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An assessment of the Integrated Services Digital Network in support of Command, Control, Communications, and Intelligence Systems

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THESIS

AN ASSESSMENT OF THE INTEGRATED SERVICES DIGITAL NETWORK IN SUPPORT OF COMMAND, CONTROL, COMMUNICATIONS AND INTELLIGENCE SYSTEMS

by

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This thesis explores the technology of the Integrated Services Digital Network (ISDN) and assesses its value to strategic U.S. command, control, communications and intelligence (C^3I). The author provides a brief overview of how telecommunication systems support the concept of C^2 and what some of the problems are in this area. A review of the ISDN concept is provided which serves as the foundation for assessing the significance of ISDN to the military and its value in meeting the particular requirements associated with C^3I telecommunication networks. Some of the more substantive issues of transitioning to ISDN are addressed such as network management and security. The author concludes that ISDN is an attractive long-term goal architecture. There are, however, several significant areas (applications, network management requirements, security architecture) that must be proactively addressed before ISDN is suitable for application in the C^3I environment..

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An Assessment of the Integrated Services Digital Network In Support of Command, Control, Communications and Intelligence Systems

by

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Captain, United States Army
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requirements for the degree of

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ABSTRACT

This thesis explores the technology of the Integrated Services Digital Network (ISDN) and assesses its value to strategic U.S. command, control, communications and intelligence (C^3I). The author provides a brief overview of how telecommunication systems support the concept of C^2 and what some of the problems are in this area. A review of the ISDN concept is provided which serves as the foundation for assessing the significance of ISDN to the military and its value in meeting the particular requirements associated with C^3I telecommunication networks. Some of the more substantive issues of transitioning to ISDN are addressed such as network management and security. The author concludes that ISDN is an attractive long-term goal architecture. There are, however, several significant areas (applications, network management requirements, security architecture) that must be proactively addressed before ISDN is suitable for application in the C^3I environment.

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LIST OF ACRONYMS AND ABBREVIATIONS

ANSI	American National Standards Institute
AUTODIN	Automatic Digital Network
AUTOVON	Automatic Voice Network
BRI	Basic Rate Interface
C2	Command and Control
C^3I	Command, Control, Communications and Intelligence
CCEP	Commercial COMSEC Endorsement Program
CCITT	International Telegraph and Telephone Consultative Committee
CCS	Common Channel Signaling
CENTREX	Central Exchange
CPE	Customer Premise Equipment
DCA	Defense Communications Agency
DCS	Defense Communications System
DCTN	Defense Commercial Telecommunications Network
DDN	Defense Data Network
DoD	Department of Defense
FDDI	Fiber Distributed Data Interface
FEMA	Federal Emergency Management Agency
GOSIP	Government Open Systems Interconnection Protocol
ISDN	Integrated Services Digital Network
ISO	International Standards Organization

ITU	International Telecommunications Union
LAN	Local Area Network
NIU-FORUM	North American ISDN Users' Forum
OSI	Open Systems Interconnection
PBX	Private Branch Exchange
POSIX	Portable Operating System Interface
PRI	Primary Rate Interface
PTT	Ministry of Post, Telegraph and Telephone
SACNET	Strategic Air Command Network
VHSIC	Very High Speed Integrated Circuits
VLSI	Very Large Scale Integration

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I. INTRODUCTION

The purpose of this thesis is to explore the technology of the Integrated Service Digital Network (ISDN) and assess the implications of this technology on U.S. command, control, communications and intelligence (C^3I) systems. Specific emphasis will be placed on considering the potential opportunities as well as problems associated with an ISDN as a preferred architectural approach for the underlying telecommunication system(s) supporting a C^3I system.

To provide direction in the research effort, three general questions were proposed as requiring an answer:

- Does the military need an ISDN to support C^3I systems and if so, why?
- What methodology is suitable for evaluating the "value-added" nature of an ISDN technology?
- If an ISDN has application in the C^3I system environment, what are the major issues that should be addressed or considered in order to permit a smooth migration towards implementation?

These are fundamental questions that must be fully considered before the Department of Defense (DoD) moves forward in embracing ISDN.

It is the author's hope that this paper will assist in building the necessary foundation of knowledge required for decisions in the future that concern the research and development, acquisition of C^3I system enhancements or the deployment of new C^3I systems based on an ISDN.

A. BACKGROUND

Rapid developments in computer and data communication technologies has resulted in the increasing merger of these two fields. Advances in the scientific of digital technologies, such as Very Large Scale Integrated Circuits (VLSICs) and Very High Speed Integrated Circuits (VHSICs), have provided much of the impetus for integrating the functions associated with information creation, storage, processing, transmission, and presentation. The movement towards integrating these information-based functions was recognized by the international telecommunications community and served as the basis for developing an Integrated Services Digital Network (ISDN). [Ref. 1:p. 1]

The ISDN is a projected integrated telecommunications network that will provide complete digital connectivity from end-user to end-user. This digital connectivity will allow the transparent transmission of voice or non-voice data over one network architecture with performance metrics that make it more cost effective and efficient than current, dedicated network architectures. Stallings believes that in practice, there will be multiple ISDNs implemented within national boundaries, but from the user's point of view, there will be a single, uniformly accessible worldwide network. [Ref. 1:p. 1]

This major advance in telecommunications will make feasible:

- the movement of substantial capability closer to individual users with significant improvements in the interface between the user and the system,
- increased connectivity among users, and
- system architectures and protocols which will make it possible to become more hardware and system software independent. [Ref. 2:p. 1-1]

These three conditions will make it possible to alter significantly the way systems are conceived, built and utilized and mark the beginning of a new era which will be characterized by "evolvable" systems. The concept of systems which can gracefully deal with change is not meant to be inferred as new. What is new is that now, current technology and methodology make it feasible to apply this concept to large information control systems. [Ref. 2:p. 1-2]

A C^3I system can be thought of as a large information control system. The ISDN concept, with its basis in digital technology and focus on standardization, appears to provide an opportunity for application in the area of C^3I systems as a new telecommunications network architecture supporting the process of command and control (C^2).

In the C^3I environment, changes in the computer and communication technologies may change the C^3I system and underlying C^2 process in:

- the means of communicating over great distances,
- the means by which a commander absorbs and assesses the existing situation, and
- the means by which he projects and predicts the probable outcomes of alternative courses of action. [Ref. 3:p. 69]

The first of these changes involves the telecommunications support system while the other two involve the situation assessment and decision support components of the C^2 process.

The issue faced by the C^3I community of planners and users is not the question of how to technically implement an ISDN. The technical implementation of an ISDN are the concern of telecommunication vendors or in the case of DoD, the Defense Communications Agency (DCA). Their motivations may differ substantially from the needs of the C^3I system planners and users.

In 1984, the CCITT ratified the first set of I-Series Recommendations on ISDN. [Ref. 4:p. 23] This is called the Red Book. The Red Book series primarily defines the standards of the interfaces for voice communications.

The next series of ISDN recommendations oriented towards data communication protocols and services is expected to be ratified in the CCITT Blue Book sometime during 1989. [Ref. 5:p. 9]

The level of effort and interest being dedicated to standardizing the international telecommunication architecture into an ISDN as well as the large number of commercial activities that have committed to the technology clearly signals its potential implementation on a national and international scale. Industry periodicals generally predict a 10 to 15 year schedule for full implementation.

