COMMAND & CONTROL

OPERATIONAL REQUIREMENTS AND SYSTEM IMPLEMENTATION

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Introduction

The objective of this paper is to examine the accepted definition of "Command and Control" (C2), and from that examination to derive the fundamental operational requirements for a Command and Control Information System, to outline the operational, system, and technical architectures for such a System, and to put forward a basis for the evolutionary implementation of an effective Command and Control capability that extends over all levels of national command.

Acknowledgements

My formulation of the fundamental requirements for a military Command and Control System is based to a large degree on the theoretical foundation for Command and Control presented in the excellent practical textbook entitled: "Command and Control, The Literature and Commentaries" authored by Mr. Frank Snyder,[1] of the USA National Defense University and the Director of its Command and Control Research Program. I have also taken into account the views and experiences contained in an AFCEA International Press book, entitled: "Principles of Command and Control."[2]

US DoD Definition

The US Department of Defense defines "Command and Control" as follows:

> "Command and Control is the exercise of authority and direction by a properly designated Commander over assigned forces in the accomplishment of the mission. Command and Control functions are performed through an arrangement of personnel, equipment, communications, facilities, and procedures which are employed by a Commander in planning, directing,

coordinating, and controlling forces and operations in the accomplishment of the mission."

"Command and Control" is the critical process employed by military commanders when exercising military power to achieve national objectives.

Command Structure

A Commander's authority is derived from a hierarchical command structure, which links the National Command Authority (for example, the head of government), through a formal military structure comprising the operational commanders having the ability to apply military power. This hierarchical command structure provides a top-down allocation of authority and responsibility to subordinate military forces, which maximizes the probability of success in mission accomplishment, while minimizing operational risk. The command structure must create and establish workable command relationships throughout the chain of command, and provide a clear definition of the functions to be performed at each echelon within that chain of command. This national Command and Control structure can be considered as having four command levels; namely National, Strategic, Operational, and Tactical.

Military Situations

Command and Control is a continuous process exercised over the complete range of situations under which a nation may decide to apply military power to achieve its national objectives. This range of situations includes: Peacetime; Military Support for Humanitarian Relief or National Civil Crises; Peace Support including peacekeeping, peace enforcement, and peacemaking; Limited War; and General War.

Military authority and direction, associated with the application of military power for each of these situations, flows from the National Command Authority through the hierarchical Command and Control structure. In each of these military situations, the appropriate command relationships must be established through the chain of command, and the functions that are to be accomplished by each command element must be clearly defined.

Command Control Process

Much has been written of the need to carry out extensive studies to define the "information exchange requirements" for a Command and Control System. I believe that there is a fundamental flaw in this type of thinking. Decision-making, not information flow, is at the heart of the command and control process. The decision-making process of command and control is very much an iterative process, strongly supported by inputs from specialist staff that address a range of "what if" questions

posed by either the commander or his senior advisors. From historical studies of past military operations, we know that decision-making for command and control also involves an aspect of chess playing as commanders plot their moves and make their decisions in the context of at least a two party conflict situation, wherein each opponent is doing the same. Any attempt to define precisely the information exchange requirements for a command and control system is limited by the inability to formulate the broad range of potential questions or issues that would be addressed during the C2 decision-making processes, associated with the entire range of military situations.

A Command and Control Information System must be designed first and foremost to provide effective and responsive decision support. To achieve that goal, the system must include support for the staff whose mission it is to provide the various inputs needed for command and control decision-making, some driven by the functional responsibilities of the staff and others driven by specific queries posed by the Commander. The system must enable the staff to access any relevant information, no matter where that information might reside in the network. This is the fundamental basis for the concept of "network-centric".

Although the focus of decision-making in Command and Control differs at the National, Strategic, Operational, and Tactical levels of command, certain of the data and information products, although used differently, are associated with decision-making at more than one level of command. Unimpeded access to all information, that is relevant to the decision-making issues of the moment, is the essential enabling function that permits timely and intelligent decision-making.

The basic goal of a Command and Control process is the *timely reduction of uncertainty to achieve intelligent decision-making*. *Sending orders and receiving reports are actions which directly result from the Command and Control process*.

