at the platform level, and between weapon systems and the engagement management areas at the platform, unit, and Battle Force/Battle Group Commander levels.

The selected architecture incorporating the chosen options is shown in Fig. 4. It depicts the basic C² structure at each command level, the internal connectivities, and the external interfaces. The distribution of information to the information management areas at each command level follows a parallel downward connectivity. It is not required that information from all higher level sources flow continuously to all lower level commands because the designation of information to be passed between nodes at any particular time is a command prerogative and remains the responsibility of the appropriate commander. In addition, information is to be tailored, both geographically and by security level, to the capabilities of the

recipient command level. Connectivity to commands below the Battle Force/Battle Group Commander level from higher level sensors is maintained only when the information sources are tasked for direct support to a particular unit or platform command.

Information management functional areas are capable of interconnecting at all command levels (using parallel connectivity) to allow for the timely exchange of information. This requirement does not imply that all information be exchanged among all command levels; rather, the determination of information distribution is the responsibility of the appropriate commander.

The connectivity of weapon systems to information management functional areas is limited to that of the platform carrying the system. Each weapon system is connected to the engagement management functional area of its own platform. The Composite Warfare Commander concept requires that the Officer in Tactical Command or his subordinate warfare commander (such as the Antiair Warfare Commander) directly control certain weapon systems, particularly those whose capability extends beyond the horizon of the platform carrying them or those dedicated to the defense of the battle group rather than own platform. In these cases, the commander at the Battle Force/Battle Group or unit level, as appropriate, maintains a direct interface with the appli-