The DoD and military services have a great interest in ISDN development and implementation, particularly in the role it will play in supporting our strategic C^3I systems, many of which rely extensively on commercial services and equipments. The DCA has, since the early 80's, monitored the standards development process and actively pursued the development and submission of military-based requirements into the national proposals for CCITT ratification. Many, such as multi-level precedence and preemption (MLPP), have been accepted and incorporated into the ISDN standards suite.

The focus and involvement of the military effort by DCA and other government agencies, however, appears to be entirely from the technical perspective. This is indicative of the often encountered trend that evidences a "technology-first" view of system acquisition where attention is incorrectly focused upon system performance rather than upon the functions which need to be supported. This observation is not unique to the military. Industry periodicals hold numerous accounts of supposed ISDN users questioning the functional merits of an ISDN.

B. SCOPE

The scope of this effort will be bounded by the C^3I system environment. An ISDN, as a telecommunications architecture, will support a number of functional environments--in the commercial as well as government sectors. Few applications, it is felt, offer the potential opportunities and complexities than those associated with the C^3I system environment.

This assessment is not intended to be all encompassing. C^3I systems are by nature extremely complex systems. The assessment will limit itself to exploring an ISDN as the replacement telecommunications architecture for supporting our strategic C^3I systems.

C. LIMITATIONS AND ASSUMPTIONS

This paper will not serve as a tutorial on ISDN. It is written with the understanding that the reader has some degree of familiarity with the concept and technology of ISDN. There are several well-written tutorials currently available and cited in the reference section of this paper. The two books by Stallings [Refs.1 and 6] are particularly recommended as worthwhile reading.

A technical examination of ISDN is outside the scope of this paper. Some technical issues will be presented in the context of providing clarity to a major issue under discussion. This does not mean to infer that C^3I system planners and users need not bother with understanding the technical merits of an ISDN. C^3I system users should always gain an appreciation for the technical operation of supporting sub-systems; to know their operating principles, capabilities, limitations; and when they are functioning outside of design limits.

A technical discussion of an ISDN from a functional perspective is also constrained by the lack of CCITT standards defining ISDN at the network and higher layers of the ISO model. Defining these functions and interfaces is the goal of CCITT work groups for the 1992 plenary session.

Finally, it will be assumed that the ubiquitous implementation of an ISDN by the commercial sector will lead to de facto implementation and use by the government and the military services, particularly as the future telecommunications architecture upon which strategic C^3I systems will be based.

D. METHODOLOGY

The methodology used as a basis for this assessment relies upon first understanding and appreciating the concept of C^3I. From this foundation, the role of the telecommunications network in supporting the C^3I system can be defined. This knowledge will permit us to evaluate ISDN in the context of the particular requirements placed on a telecommunications architecture supporting the C^3I system. From this assessment, we can develop the significant issues concerned with the transition towards and implementing an ISDN in support of C^3I.

E. RELATED STUDIES

A literature search revealed that there is a great deal of material discussing the concepts of C^3I and ISDN but very little relating the two. Impetus for this research was based on an article published in *Signal*, a magazine of the Armed Forces Communications and Electronics Association, that briefly discussed the technical merits of an ISDN in supporting C^3I [Ref. 7].

Two technical evaluations of ISDN have been performed by GTE, Inc. for the DCA. Both reports limit the discussion of ISDN to the technical issues related to integrating ISDN technology into the Defence Communications System (DCS) [Refs. 8 and 9].

There appears to be a scarcity of private sector initiatives in this area. Although there are many field trials underway, many of these trials are sponsored by service providers who are primarily interested in technical issues. The author has learned, however, that AT&T recognizes the marketing problems of this applications void and has instituted the "Trivista Program," an effort at exploring the potential applications for an ISDN in specific industry groups, e.g., banking, telemarketing, etc. [Ref. 10]

F. ORGANIZATION OF THE STUDY

This study consists of seven chapters. Chapter II lays the foundation for the study by defining the C^3I system in terms of the C^2 concept and process. The relationship and characteristics of the telecommunication network to the C^3I system is explored.

Chapter III provides a non-technical, user oriented, description of ISDN. Chapter IV describes the factors that make ISDN important to the military, particularly as a means of supporting our strategic C^3I systems. Chapter V assesses the ability of ISDN to support our C^3I systems. Chapter VI provides the significant issues and actions related to incorporating ISDN technology into our C^3I systems. Chapter VII provides the study's conclusions and recommendations.

II. COMMAND AND CONTROL

This chapter defines the command, control, communications and intelligence system (C^3I) and the command and control (C^2) process of the commander that the C^3I system supports. This serves as the foundation for understanding the relationship and function of a telecommunications network in the C^3I system environment.

A. C^2 CONCEPT

The C^2 system concept lacks a precise definition that is commonly accepted by all parties. Kenneth Moll, in his article, "Understanding Command and Control," in [Ref.11:p. 42] (June-July 1978) states:

> One of the least controversial things that is said about command and control is that it is controversial, poorly understood, and subject to wildly different interpretations. The term can mean almost everything from military computers to the art of generalship: whatever the user wishes it to mean.

C^2 and its derivatives command, control and communications (C^3); command, control, communications, and computers (C^4); command, control, communications and intelligence (C^3I); and, command, control, communications, intelligence and interoperability (C^3I^2) are all, it would appear, aptly named and concisely abbreviated but unfortunately, not as easily defined. [Ref. 12:p. 23]

The DoD defines C^2 as:

> 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 mission. [Ref. 13:p. 74]

This definition, provided by the Joint Chiefs of Staff, was developed in an environment where group consensus dominates organizational decision making and so lacks the detail and substance needed to support derivative applications.

A different view of a C^2 system was offered by the Defense Science Board Task Force on Command and Control Systems Management:

> A command and control system supporting a commander is not just a computer with its associated software and displays; it is not just communications links; and it is not even just all the information processing and fusion that must go into any well-designed and operating command and control system. It is all of the above and much more. The ideal command and control system supporting a commander is such that the commander knows what goes on, that he receives what is intended for him and that what he transmit is delivered to the intended addressee, so that the command decisions are made with confidence and are based on information that is complete, true and up-to-date. The purpose of a command and control system is, in the end, to provide assurance that orders are received as originally intended with follow-up in a timely fashion, which can make the difference between winning and losing wars. [Ref. 3:p. 9]

Synder offers a clear and concise breakdown of the C^2 system as one composed of three constituent parts: command being the function to be performed by the system; command, control, and communications represent the supporting system; and, command and control as the process that commanders follow as they utilize C^3 systems in discharging the functions of command. [Ref. 3:p. 11]

Yet even Synder's definition lacks some clarity and fails to account for the element of "intelligence" in C^3I. A Command and Control Workshop conducted in January 1985 by the Military Operations Research Society (MORS) found it useful to model the C^2 concept as an amalgamation of three principle components: physical entities, structure, and a C^2 process. [Ref. 14:p. 2-3]

By examining these perspectives from the sources presented above, we can justifiably infer that a C^2 or C^3I system, the latter being the most current terminology used and the term that will be used throughout this paper, is a complex system composed of physical entities and interrelationships (structure) that serve to support a specific function--command and control--by the performing of a certain process(es). The C^3I system is a cybernetic system and can be modeled accordingly. [Ref. 15:p. 56]

These descriptions of a C^3I system also serve to illustrate the scope of C^2. Taken together, they imply that a C^3I system is heavily weighed by the creation, processing, transmission and receipt of "perfect" information that is used by the commander in his decision making process. One of the considerations that permeate C^3I systems is the fact that the state of "perfect" information is unachievable. A commander must deal with some degree of uncertainty his decision-making processing. What must be clear is that the level of this uncertainty should not be aggravated by the operation of the C^3I system. Information, however imperfect it may be, should be processed and transmitted so its original condition is left intact.