Command Decisions

To win, a commander must gain the initiative and avoid being placed into a reactive mode by letting his opponent seize the initiative. To achieve that goal, the commander must operate "inside the decision loop of his opponent."[3] Therefore:

- The commander's command and control decision-making process, and the information systems that support that process, must be quick and agile;
- Actions also can be taken to impede his opponent's decision loop by injecting uncertainties that slow, deceive, or disrupt the opponent's process.

The need to operate inside the opponent's decision loop relates to all three types of command decisions:

a. Informational Decisions ("What is the situation?");
b. Organizational Decisions ("How to organize to achieve goals?");
c. Operational Decisions ("What actions should be taken?").

"Operational decisions" (about the actions to be taken by subordinate commanders) are always preceded by "informational decisions" (about what is happening.)

Information Support

To be responsive to the full range of decision-making, I believe that a Command and Control Information System must include two modes of operation:

- "Information Push," wherein pre-defined data and information products are provided to the decision-maker, or supporting staff, automatically by the system. These might take the form of reports or situation data derived from a pre-defined set of databases or threshold type reports;
- "Information Pull," wherein the decision-maker, or supporting staff, obtains desired data or information products by accessing local or remote databases, interactively, through use of appropriate search engines in order to obtain the inputs considered by the decision-maker or analyst to be necessary for the decision issue being addressed.

Informational Decisions

Informational decisions, either implicit or explicit, always precede the other two types of command decisions. Situation assessment is the general term. Prior to making an operational decision on the actions to be taken, a commander must decide what is actually happening, and what course the events are taking. These critical decisions are actually made on the basis of what the Commander believes is happening. The key issue, in both combat and crisis situations, is whether or not the Commander believes the strength, objectives, or rules of engagement of the enemy have changed to a degree that makes it necessary to change his prior assessment, and perhaps even his previously adopted operational plan.

Much of the information that a commander relies upon for decision-making is provided by his specialist staffs based on their assigned staff missions or specific tasks issued by the commander or his command group.

Intelligence is a good example of a functional area staff information product. In the case of the intelligence process, information rarely moves in its raw state directly from the sensor to the commander. Intelligence data not only passes through the links of a reporting system, it is also processed at intelligence nodes. This processing typically includes filtering, fusion, correlation, and analysis. Informational products

provided by the other functional staffs, such as Operations, Logistics, CIMIC, and CIS also result from staff work carried out within a functional staff area; each product is also subject to similar processing actions.

Due to the importance of informational decisions, and the associated need for staff development of specialist inputs, a Command and Control Information System must include specific provisions for the accomplishment of this specialist work, and for the timely and accurate dissemination of the resultant information products. The System must make these products available to those, both local and distant, who are associated with the command and control process and who might have a need for them. The facilities that support specialist staff work are organized under the "Functional Area Subsystems" of the Command and Control Information System.

Organizational Decisions

The objective of "organizational decisions" is to achieve Unity of Effort in the pursuit of action through the establishment of a chain of command for an operation, definition of the lines of authority and responsibility, establishment of the flows of information, and identification of which commanders can make what decisions. Organizational decisions, made by the commander, are based on inputs obtained from subordinate commanders and specialist staffs. Since the proposed command decisions are normally developed under coordination by the command group and, when made, issued as orders by the Commander, support for these processes, and the rapid and effective promulgation of the resultant decisions, are important requirements to be met by a Command and Control Information System.

Operational Decisions

Operational decisions are the decisions made by a Commander when identifying the actions that are to be taken by his subordinate forces, based on his assessment of which course of action is the most effective one to pursue to achieve a mission. In addition to uncertainties about the situation and the course of action the opponent is about to select, operational decisions must be made in the face of uncertainties about the outcomes that would result from the interactions between the courses of action available to the commander and those available to his opponent. As an added complication, these interactions are influenced by decisions taken by a number of subordinate commanders on both sides. Operational decisions are also constrained by limits placed on the use of force imposed by the Rules of Engagement that are set by higher authority. Operational decision-making is complex, and made very difficult by the enormity of the potential outcomes that could result from the decisions made.

Operational decisions are made within the framework of a military planning process, which includes:

- "Development of the Commander's Estimate of the Situation" (an informational decision necessary to choose a course of action);
- "Development of a Plan to Execute the Selected Course of Action" (a set of decisions which establishes the organization that is to execute the selected course of action, and defines the tasks to be accomplished by each of its component elements);
- "Promulgation of a Directive/Order" (orders and allocation of the authority to execute the Plan); and
- "Supervision of the Planned Action" (monitoring progress made to determine if changes in the Order, issued for the Plan, are necessary to accomplish the mission).