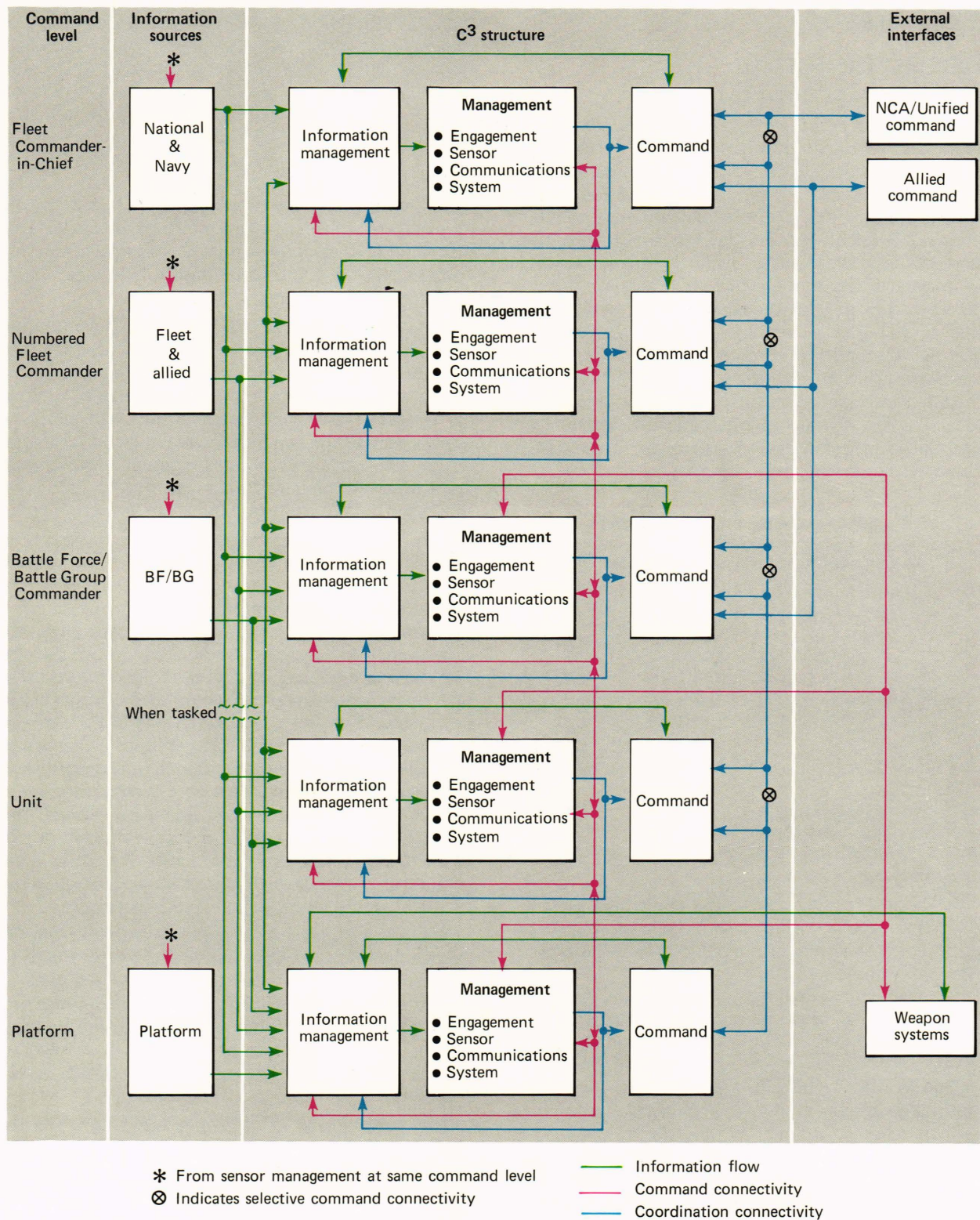


Figure 4 — The selected command and control architecture is represented by the C² structure, the functional connectivities, and the interfaces. The basic structure, consisting of the six functional areas, appears at each command level. The command functional areas are interconnected by an adaptive hybrid control connectivity that can support hierarchical, virtual, or independent control. The information management functional areas are connected in parallel. Information sources exhibit a parallel downward dissemination to the C² system. Weapon systems obtain information and direction at their level but can also be controlled from battle group and unit levels of command. Information sources are managed from their own levels; tasking of higher level sensors must be requested up the chain of command.

cable weapon systems via the engagement management functional area.

DESCRIPTION OF THE CONCEPTUAL SYSTEM

We expanded the selected command and control architecture presented in Fig. 4 into a conceptual C² system for the year 2000 by mapping the actual Navy commands and various types of information sources on the architecture. The different operational Navy commands identified in the diagram (those commanders that are expected to direct the employment of combat assets in a conflict situation) are listed in Table 4. A portion of the conceptual C² system, limited to the Fleet Commander-in-Chief, Numbered Fleet Commander, and Battle Force/Battle Group Commander levels, is shown in Fig. 5. This portion includes both ashore and afloat subsets of the C² system. The key features of the conceptual system are described in the following paragraphs; most of them can be seen in or inferred from Fig. 5.

Table 4 — Operational Navy commands.

<i>Command Level</i>	<i>Commanders</i>
U.S. Fleet	CINCLANTFLT CINCPACFLT CINCUSNAVEUR
Numbered Fleet Commander	COMSECONDFLT COMTHIRDFLT COMSIXTHFLT COMSEVENTHFLT
Battle Force/Battle Group Commander	OTC CWC
Area	USCOMEASTLANT COMSOLANT Area ASW commanders
Fleet air	COMFAIRLANT COMFAIRMED COMFAIRWESTPAC COMFAIRMIDPAC
Submarine force	COMSUBLANT COMSUBPAC COMSUBGRPS
Surface unit	Warfare commanders SAG commanders
Air unit	ASWOC commanders
Platform	Surface ship Submarine Aircraft

The information management functional area comprises functions associated with acquiring, processing, evaluating, and distributing data and information. Three major characteristics of information management are the existence of the information base at each command, the processing of information at each level (ashore and afloat), and the evaluation of tactical intelligence at most command levels. Information processing, as used in this context, refers primarily to the determination of locations of all platforms of interest and their classification. This information is usually acquired in data format for computerized processing because of its volume and its timeliness constraints.