Every system has a goal and the goal of the C^3I system is to provide the force commander with the means of directing and controlling his forces to accomplish the mission.

B. C2 PROCESS

"The C^2 process is the focal point of the C^3I system. The C^2 process is common to commanders at all echelons, in all battlefield functions, in all levels of conflict, whether at tactical or operational levels of war." [Ref. 16:p. 63] The C^2 process involves the making, disseminating and implementing of informed command decisions in order to obtain optimum effectiveness of the nation's military forces and resources in peacetime, crisis, hostile actions and war. [Ref. 17:p. vii]

Joel S. Lawson, Sr. dedicated a substantial study to the C^2 process and developed what is now referred to as Lawson's C^2 Process Model which he published in his report entitled "The State Variables of a Command Control System." [Ref. 12:p. 24] In Figure 1, Lawson defines the C^2 process as being composed of five functions and associated interfaces:

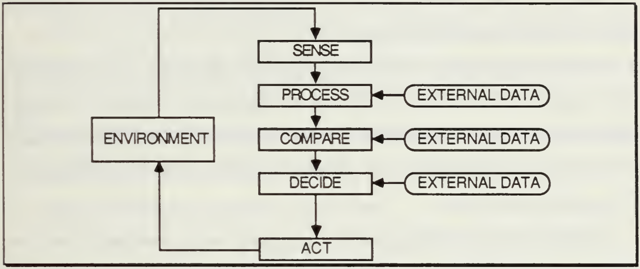

Figure 1. Lawson's C^2 Process Model

Using this model, we are able to ascertain the five functions of C^2 as: information gathering; situation assessment; action selection; response planning and execution; and, monitoring of the implementation of alternative courses of action. [Ref. 17:p. 55]

Lawson's model is clearly centered on the decision making process of the commander. This, the introduction of the human element in the form of the commander, is a major characteristic of military C^3I systems and the reason for many of the complexities involved in their design and implementation.

Decisions made by commanders may be type-classified as operational, organizational, and information decisions. Operational decisions result in directives to subordinate commanders. Before making an operational decision, however, a commander will have already reached an organizational and information decision state. A commander has made an organizational decision when he establishes the chain of command and information flow to support the operational decision. Information decisions, often going unstated, are committed when the commander reaches a personal, internal consensus on what is actually happening, the state of nature, and what actions must be taken to resolve conflict and achieve a desired state. [Ref. 17:p. 18]

Although organizational decisions are important, the above analysis indicates the importance of information decisions in the commander's C^2 process. It is the data that he receives and internally transforms into information that forms the basis for his information decisions. These information-type decisions form the basis for his operational decision(s).

It follows then that information value is critical to the commander's decision process and poor information will, in all likelihood, lead to a poor operational decision(s). This hypothesis has been proven in many military engagements the most recent of which took place in the Middle East with the firing on and destruction of a civilian airliner by a U.S. naval ship. The commander's operational decision to fire, according to news accounts, was based on faulty information provided by the man-machine interface of his inboard C^3I system.

In order for the C^3I system to achieve its goal, information must be provided to the commander that is timely, qualitatively correct and relevant to the decision(s) at hand. This will, it can be concluded, lead to a decrease in the commander's level of uncertainty and the proper execution of his C^2 process.

C. C3I SYSTEM ENGINEERING OBJECTIVE

The information systems supporting C^3I are uniquely different from other systems because they exist to support the human decision making process of the commander in a time pressured, dynamic environment with multiple, often conflicting goals, and with information that can rarely be properly valued or processed by the user. [Ref. 17:p. 86]

The basic objective is the development and deployment of a coherent and integrated C^3I system for providing support in a multi-echelon command environment across a full spectrum of operational situations. [Ref. 18:p. 5] The C^3I system which will realize the objective will be characterized by distributed, decentralized information processing, display, and decision making. [Ref. 18:p. 8]

D. TELECOMMUNICATIONS NETWORK

The conduit for information flow in the C^3I system is the telecommunications network. "A network is a set of nodes and links that provides connections between two or more defined points to facilitate telecommunications between them." [Ref. 4:p. xiv] The telecommunications network facilitates and makes possible the networking function between commanders and the resources of a C^3I system. The networking function is defined as: "The establishment of a reciprocal relationship among a group of people with a common interest or task that makes the smooth distribution of necessary information and thus the sharing of information (knowledge, wisdom, ideas) possible." [Ref. 19:p. 75]

The physical separation of decision makers from each other and from the facts on which they should rely to make their decisions creates the need for telecommunications. [Ref. 3:p. 58]

To understand the telecommunications process, it is necessary to appreciate two of its aspects: it is symmetrical and it is arbitrary. As ideas move from the mind of one commander to the mind of another, the transformations that are undertaken on the transmit side must be exactly matched by the reverse process on the receive side. This includes: analog-digital and digital-analog conversion; encryption and decryption; and, modulation-demodulation. Any unmatched step will result in a communications failure. Yet, given perfect physical communication of the information there still exists the possibility that the information will be interpreted by the receiving commander in a manner not intended by the transmitting commander. It should be clear that with all the alternative methods available for performing communications, the dominant issue in establishing a telecommunications path is not its optimization but the standardization of its process. [Ref. 3:p. 58]

A telecommunications network is one of the entities previously defined as a part of a C^3I system. Its purpose is to support the flow of information in the C^3I system. This information flow often has a sense of progression from data to information to knowledge. It should be noted that the commander is the ultimate recipient of the information flowing through the C^3I system but there are interim processes that take place. One of these is the transformation of sensor data by computer processing into a form more suited for human interpretation.

In supporting the commander, the telecommunications network must perform analog-to-digital and digital-to-analog conversion on the information elements. An important issue that must be considered on the output side is the display of this processed data. Digital displays may not reflect the degree of uncertainty that surrounds the information displayed. [Ref. 3:p. 70]

This relationship between the human and computer elements supported by the telecommunications system(s) creates a tension in the design of C^3I systems. [Ref. 3:p. 59] As C^3I systems incorporate more sensors, computers and other digital-based devices, the tension can be expected to escalate.

The methodology adopted in previous C^3I system designs has been to design and implement special purpose networks that are ideally suited for their specific function. Examples of these special purpose networks at the DoD level include Automated Voice Network (AUTOVON), Automated Digital Network (AUTODIN), the relatively new replacement for AUTODIN, the Defense Data Network (DDN), or the Defense Commercial Telecommunications Network (DCTN) designed to meet the wide-bandwidth requirements of video and secure-voice conferencing. There are numerous other special purpose dedicated networks including those developed by the individual services, e.g., SACNET.

These special purpose networks have become expensive to operate and maintain. They also fail to support the sophisticated information requirements of the commander; that is, they lack the ability to filter, correlate and analyze the data and display or present the results in a manner suited to the particular needs of the supported commander. This failure is a result of a lack of integration and interoperability among and between the different network architectures.