When making the fundamental operational decision as to the Course of Action to select, alternatives must be postulated and analyzed to assess:

- Suitability: "Will successful execution result in mission accomplishment?"
- Feasibility: "Can the potential course of action be accomplished with the means available?"; "Is the potential course of action consistent with the Rules of Engagement?"; "Does the potential course of action take into account the opposition expected?"
- Acceptability: "Do costs (losses) exceed the value of the objective achieved?"

Since the Command and Control process must enable the commander to operate inside the decision loop of his opponent, while at the same time providing for the timely reduction of uncertainty to support intelligent decision-making, an effective Command and Control Information System is one that includes embedded Decision Support Tools designed to assist in assessing the suitability, feasibility, and acceptability of the potential courses of action. The primary objective of these Decision Support Tools should be to provide insights into the probable consequences of the alternative courses of action, by predicting the probable outcomes of the possible interactions among the courses of action that might be selected by the Commander and his opponent.

Required System to Support Command and Control

The primary elements of a Command and Control Information System are:

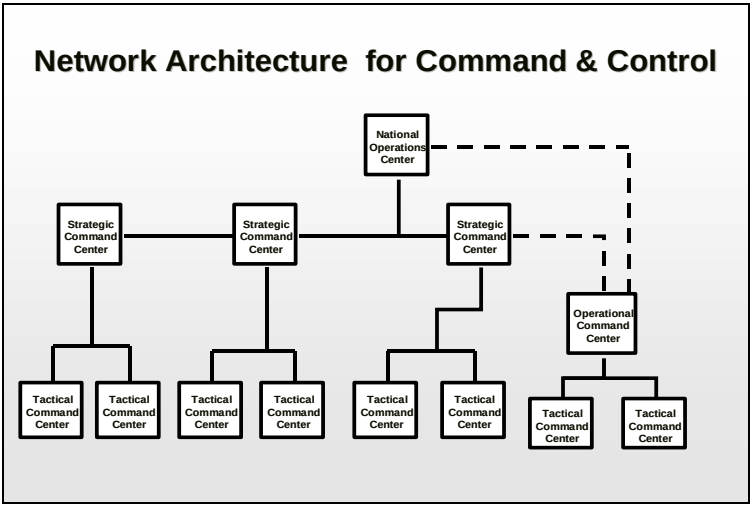
- Communications Network: A responsive and secure communications

network, to link the military headquarters across all levels of command (National, Strategic, Operational, and Tactical), is the essential capability which enables the National Command Authority, and its associated chain of command, to effectively control all national military forces in the application of military power to achieve national objectives. The communications network must provide for the timely transmission of orders and directives from higher headquarters to all subordinate forces, and the timely receipt of reports, from all subordinate headquarters of the constituted military force structure. This capability enables the empowered headquarters, in the chain of command, to monitor and control the authorized military operations. Both secure voice service and secure data transmission capabilities are required.

- Headquarters Information System: An information system is required at each command headquarters to provide timely and effective analytic support to the commander, and his specialist functional area staffs, to enable the commander to issue orders and directives that are both timely and based on a process designed to reduce uncertainty and enable intelligent decision-making across the entire spectrum of "informational," "organizational," and "operational" decisions. This requires information subsystems, organized along functional area specialist lines, that include the databases and decision support tools necessary to enable the specialist staffs to accomplish their work in a timely and competent manner.

A Network Architecture for Bulgarian Command and Control

A network structure for Bulgarian Command and Control could be as illustrated below:



The Bulgarian command levels could be defined as follows:

- National: Chief of the Bulgarian General Staff, operating under the authority and direction of the National Command Authority;
- Strategic: Commanders of the Bulgarian Land Forces, the Bulgarian Air Forces, and the Bulgarian Naval Forces;
- Operational: Commander of an appropriate Strategic Command, or Commander of the Rapid Reaction Corps; designated on a case by case basis by the Chief of the General Staff;
- Tactical: Commanders of Rapid Reaction Corps, 1 Army Corps, 3 Army Corps extending down to the Commanders of subordinate Brigades; Commanders of Tactical Aviation Corps and Air Defense Corps extending down to the Commanders of subordinate units considered equivalent to Brigades; Commanders of Varna and Bourgas Naval Bases extending down to the Commanders of subordinate units considered equivalent to Brigades.