Surveillance assets at each command level provide information on air, surface, and subsurface contacts to information management at own level and below (down to the battle group level for its area of interest on a regular basis, and down to unit and platform levels whenever tasked or assigned in direct support). Again, the warfare commanders under the Composite Warfare Commander concept at the unit level shall be provided with surveillance information pertinent to their warfare and geographical areas of interest from sources at higher levels on a continuous basis.

Whereas the information acquired from the various sources and sensors flows at its own level and downward, reflecting the parallel downward dissemination, the exchange of processed information (the tactical picture) can take place upward or downward, as needed. The latter movement should always be tailored to the interests and capabilities of the recipient, that is, to his mission and area of responsibility. This parallel connectivity between information management areas, which would allow the Fleet Commander-in-Chief to extract needed information directly from any platform under his control, is essential for purposes of timeliness and accuracy in the face of a highly sophisticated future threat.

Weapon systems are normally controlled from the engagement management functional area of the command to which they are assigned. Data required by weapon control and fire control systems (consisting of target assignments and targeting parameters) are supplied from information management or directly from own sensors if the target is detectable by the platform.

The battle group or unit command may control platform weapon systems when there is a need for a coordinated defense or attack. This control may be accomplished by assignment of platform systems to specific targets or by actual control of the weapon if such a capability were to exist in the battle group. When the Composite Warfare Commander concept is employed, the warfare commanders at the unit level can control platforms appropriate to their warfare responsibilities and assigned to them by the Composite Warfare Commander. For example, the Antiair Warfare Commander is responsible for the