Another characteristic of today's telecommunications networks is that information appears to be "pushed" through by sensors and reporting commanders. However, it also ought to be seen as having been "pulled" out of the system by commanders who first identified the decisions they expect to make, who then determined what information could reasonably be expected to contribute to the quality of those decisions, and who then actively sought out such information, suppressing whatever was irrelevant in order that the reporting and analysis system (as well as the commander) could concentrate on information that is significant. [Ref. 3:p. 29]

It can be concluded that the basic requirement imposed on a telecommunications network is to provide aggregated, reliable, timely, and relevant information displayed or presented in a multi-media form best suited for correct interpretation. [Ref. 3:p. 29]

E. PROBLEMS WITH CURRENT C3I TELECOMMUNICATION NETWORKS

There are three primary areas that must be addressed to support the development of efficient and effective support systems for C^3I functions:

- the technological design of communications systems hardware and software for command and control;
- the human information processing concerns and how human information processing capabilities can be enhanced through use of knowledge support systems; and
- user requirements and leadership characteristics as they affect the need for and the use of support systems to aid in command and control functions [Ref. 17:p. 71]

These are the essential concerns that must be considered in designing the telecommunications networks supporting C^3I systems.

A Defense Science Board Report identified the special problems of developing C^3I systems. These problems can be characterized as technical, managerial, organizational and conceptual. [Ref. 20:p. 8] Although the report focuses on the development problems of C^3I systems, there are lessons that can be applied in the design of future C^3I telecommunications systems.

C^3I systems are technically complex and "information rich." The operation of the system depends a great deal on the type of information transmitted and the demands placed upon it. C^3I systems must be adaptable to many physical and application environments and offer performance measures that are often times more stringent than found in the commercial environment. A great deal of the technical design cost is driven by the extensive software development required to support the complex network control requirements. Finally, the range of technical choices together with often subjective performance criteria presents a further complexity to system development. [Ref. 20:p. 9]

These technical issues make management of system development and operation difficult. Management must integrate the many users' diverse requirements with the wide range of technical options available. [Ref. 20:p. 10]

Organizational factors add another layer to the problems already discussed. C^3I systems often cut across many service organizations each with their associated parochial interests, needs and missions. [Ref. 20:p. 10]

Politically, the network administrator's constituency is often narrowly construed as the agency's users of the information or C^3I system. Satisfying their varied requirements would be a significant challenge in itself. The pressure to satisfy the immediate demands made by both internal and external users is formidable and usually consumes the administrator leaving no time for the needed planning, design and acquisition efforts. [Ref. 2:p. 2-5]

The conceptual problem is related to the complexity of the system and determining what are valued system performance criteria and effectiveness measures. [Ref. 20:p. 11] This issue is of particular importance in conducting this assessment of ISDN and will be discussed in the next section.

Design and development of the C^3I system takes place under significant constraints and performance requirements. Some of these constraints involve:

- high data rates due to more/newer sensor sources
- shorter decision time due to increased counter force capabilities
- self-defined, but anticipated, mission variations
- projected interfaces with other C^3I systems, some of which are not defined
- a wide choice among candidate architectures (processors, communication links, terminals, etc.)
- cost and longer life-cycle requirements

As a result, each C^3I system requires the designer/developer to answer questions concerning flexibility, sensitivity, timing, sizing, survivability, availability, and extendability. [Ref. 21:p. 3]

F. EVALUATING THE EFFECTIVENESS OF TELECOMMUNICATIONS NETWORKS

A telecommunications network, by itself, can usually be easily described in terms of its technical performance. The difficulty that arises is in determining what the network performance contributes to the operational effectiveness of the system in which it supports. This is precisely the case with C^3I systems. There is no widely accepted method for relating the performance of the telecommunications network to the operational effectiveness of the C^3I system. [Ref. 14:p. 4-20]

Dr. David S. Albert has proposed an evaluation methodology that resolves this dilemma. Dr. Albert has developed a hierarchial-based assessment methodology that enables the assessment of a telecommunications network: at the technical level by examining its performance measures; at the next level by examining measures of information attributes, and at the highest level where measures of information value are estimated. The linkage between levels requires acceptance of two hypotheses.

First, it is hypothesized that improved performance will result in like improvements in the information attributes. Secondly, it is hypothesized that improved information attributes will contribute to increased user acceptance and greater "value" to the user's decision or function. [Ref. 22:p. 6] A graphical representation of Dr. Albert's model is presented at Figure 2.

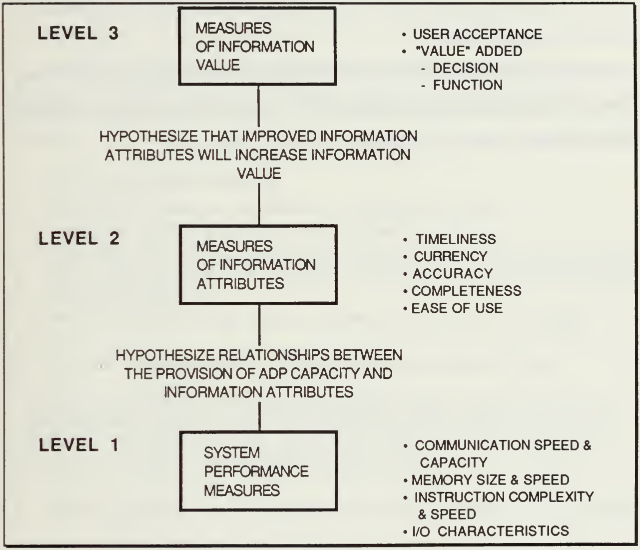

Figure 2. Dr. Albert's C^3I Systems Assessment Model

Further discussion of Dr. Albert's work is outside the scope of this paper. By accepting the two stated hypotheses, we have a structure within which we can assess an ISDN in the C^3I system environment.

The structure is not complete unless we consider the second dimension of the problem. There are factors external to the system that often must be considered; Dr. Albert calls these the family of "-ilities" (flexibility, reliability, survivability, etc.) and cost. [Ref. 22:p. 8]

Finally, there are the implementation factors that must be considered. These generally include cost of implementation, risks associated with implementation and technical factors involving transition issues. [Ref. 14:p. 4-21]

III. ISDN: THE CONCEPT AND PROMISE

This chapter provides a broad overview of ISDN from the users perspective. This perspective is used as the foundation for assessing the opportunities and advantages provided by an ISDN in supporting C^3I systems.