In this construction, it is assumed that the role of an Operational Headquarters, should one be required for a particular operation, would be assigned either to one of the Strategic Commands or to the Rapid Reaction Corps. The need for a deployable Command Center to support an Operational Headquarters, as is the case for a NATO Combined Joint Task Force (CJTF) Headquarters, should be considered.

Generic Command and Control Node

From an architectural point of view, a Command and Control Node can be considered to comprise the following major generic elements:

- Common System Services Element,
- Functional Area Software Support Subsystems Element,
- Operations Center Element.

Each of these elements can be defined in terms of both structure and capabilities.

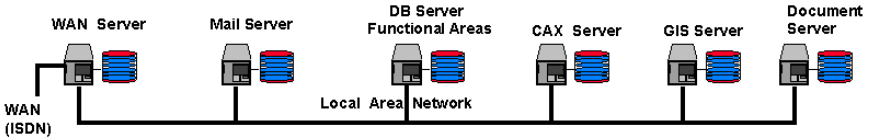
C2 Node (Common System Services Element)

Each node of a Command and Control System should include the capability to provide common system services in support of the Commander and all functional area subsystems associated with the Command Center. These Common System Services should include: access to the external wide area communications network, electronic mail, messaging, file exchange, command briefing support, functional area database servers, geographic information services, information management (archival, documents, bulletins), information security (system access, firewalls, and guards),

and technical support for local and distributed training and exercises, e.g., Computer Assisted Exercises.

Structurally, the common system services would be obtained by the users through Servers, accessed over a Local Area Network as illustrated in the Figure 2.

Figure 2
Generic C2 Nodal Architecture
(Common System Services Element)



These common system services, on their own, provide a very effective level of technical support for Command and Control, if provided in a TCP/IP router-based sub-network, and if implemented at each Command Center in the chain of command. With such capabilities, the Commanders are linked through a secure data network that enables secure and timely dissemination of Orders and Directives to all subordinate commands, upward transmission of Reports from all subordinate commands, and lateral coordination among the commands at all levels. Staff work at each command would be facilitated through the provision of a standard set of briefing support packages that are compatible throughout the chain of command, thereby permitting analyses and briefings to be assembled using inputs provided directly by dispersed subordinate units. A common geographic information service implemented throughout the chain of command, would ensure consistent mapping as well as timely and accurate location information.

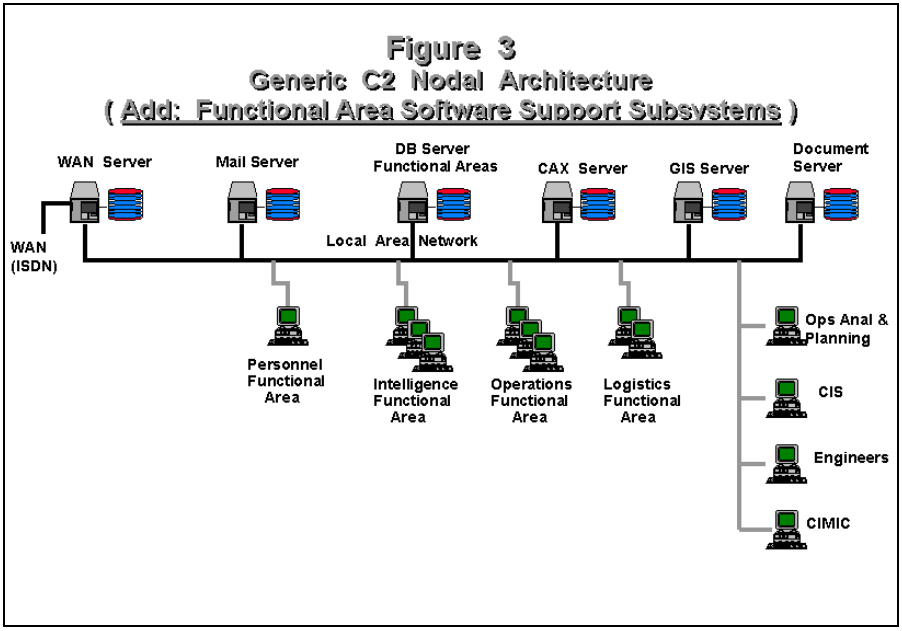
These Common System Services, resident at each Command Center, provide an essential foundation for subsequent expansion of the System through the addition, on an incremental and evolutionary basis, of the Operations Center capabilities and the Functional Area Software Support Subsystems.