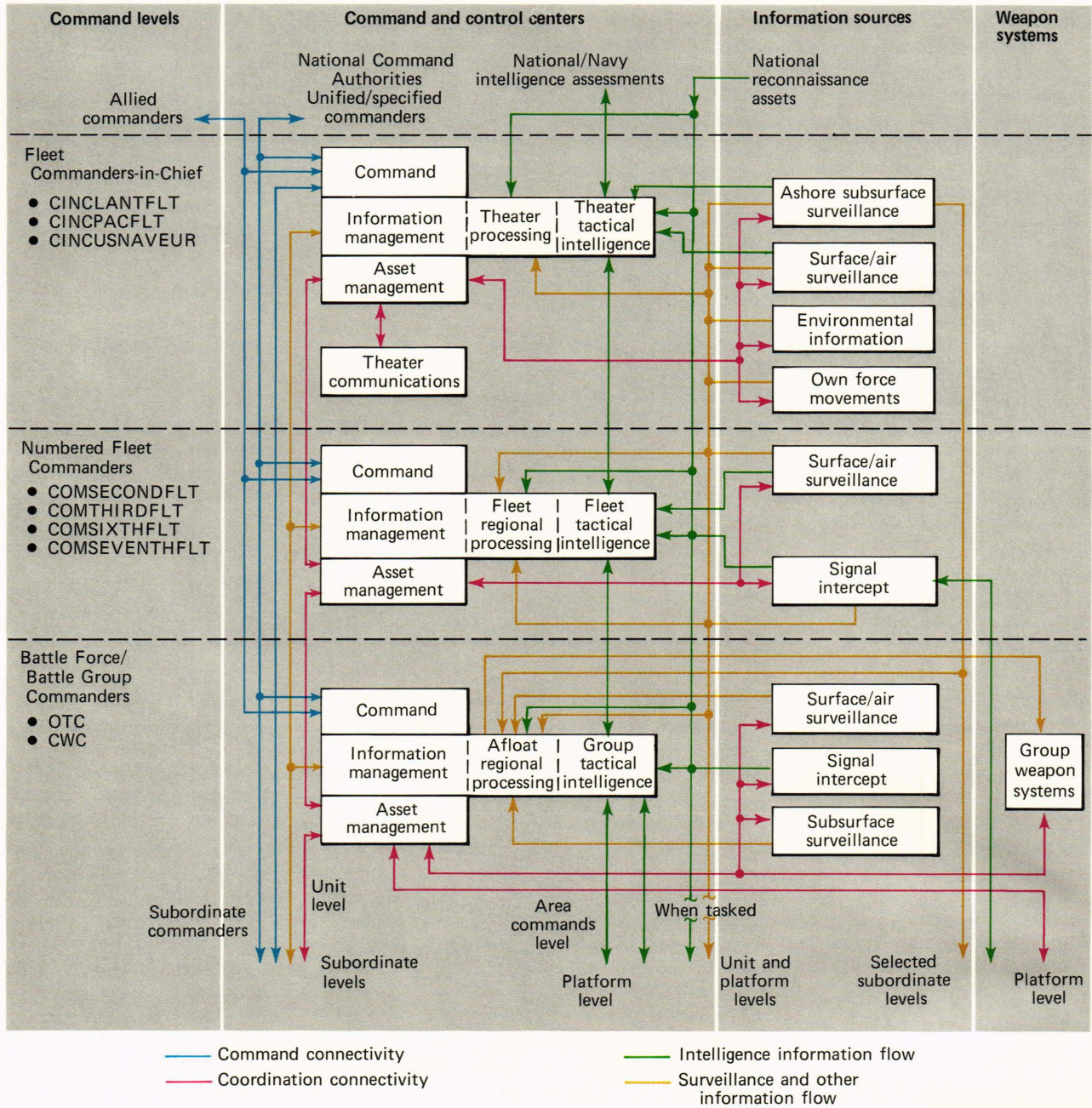


Figure 5 — The selected command and control architecture was expanded into a conceptual diagram of the Navy tactical C² system for the year 2000. This figure shows a portion of the system, limited to the Fleet Commander-in-Chief, Numbered Fleet Commander, and Battle Force/Battle Group command levels. The surveillance and intelligence functions of information flow are separated because of different handling and processing operations. Moreover, some commands at lower levels do not perform an explicit intelligence function. Information flow from higher level sources is provided to the unit and platform levels when tasked to do so, which is a command prerogative. Each information management functional area develops the tactical picture for its area of interest based on inputs from own sensors and any higher level sensors as available. In addition to weapon systems at the platform level, we show weapon systems at the battle group level (strike aircraft, for example). Control of the platform weapon systems can be exercised from the battle group, unit (Warfare Commander), or platform command levels.

defense of the battle group against air attack. The Anti-air Warfare Commander may assign fighter-interceptors (which are battle group assets) as well as surface-to-air missiles residing on various platforms

to specific targets. The fire control requirements, including midcourse guidance, are the responsibility of each combat asset and thus are outside the scope of the C² system.

SUMMARY

The development of a functional C² architecture represents a significant step toward achieving an effective future Navy command and control capability. In the past, command and control systems for the Navy had been procured to satisfy a particular warfare need or function. Although this procedure was satisfactory for meeting individual needs, it did not take advantage of the increased knowledge obtained from the synergism of interrelating the many subsystems. The advent of weapons that reach beyond the range of the platform's sensors highlighted this problem and forced an approach to command and control that addresses the process as an entity. The C² architecture accomplishes this purpose.

The next logical effort was the development of a conceptual system that mapped the actual Navy com-

mands and various types of information sources on the architecture. This conceptual system was incorporated into the *Navy Command and Control Plan* issued by the Director of Navy Command and Control (OP-094). The Navy C² plan provides guidance to the Systems Commands of the Navy in the design and procurement of equipments to support Navy command and control. For the first time, the Navy has a blueprint that allows for evolutionary development of individual C² systems within the context of an overall architecture that will provide a way to achieve an integrated C² capability.

REFERENCE

¹*Johns Hopkins APL Tech. Dig.* 2, 237-255, 299-313 (1981).