A. CONCEPT

An ISDN is a fundamental severing of ties with Bell technology--a technology designed to support telephony. An ISDN is based on the following fundamental concepts:

- end-to-end digital connectivity
- limited set of standard multipurpose user network interfaces
- integrated access to a myriad of voice and non-voice services
- providing an intelligent network control layer (common channel signalling) for service features, administration, maintenance, and other network operations functions
- evolve network from the current telephony network [Ref. 13:p. 366]

An ISDN is formally defined, using these concepts, by the CCITT as;

> A network evolved from the telephony Integrated Digital Network (IDN) that provides end-to-end connectivity to support a wide range of services, including voice and non-voice services, to which users have access by a limited set of standard multipurpose customer interfaces. [Ref. 18:p. 89]

There are presently two conceptual views of ISDN and how an ISDN will be implemented to support national telecommunications requirements. The U.S. industry, spurred by the regulatory climate, views ISDN from an abstract perspective. In the U.S., there will be many ISDNs each interoperable with the others and all servicing, in a competitive fashion, the basic service needs of information users. Other nations, without the deregulated climate of the telecommunications industry, view ISDN as a monolithic system designed to replace the capabilities, services and features of the current national network. [Ref. 23:p. 363]

This dichotomy in views is important to understanding the development and eventual service features of an ISDN. The somewhat narrow view of the monolithic concept precludes consideration of enhanced services and clear delineation of network and customer premise equipment (CPE) interface points. There is a substantial divergence of views as to what services will be provided by whom at which points in the network architecture. [Ref. 24:p. 22]

Currently, C^3I system users employ a variety of separate information networks to satisfy voice, data and video requirements. Each network has associated with it a different access scheme. Alternatively, an ISDN is intended to eliminate the diversity of network architectures by agreement on a standard architecture to serve voice and data users. The main objective of ISDN is to inhibit further evolution of separate voice and data networks--taking advantage of the economies achieved in digital switching, transmission, and signaling--and to provide the user with a universal access standard for plug compatibility. [Ref. 25:p. 91] The conceptual view calls for the masking of network implementation of voice, data, or video services to the user by using standard interfaces. [Ref. 26:p. 50.3.2]

B. OBJECTIVES

Despite the differing perspectives, a common set of objectives has been stated by the CCITT to guide the development of ISDN. These objectives include:

- Standardization: Develop a set of ISDN standards that permit universal access and permit the development of cost-effective equipment.

- Transparency: The most important service to be provided is a transparent transmission service. This permits users to develop applications and protocols with the confidence that they will not be effected by the underlying ISDN.
- Separation of Competitive Functions: Distinguish ISDN services as basic or enhanced with enhanced services forming the basis for competitive provisioning and marketing.
- Leased and Switched Services: The ISDN should provide dedicated point-to-point services as well as switched services. This will allow the user to optimize the implementation of switching or routing techniques.
- Cost-Related Tariffs: The price for ISDN service should be usage sensitive and not based on data classification. One type of service should not subsidize other types of service.
- Smooth Migration: An ISDN should evolve from current interfaces and provide a reasonable and planned migration path for users.
- Multiplexed Support: In addition to supporting individual low-capacity users, multiplexed support should be available to support user-owned exchange systems and local network equipment. [Ref. 1:p. 9]

C. ARCHITECTURE

The ISDN network architecture is based on three fundamental concepts: limiting the number of digital access interfaces; using both switched and dedicated transport services; and providing advanced voice, data, and video services. [Ref. 27:p. 98] Figure 3 provides a graphical representation of an ISDN architecture.

The limited number of access interfaces are classified as the basic rate interface (BRI) and the primary rate interface (PRI). The BRI is referred to as 2B+D and consists of two 64 kilobits per second (Kbps) B channels that can carry voice or data and one 16 Kbps D channel used for network signaling and control as well as user packet data. [Ref. 28:p. 281]

In North America, the PRI is referred to as 23B+D. It consists of 23 64Kbps B channels and one 64 Kbps D channel. The PRI will support 1.544 megabits per second (Mbps) bidirectional transmission rates. It can be used to interconnect computing facilities or switching centers. [Ref. 28:p. 281] The switched and dedicated transport services will support channel rates from 64 Kbps to 135 Mbps in either X.25 packet switching or circuit switching modes. [Ref. 27:p. 98]

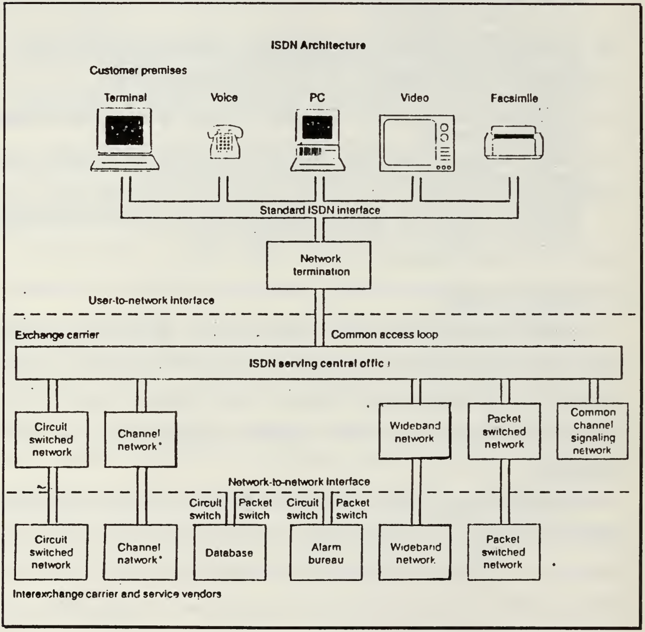

Figure 3. ISDN Architecture

The ISDN protocol suite is built to support the Open System Interconnection (OSI) Model. The ISDN protocols will primarily occupy the lower three layers; the network, datalink, and physical layers. These three layers define the basic services offered by ISDN. The upper four remaining layers will define the enhanced services of an ISDN. Figure 4 illustrates the current and future OSI model incorporating the ISDN standards suite.

The unique aspect of the ISDN architecture is the out-of-band signaling provided by the D channel for carrying Q.931 signaling messages. This channel will provide network intelligence features such as management, security, maintenance, etc. as well as user access for additional packet message services.

An important characteristic of the architecture is that it separates the access functions--how to get into the network--from network functions--those internal to the network. The focus is on how access nodes interact with the user rather than how network elements interact with each other. [Ref. 29:p. 237]

In later sections, ISDN will be considered based on the following general characteristics of its architecture:

- Integrated Access
- Common Channel Signaling
- Network Intelligence
- Digital Switching
- Digital Transmission
- Universal Standards

These characteristics are important because in some ways they constrain the digital network performance character of ISDN yet in other ways, offer significant benefits to the C^3I system planner and user.

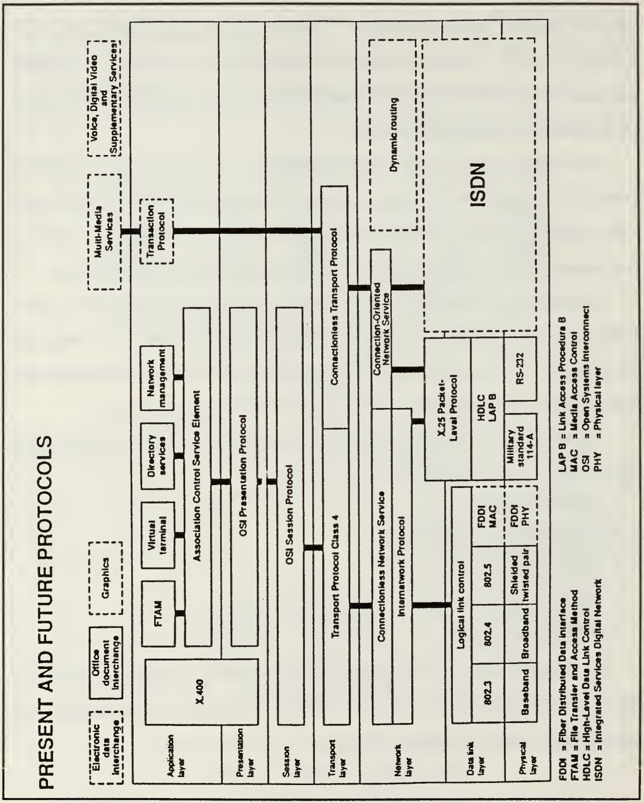

Figure 4. Current and Future OSI Model Incorporating ISDN Protocols

D. PROTOCOLS AND STANDARDS

ISDN standards are an attempt to bring the sophistication of data communications protocols to the world of circuit switching. Initially, the aim of the international and American standards activities was to replicate existing circuit-switched voice and data services. Recently, however, the physical, datalink, and network layers of ISDN have begun to solidify. These three layers, collectively called the subnetwork layers, may form the basis of most future networking technology. They are the basis for defining the "basic" services that will be offered by an ISDN. [Ref. 29:p. 237]

ISDN standards cover both circuit and packet switching. The circuit switching standards are the first to have been defined, and publication by the 1988 plenary session of the CCITT is expected soon. The packet mode standards had a much later start and are therefore only available in draft form. The period from 1988 to the next plenary session in 1992 is expected to focus on expanding the capabilities of packet-mode services.