C2 Node (Functional Area Software Support Subsystems Element)

A Command and Control Information System should be organized to accommodate the specific decision support requirements placed on the specialist staffs assigned to each command headquarters. This orientation permits each C2 Functional Area

Subsystem to be designed to respond to specific functional staff requirements. This subsystem orientation is also consistent with the Command and Control Information System structure chosen by NATO. Adoption of this approach by Bulgaria would not only facilitate interoperation with NATO systems but also would enable Bulgarian personnel to gain experience in headquarters operations that would prepare them for future assignments, either in a Combined Joint Task Force (CJTF) Headquarters of a NATO-led Peace Support Operation, or ultimately in a NATO military headquarters such as SHAPE or Regional Command South.

This element of the Command and Control Information System would be organized to include Functional Area Staff Subsystems for Personnel (J1), Intelligence (J2), Operations (J3), Logistics (J4), Operations Analysis and Planning (J5), CIS (J6), CIMIC (J9), Engineers, and Weather (see figure 3).



Key capabilities would include:

a. Production of specialist staff inputs for command decision-making;

b. Support for the effective management of the specialist staff work;

c. Development and maintenance of the functional area databases;

d. Reach-back access to databases held at other commands;

e. Interfaces with databases held by other functional area staffs;

f. Employment of appropriate Decision Support Tools;

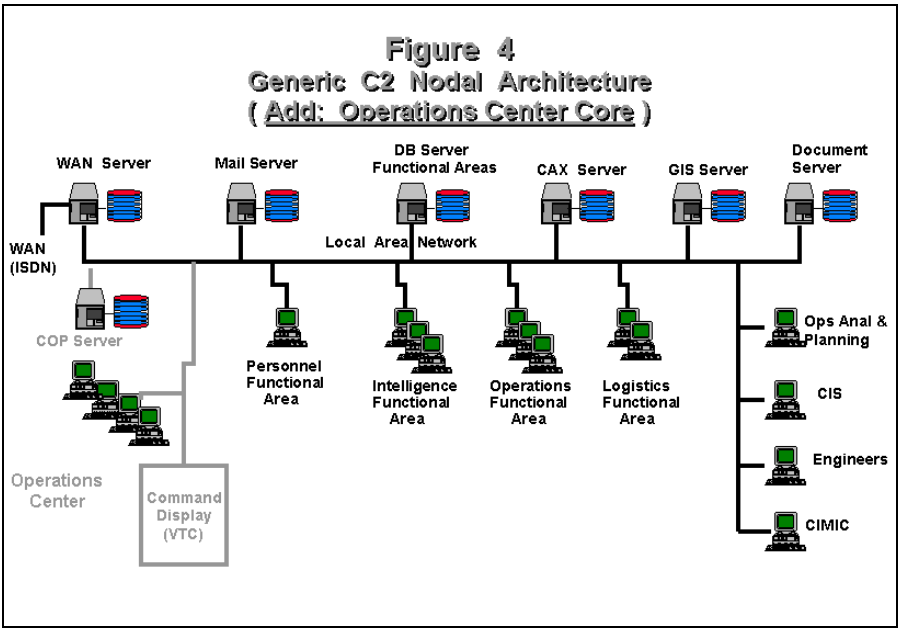
g. Promulgation of orders and tasks to local and dispersed subordinates, assigned to work in the specialist functional staff served by the subsystem;

h. Response to imposed orders, tasks, and process requirements;

i. Production of data and information for consumption by other local and distant functional area subsystems;

j. Response to local and remote requests for expert data and assessments.

Structurally, the functional area software support capabilities would be implemented at each Command and Control Node through one or more staff workstations, that access the common system services and exchange information with each other over Local Area Networks as illustrated in Figure 3. The servers for the functional area databases would be associated with the common system services element to facilitate access from other Command and Control Nodes and from other functional staff elements within the command headquarters.



C2 Node (Operations Center Element)

The Operations Center Element, of the Command and Control Node, provides the facilities used by the commander's headquarters staff to support the work of the Commander in reaching his "informational," "organizational," and "operational" decisions.

The major capabilities would include:

a. Coordination of the staff work carried out by the functional area staffs of the headquarters;
b. Analysis and coordination of Course of Action alternatives;
c. Development of coordinated Staff Recommendations for consideration by the Commander;
d. Construction and maintenance of the Common Operational Picture held by the Command, integrating information provided by the functional area staffs;
e. Employment of appropriate Decision Support Tools;
f. Coordination of Command Decision Briefings;
g. Promulgation of Command Decisions and Directives;
h. Management of the Commander's Decision Briefings and Conferences.

As indicated on Figure 4, these functions would be accomplished through staff workstations and a Common Operational Picture (COP) server that access the facilities of the common system services element via Local Area Networks, a video-teleconferencing center, and a command center display facility. The video-teleconferencing and command center display facilities would be designed to interoperate with like facilities employed in the other Command and Control Nodes of the network. It is highly desirable that the video-teleconferencing and command center display facilities be compatible with those used by NATO, to facilitate Bulgarian participation in NATO-led Peace Support Operations, or ultimately in NATO collective defense activities.

Components of a Command and Control System

The main C2 system components, that emerge from the analysis of its operational requirements and structure, include: Personnel; Processes and Procedures; Data and Information Processing Equipment comprising local databases (structured and unstructured), access to local and remote databases (structured and unstructured), local analytic and decision support tools, and collaboration tools (local and remote participants); Displays; Communications Equipment comprising TCP/IP routers, local area networks, access to wide area networks, and video teleconferencing facilities; Electronic Support Means such as sensors and electronic warfare elements; and Access to Common System Services.

Architectures

To provide a foundation for the design, development, and implementation of a Command and Control Information System, three types of architectures are generally

developed; namely, an "Operational Architecture," a "System Architecture," and a "Technical Architecture." When developing these architectures, it must be kept in mind that architectures are only a means to an end, not ends unto themselves! Accordingly, each architecture document should be minimum in depth, maintain some flexibility, and considered a "living document" so changes can be incorporated as requirements, threats, or technology evolve.

Operational Architecture

The purpose of an Operational Architecture is to identify the principal organizations that are to be served by the Command and Control System, the functions of the participating organizations, the inter-relationships among the organizations, the basic functional composition of the system, the general types of information to be exchanged in the system, and the primary external system interfaces that must be accommodated. Since the Operational Architecture provides a simple description of the primary operational requirements for the system, the main points to be addressed for a Bulgarian C2 System should include:

a. Organizations Served: Confirmation that the chain of command consists of four levels as described, and the identification of the Bulgarian commands at each level; confirmation that the tactical structure to be served includes organizations of Brigade size and larger; clarification of the Operational Level of command, and the need for a deployable Command Center for that level; and the identification of the functional staff organization at each command level.

b. Functions of System: Statement of the basic functions to be supported by the system (e.g., the need to support the command's informational, organizational, and operational decision-making); the need to provide easily accessible network-wide databases; and the need to provide appropriate Decision Support Tools for each functional area subsystem.

c. Operations Center oriented System Nodes: Statement of the need for "Operations Center" oriented Nodes having both Joint and Single Service configurations; requirements to support Command decision-making and promulgation of Orders and Directives; requirement to provide distributed Briefing and Information Support; need for a design which is Staff Cell driven; and the need for interoperability with National, Regional, and NATO Commands.

d. Modes of Information Transfer: Types of traffic required (voice, data, e-mail, video-teleconferencing); identification of the Command levels at which video-teleconferencing is required; requirement to provide reach-back capabilities (intelligence support, logistics, personnel, troop morale) to minimize the need for forward deployed databases; and the security requirements of the system.

e. System Flexible in Configuration and Use: Definition of capability for use at the National, Strategic, Operational, and Tactical levels of command; capability for use in National, Regional, and NATO-led Military Operations; capability for use in Combat, Peace Support, and Humanitarian Relief Operations; capability to accommodate tactical levels from Corps to Brigade; and need for components which are dismountable for use in buildings of opportunity.