In the short term, X.25 packet-switching networks will undergo little change from the way they operate today. Although gateways to ISDN will be needed, the ISDN packet-mode protocols will support current X.25 network implementations. After 1992, significant changes to the X.25 protocol are planned to take advantage of wideband ISDN and the expected widespread availability of fiber optics. [Ref. 29:p. 237]

Tracking the status of the standards is important to the telecommunications product, service and user communities. [Ref. 29:p. 237] Product developers must base next-generation equipment design on published standards. Service providers must ensure the standards meet marketplace and service requirements. Users must monitor the process to protect current investment and ensure application requirements are considered. Users can generally expect a two to three year delay from CCITT approval to commercially acceptable new product or service introduction. [Ref. 29:p. 237]

A detailed examination of ISDN standards and protocols is not feasible in this paper but there are significant issues in this area that are of concern to users.

The ISDN is defined by its access points where the user-network interface takes place. The user-network interface is comprised of all the equipment between a user's customer-premise equipment (CPE) and the network. Each device in the user-network interface has a particular function or set of functions and is called a functional grouping. The interfaces between functional groupings are known as reference points. Functional groupings are considered to be an extension of either the network's or the user's equipment. Network termination (NT) equipment handles the communications from the network while the terminal equipment (TE) is responsible for the communications from the user. Figure 5 provides a graphical illustration of the ISDN access architecture that references the interface points and functional groups. [Ref. 29:p. 238]

Each reference point has somewhat different characteristics. The S and T reference points physically consist of two twisted-wire pairs for full duplex operation. The range of the S and T reference points is 1000 meters point-to-point or 150 meters in a multidrop passive-bus configuration. The U interface will have a maximum length of 6,500 meters. The V interface will be a nonstandard interface used within the exchange office. [Ref. 29:p. 241]

Various points of demarcation. The user-network interface is divided between network equipment and terminal (user) equipment. In the United States, the terminal equipment includes everything from the NT1 to the TE devices, whereas in Europe, ISDN users will control all devices from the NT12 to the TEs.

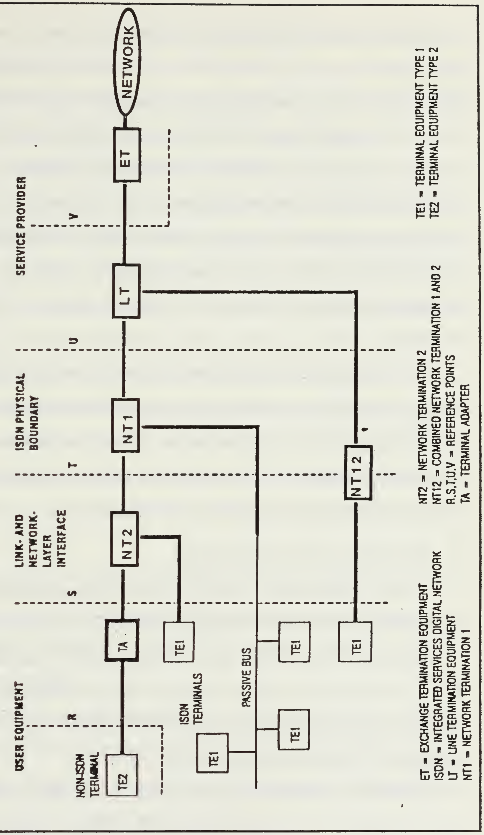

Figure 5. ISDN Access Architecture

This access architecture is important because it has several important implications to a user. The U.S. differs with other foreign nations on the standard public network demarcation point; this is a result of our deregulated environment. In the U.S., both NT1 and NT2 functions are considered to be a part of the CPE, requiring the use of a nationally standardized U interface to meet competitive service requirements. In Europe, however, the NT1 function is assigned to the PTT thereby eliminating the need for a standard U interface. It is still uncertain whether a U interface will be accepted by the CCITT. If it is not, many international companies and the government may find themselves without global terminal portability.

The ISDN standards for the interface points also place distance constraints on the user loops. This is required to ensure an acceptable level of digital service using twisted-pair as the transmission medium. These standards are more stringent than those incorporated in the present telephony suite and will be a significant factor in network design and implementation. [Ref. 29:p. 241]

E. SERVICES AND FEATURES

An ISDN will provide a variety of services, supporting existing voice and data applications as well as providing applications still under development.

"Services" is a relatively vague term that refers to that which is offered to the user. It is, however, a controversial term in the national and international ISDN worlds. The controversy is caused by the merger of the communications and computers in telecommunications. [Ref. 4:p. xix]

The CCITT defines basic services as those that offer information transport to a user. These are covered by the lower three OSI layers. Teleservices, defined in the upper four OSI layers, consists of all services offered a user to include information transport. [Ref. 4:p. xix]

In the U.S., there is a clear distinction between basic and what is referred to as enhanced services, those services provided by the four higher OSI layers.

The list in Table 1 illustrates this variety of services that could be provided by an ISDN. These services fall into the broad categories of voice, data, text and image (including slow motion video). Most of these services can be provided with a transmission capacity of 64 Kbps or less--the standard for an ISDN. Some services require considerably higher data rates and may be provided by high speed facilities outside the ISDN, e.g., dedicated networks such as LANs or CATV. However, these higher-speed services may intersect with the ISDN and make use of high-capacity ISDN links, using the PRI, for part of the transmission path. [Ref. 1:p. 10]

What must also be considered is the evolution towards a wideband ISDN--a concept already under discussion by the industry. A wideband ISDN would significantly expand the service capabilities by providing operating rates equivalent to present day LANs.

The multimedia capability of ISDN is supplemented with another feature that provides a significant means for enhanced service provisioning and management. An ISDN will also be an "intelligent network" by incorporating the use of out-of-band signaling on the D channel.

"Intelligence" in an ISDN implies the ability on the part of the user to engage in a sophisticated dialogue with the network to define the information service support desired. It also implies an extremely diverse range of information service offerings instead of mere information transport. [Ref. 4:p. xvi]

TABLE 1. LIST OF ISDN SERVICES

	Service			
Bandwidth	**Telephony**	**Data**	**Text**	**Image**
Digital voice (64 kbps)	Telephoned	Packet-switched data	Telex	
		Circuit-switched data	Teletex	
	Leased circuits	Leased circuits	Leased circuits	
	Information retrieval (by voice analysis and synthesis)	Telemetry	Videotex	
		Funds transfer		Facsimile
		Information retrieval	Information retrieval	Information retrieval
		Mailbox	Mailbox	Surveillance
		Electronic mail	Electronic mail	
		Alarms		
Wide band (>64 kbps)	Music	High-speed computer communication		TV conferencing
				Teletext
				Videophone
				Cable TV distribution

Access by the user to the network intelligence of an ISDN will allow the development of applications that tailor the services provided by the network to the specific requirements of each user.