System Architecture

The purpose of the System Architecture is to identify the form of the system, to identify the subsystems that will be used to implement the system and to fulfill the system requirements, and to allocate performance and functional requirements to the associated subsystems. The main points to be addressed should include:

a. Identification of System Structure: Establishment of the scope of the system; definition of the operational capabilities to be provided; and specification of the end-to-end performance requirements of the system.

b. Identification and Definition of Subsystems: Identification of the operational drivers for the subsystem definitions; alignment of the subsystems with the Command and Control Process; and the identification of the participants in subsystem processes.

c. Allocation of Functions to Subsystems: Derivation of the required subsystem functions from the defined system capabilities; identification of the basic subsystem inputs and outputs; and the specification of the performance requirements to be satisfied.

Technical Architecture

The purpose of the Technical Architecture is to identify the technology and technical standards to be applied to the design and implementation of the system. This need not be an extensive elaboration of all matters; of most importance is that the essential or critical technical standards be identified. The Technical Architecture should address: requirements for application of ISO/OSI Open System Standards (NATO Compatible); use of Client-Server networking; incorporation of web-enabled database access software; employment of a Geographical Information System which complies with NATO standards; establishment of a TCP/IP router-based data sub-network; provision of access to Wide Area Networks, including strategic communications networks based on ISDN standards and tactical communications networks based on Eurocom D/1 standards; adoption of video-teleconferencing standards compliant with those of NATO; establishment of a strategy calling for maximum use of Commercial-Off-The-Shelf products, with designation of preferred products; and definition of feasible INFOSEC concepts.

Command and Control System (Development and Acquisition)

Since a Command and Control System must support complex, multi-echelon, command decision-making, it is virtually impossible to build a Command and Control System as a "turn-key" solution. To succeed in implementing this class of system there must be close and continuing interactions throughout the development process with the user community, and with senior commanders and their functional area staffs in particular.

Experience indicates that the most successful development and implementation paradigm for a Command and Control System is one that incorporates an *Evolutionary Development and Acquisition approach*, which is firmly based on a program of User-Oriented Prototyping and Testbedding to capture the operational requirements and to provide proof of concept prototype solutions, suitable for evaluation, prior to any large commitment of money for the implementation phase. Cost and performance risks are minimized by involving the user, at the earliest possible time, in the translation of operational requirements into system solutions and by the evaluation of prototyped proof of concept implementations.

Evolutionary Development and Acquisition also provides an ability to time phase the implementation of a System in a manner consistent with the availability of procurement funds, an ability to easily respond to the identification of new or revised operational requirements necessitated by changes in operational concept, threat, or technology, and an ability to continually exploit emerging technology in order to implement new operational capabilities.

With the Evolutionary Acquisition paradigm, a Command and Control Information System is implemented in an incremental manner. Increments are designed either to add a new capability to the system, to increase the capacity or scope of the system, to infuse new technology to reduce costs, or to obtain a capability that previously had not been feasible due to technology limitations. The initial core capability of the system and all incremental enhancements to the system are formulated in compliance with the operational, system, and technical architectures established for the system.

Under the concept of User-Oriented Prototyping and Testbedding, both the application of commercial products and the development of all functional area software support subsystems and their associated decision support tools, follow a development and acquisition path that involves laboratory prototyping to technically determine the optimum method for implementing, or integrating, a desired new capability into the Command and Control System as it exists at the time.

When all technical issues are resolved, the prototyped capability is integrated into a laboratory testbed to obtain informal user reaction; if found to be of apparent

operational value, the capability is then implemented in a system model, maintained by a Bulgarian Technical Center, which faithfully emulates the fielded Command and Control System, for the purpose of obtaining a more complete user evaluation of the proposed incremental capability. Operational personnel, assigned to a Command Center, would carry out this user evaluation. If the user evaluation is favorable, a proposal will be prepared, for approval by appropriate Bulgarian authorities, to acquire the capability for integration into the operational Bulgarian Command and Control System. A field evaluation would then be conducted at one or more of the implementation sites to confirm user acceptance.

As can be seen, the steps of the process significantly reduce not only the cost risk but also the risk associated with ultimate user acceptance of the fielded product. The process ensures effective technical integration into the fielded System. It also produces sound data to support acquisition decisions by the procurement authorities since technical feasibility would have been demonstrated, the operational acceptability of the proposal would have been confirmed by the users, and reliable cost figures would be available.

Another attribute of the process is its inherent compatibility with the strategy of maximizing the use of commercial off-the-shelf products and the objectives of maximizing national content and maintaining firm control of the development and acquisition process.

Recommended Incremental Strategy for C2 System Implementation

The following incremental strategy for implementing the Bulgarian Command and Control System is recommended:

a. Step 1: Establish the basic router-based communications infrastructure and implement an initial core system capability by prototyping, evaluating and acquiring the Common System Services Element of the C2 System, as defined above and illustrated in the Figure 2, but with the following initial modifications:

(1) Delay implementation of the Functional Area Database Servers;

(2) Delay implementation of the CAX Servers;

(3) Provide two or three workstations as an initial capability for accomplishing the work of a Command Center, to provide messaging capabilities that include electronic mail, and to implement effective capabilities for transmission of Orders and Directives from higher headquarters, and receipt of Reports from subordinate headquarters.

This initial capability should be implemented at all Command and Control Nodes, thereby linking all headquarters of the military chain of command to provide

the essential communications and information system support needed for combat, peace support, and civil crisis operations. Even in its initial form, the establishment of such a secure and responsive C2 Network, linking all national forces with their National Command Authority, would be viewed as very significant with regard to NATO preparation.

b. Step 2: Define, develop, prototype, evaluate, and acquire the three functional area databases considered of most importance to support the work of the Intelligence and Operations staffs of a Command Center. Tailor these capabilities as appropriate for the level of command at which they are to be implemented. Also, acquire the staff workstations and necessary Local Area Network capabilities to connect these two functional staffs into the Command Center, as illustrated in the Figure 3. Provide functional area database servers and integrate the acquired capabilities into the Command Centers of the System.

c. Step 3: Define, develop, prototype, evaluate, and acquire the three most important capabilities required to implement the Operations Center Element of the Command and Control System, as described above and illustrated in the Figure 4. These capabilities should be tailored, as appropriate, for the level of command at which they are to be implemented.

d. Remaining Steps: Similarly defined follow-on incremental steps for the continued evolution of the Bulgarian Command and Control System should be formulated in conjunction with the General Staff. These follow-on steps should provide for the definition, development, prototyping, evaluation, and acquisition of the additional capabilities needed to evolve the capabilities of the system, to develop the databases needed by the remaining functional area staffs, to implement the necessary decision support tools for all functional subsystems, to enhance the capabilities of all functional area software support subsystems, to implement web based database access capabilities to support access by personnel of other functional areas and other operational commands, to complete the capabilities of the Operations Center Element, and to generally expand the system capabilities in response to user requests.

Conclusions

This Paper has provided an examination of the accepted definition of "Command and Control," and from that examination derived the fundamental operational requirements for a Command and Control Information System, outlined the operational, system, and technical architectures for that system, and put forward a basis which can serve as the foundation for the evolutionary implementation of a Command and Control capability that extends across all levels of command to include National, Strategic, Operational, and Tactical requirements.

Employment of an evolutionary development and acquisition paradigm for implementing the required C2 capabilities is recommended because it not only minimizes operational and technical risks but also ensures that an effective core system capability is realized in a timely manner, while establishing a sound basis for the follow-on enhancement of that capability at a rate commensurate with the availability of the necessary additional funding. User oriented prototyping and testbedding should be a part of that process to ensure active user involvement, supported by proof of concept prototyping, thereby ensuring user acceptability of the developed capabilities and the reduction of cost risk.

References:

1. Frank M. Snyder, *Command and Control: The Literature and Commentaries* (Washington, DC: National Defense University, 1993). Further readings include Kenneth Allard, Command, Control, and the Common Defense, revised edition (Washington, DC: National Defense University, 1996); David S. Alberts and Richard E. Hayes, *Command Arrangements for Peace Operations* (Washington, DC: National Defense University, 1995). The latter books are available in electronic at http://www.ndu.edu/inss/books/
2. Jon L. Boyes and Stephen J. Andriole, eds., *Principles of Command and Control*, Foreword by Gen. Russell E. Dougherty (Fairfax, VA: AFCEA International Press, 1987)
3. John R. Boyd, *A Discourse on Winning and Losing* (Maxwell AFB, Alabama, 1987).

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