Some commercial applications have already been developed; these include call forwarding, call screening, automatic calling number identification, automatic conferencing, and remote sensor polling. A user will be able to re-allocate network resources such as bandwidth and routing to provide optimum service at minimal cost.

For example, the intelligent ISDN will be able to recognize a called number and establish the proper type connection using a designated least-cost route in a time period that is significantly shorter than that provided by the current system. The ISDN will also be able to allocate bandwidth for data service based on the required operating rates of the user: no longer will users have excess capacity sitting idle or wasted. [Ref. 28:p. 281]

The most exciting aspect of an ISDN from the user perspective is the capability to develop applications, independent of the telecommunications network, that provide information in a multimedia format. The services and features of the ISDN will permit users to integrate information from a multitude of sources far more easily and effectively than can be accomplished using today's technology.

This ability to functionally integrate applications is already being used today by American Express, the credit card company. AT&T recently provided ISDN service to American Express that permits a caller's inquiry to automatically trigger retrieval and display of their credit file before the service representative has a chance to answer the telephone. [Ref. 30:p. 1]

Imagine the ability to improve worker productivity by giving them the opportunity to converse with one party, see a photograph of the party from a remote storage digital archive, and doing this while sending a message to a different party, all while using the same desktop terminal.

IV. SIGNIFICANCE OF ISDN TO THE MILITARY

This chapter reviews the role of commercial telecommunications in supporting military communication requirements. The unique characteristics, i.e., the physical and functional integration provided by an ISDN and objectives of the ISDN are considered in light of the special requirements associated with supporting C^3I systems. This chapter essentially assesses the first question of whether the military needs an ISDN.

A. COMMERCIAL COMMUNICATIONS

The employment of commercial telecommunications system services and technology to meet military C^3I requirements is not new and will not change. With the movement away from "stove-pipe" networks (dedicated networks designed specifically to support a particular function, e.g., personnel administration, finance, etc.) in the military and reliance on commercial sources in a competitive environment, use of commercial telecommunications services and technology is likely to grow. [Ref. 31:p. 15]

The global telecommunications infrastructure is valued at over $500 billion. In 1985, the U.S. infrastructure alone represented half of this investment. Each year, over ten percent of our terrestrial and space networks are modernized. [Ref. 31:p. 15]

The large sums of money needed to build and maintain a modern military force dictate that financial resources for C^3I systems go towards maximizing the use, when appropriate, of commercial telecommunications services and technologies. Developing and implementing non-standard communication architectures is an expensive and time consuming process. Purchasing or leasing national commercial products or systems are solutions to fulfilling C^3I system requirements. [Ref. 31:p. 15]

Cost alone is not the only factor in using private sector telecommunications resources. Many of our commercial networks are widely available, offer robust facilities, and provide a trained pool of technicians to perform operation, maintenance and installation. Finally, our national communications system is organized under the auspices of the Defense Communications Agency (DCA) and the Federal Emergency Management System (FEMA) to provide critical services and established priorities to our nation's authorities in support of national security and crises. [Ref. 31:p. 16]

Our military telecommunications networks span the globe and rely not just on our own national systems but on those of our allies. In Europe, the national Ministries of Postal, Telegraph and Telephone (PTTs) play a major role in supporting NATO and U.S. requirements. Some of our allies, through their national PTT, provide fully integrated strategic and tactical systems. In France, the tactical RITA communications system--akin to cellular telephone on the battlefield--is interoperable with their national telephone network. The Federal Republic of Germany's "Grundnetz" fixed network is designed to support military requirements and is able to accept several of its allies' tactical systems. [Ref. 31:p. 16]

There are special considerations and constraints that must, however, be made when using private sector resources: security, user mission, and interoperability are but a few. In some cases, a parallel military system to meet these unique requirements is justified. For a great many peacetime C^3I telecommunications systems requirements, however, use of commercial sector resources is appropriate and desirable.

B. COMMERCIAL STANDARDS

Commercial networks, standards, and protocols are primary concerns of the C^3I system planners and users. [Ref. 31:p. 16] In recent years, private industry and the government (including the DoD), have been moving towards the development and voluntary adoption of communications and computer standards. In some cases, the DoD has mandated their use. Several of these standards include, for example, the OSI model, the Government Open System Interconnection Protocols (GOSIP), and the Portable Operating System Interface (POSIX).

It has long been accepted in the communications industry that standards are required to govern the physical, electrical and procedural characteristics of communications equipment. The key advantages of standardization are:

- A standard assures that there will be a large market for a particular piece of equipment or software. This encourages mass production and, in some cases, the use of VLSI and VHSI techniques results in lower costs.
- A standard provides universal access to communication network interfaces thus encouraging a multi-vendor environment and thereby giving the user flexibility in equipment selection and use. [Ref. 1:p. 77]

The principal disadvantage of standards, it has been argued, is that they tend to freeze technology. By the time a standard is developed, reviewed and promulgated, more efficient techniques are possible. [Ref. 1:p. 77]

The motivations for this movement towards standardization are not relevant to this discussion. What is germane is the window of opportunity that exists for the DoD for influencing the development of and use of these standards. In the case of

ISDN, the DCA, as proponent for the DoD, has the ability to influence the standards being considered for the future global telecommunications architecture.

C. C^3I SYSTEM SUPPORT

C^3I applications require the integration of voice and data. In the current environment, this often means the sharing of the transmission channel where the different signals are multiplexed at the source and separated, after transmission, at the destination into their original form. In an integrated information environment, the two infrastructures supporting voice and data are transformed into one that functionally supports a common objective. The first mode of integration--the sharing of transmission channels--is "physical" integration, while the second is "functional" integration. Physical integration reduces facilities costs while functional integration permits increased work force productivity. [Ref. 1:p. 30]

The architecture of an ISDN is based on three basic concepts that support the objectives of physical and functional integration. [Ref. 1:p. 31] These previously introduced concepts include, limiting the number of digital access interfaces, using both switched and dedicated support services, and providing advanced voice and data services. [Ref. 27:p. 98]

The physical integration of ISDN applies to the bottom three layers in the OSI model--the subnetwork layers--while the potential to invoke functional integration exists at the top four layers. Functionally integrated applications, much like those required in C^3I systems, will demand a more intensive transaction-based interaction between the telecommunications and computing environment. An ISDN will be well-suited for providing this interactive environment where the D channel signaling is available to provide the exchange of the service primitives.

[Ref. 1:p. 31] These functions, supported by the ISDN architecture, are commonly referred to as the "enhanced" services.

The physical integration issues related to incorporating ISDN into the Defense Communications System (DCS) have been studied by GTE, Inc.. This DCA contracted study resulted in two published reports [Refs. 8 and 9]. To a C^3I system planner or user, these reports have marginal utility because they focus on the technical issues involving ISDN.

The area of specific interest and most concern involves the functional integration permitted by the ISDN and the implications to the user of the physical integration concept.

The physical integration of voice and data can be expected to have one major result--a further exponential growth in the amount of information made accessible to an ISDN user. Users will no longer be physically constrained, in a large degree, by the physical parameters of a network that serve to isolate users from information. Instead of one phone call, he can now make one, receive another, and send a message, too. This, the author believes, will lead to a serious information quantity and quality problem. Decision makers may become inundated with information that is provided in the wrong format, at a level of detail not needed, and with a low expectation that it is correct. This information overload problem may lead to the decision maker becoming paralyzed, a state where he is unable to reach a decision state, or he reaches this state by shutting out the external stimulus provided by the telecommunications network, i.e., he stops using the C^3I system.

The implications of the physical and functional integration concepts to the C^3I system user should be clear. The DCA is and has been active in understanding the technical issues of an ISDN. Little research, the author believes, has been conducted towards understanding these two concepts together, particularly in the area of C^3I.

D. ISDN OBJECTIVES FOR A C^3I SYSTEM USER

The following are some general objectives for the ISDN from the user's perspective:

- The ISDN should provide competitive price performance.
- The ISDN should be transparent to the user across a wide range of applications. This should be achieved through the provision of a consistent set of procedures used to access similar capabilities in different network services.
- A small family of network interfaces should be provided with each interface defined by a common structure. Furthermore, network services and features should be structured in an upward-compatible, nested arrangement so that simple terminals can use the simpler aspects of sophisticated ISDN capabilities.
- The same protocols should be used to perform similar functions for a given class of terminal equipment even though different interfaces are used.
- A choice of performance or service grades should be available for all services and interfaces to allow the user to exercise economic trade-offs.
- There should be the capability for terminals to be compatible with ISDN and there must be arrangements for the ISDN to interconnect/interoperate with other networks. [Ref. 8:p. A-2]

These objectives may be achievable with ISDN. There are, however, trade-offs towards realizing their full potential. It must be remembered that ISDN, by its nature, is a compromise between a voice network architecture unsuited for data communications and a data network architecture that conflicts with the desired characteristics required in supporting a C^3I system.

V. ASSESSING ISDN

This chapter assesses the value of ISDN technology to the C^3I system planner and user. This is the keystone chapter in that it correlates the unique requirements and characteristics of a C^3I system (Chapter II) with the concept, objectives, architecture, and standards of ISDN. This allows us to evaluate the value of ISDN using the factors considered in Dr. Albert's model [Ref. 2].

A. C^3I AND ISDN: ARCHITECTURES

The architecture of ISDN may be well-suited for integration into the C^3I system architecture. The physical and functional partitioning of the ISDN and the services offered to the user are, in many ways, similar to the special requirements and characteristics associated with C^3I systems that were introduced in Chapter II.

Generally, it can be said that an ISDN supports a decentralized, distributed information processing, display, and decision making environment--the design objective for C^3I systems.

The ISDN concept and its design objectives in many cases mirror the unique qualities demanded in an "ideal" telecommunications system supporting C^3I. Some of these characteristics of the ISDN architecture will be considered below.

There is a weakness in the ISDN architecture that C^3I system users and planners must consider. When ISDN service is interrupted by on-site CPE power loss and the local loop is still available, the basic phone service will be interrupted. The current standards for ISDN do not require the central switching office to provide power to the NT interface. This means users must provide their own back-up battery power. This alternative can be costly and may not contribute to improved reliability and maintainability on the user side of the network.

1. Evolvability

The ISDN architecture may permit the network and user to evolve gracefully and independently. New user applications can be developed independent from the operation of the network or the network can be changed without affecting the user interface. This is a critical need in large, complex and costly C^3I systems.

2. Flexibility

The ISDN architecture is extremely flexible in the manner in which it can be configured to support a variety of information transport types and services. C^3I users may be able to use one network for the transmission of voice, computer, sensor and video information instead of developing separate network architectures.

3. Survivability

The ISDN architecture, if implemented in accordance with CCITT plans and objectives, will be ubiquitous throughout the U.S. and the world. Integrating military networks and the networks of commercial ISDN carriers will provide a robustness not available in today's network architectures. Further, the standardization of the architecture may allow rapid network reconfiguration or reconstitution. The military will be able to rely on compatible and interoperable commercial resources, i.e., personnel, equipment and systems.

4. Interoperability and Compatibility

The ISDN architecture will provide the interfaces required to provide the widest possible interoperability and compatibility between military and civilian, U.S. and NATO, and strategic and tactical telecommunication networks.

5. Adaptability

The ISDN architecture will allow the user, by reconfiguring or re-allocating network resources, to adapt the network to the changing operating environment and to his own unique set of information service needs. This change can be dynamically accomplished using the network intelligence available in the ISDN. This is especially significant to the C^3I system user. A commander will no longer have to conform to the operations of the information system, he can mold the system to meet his own personal decision making needs.

6. Costs

The ISDN architecture is attractive to telecommunications carriers because it offers economies and flexibility not available using today's technology. There are, in addition to the cost savings that will be realized by any user, significant economies that can accrue to the C^3I system user. Many C^3I systems are complex and costly because they require the expensive and time consuming development of software and hardware to provide the facility for controlling information flow through the system. This component in C^3I system development may no longer be necessary--the ISDN may be able to support this function.

7. Security

The ubiquitous nature of ISDN and the standardization of link operations may present a number of challenges concerning the security and integrity of the ISDN and the protection of information carried on the network. Of particular concern is maintaining the integrity of the computers and associated databases that are integral to the network or connected with it.

B. ATTRIBUTES

In Chapter III, the fundamental concept of ISDN was introduced as being based on the following attributes:

- End-to-End Digital Connectivity
- Integrated Services
- Standard Interfaces
- Out-of-Band Signaling
- Network Intelligence

These attributes will now be considered from the perspective of what they offer the C^3I system user or planner.

1. End-to-End Digital Connectivity

The use of digital technology in an ISDN facilitates more inherently digital communications such as switched high speed digital transmission between computers than is possible when analog to digital and digital to analog conversions are occurring in the network. [Ref. 32:p. 50.5.2]

Performance in telephony networks is focused on a simple application--voice. The same applies for data networks designed specifically to support the transmission of digital-type traffic. The performance attributes of both types of network applications are well understood and relatively easy to define. ISDN, however, is designed to support a variety of applications--voice and data--using different transport technologies such as circuit and packet switching. Additionally, it is anticipated that many ISDN applications will themselves be complex. [Ref. 1:p. 25] The problem then is determining the appropriate measures of performance in an ISDN environment.

From a user perspective, performance must focus on the perception of the end users (people or computers) and includes the man-machine interface. These performance measures would include call set-up time, proper activation of features, call completion and satisfactory information transfer measured by available error rates and bit rates. [Ref. 1:p. 26]

The ISDN is constrained by the physical transmission medium used, i.e., twisted pair wire and the concept calling for integrated services by the use of circuit and packet switching technologies. These two intentionally imposed design constraints place the data transmission performance of an ISDN well below that which is achievable by LAN and Fiber Distributed Data Interface (FDDI) technology. The ISDN BRI and PRI operate at standard rates of 64 Kbps and 1.544 Mbps, respectively. LAN performance is in the area of 10 Mbps and FDDIs will exceed 100 Mbps. An ISDN would be inappropriate for applications involving data transmission rates that exceed 1.5 Mbps.

The use of digital technology will allow capabilities that are currently available only in secure terminal and encryption equipment. The use of low transmission rates in secure voice are driven, in large part, from the cost of high speed modems to perform the analog to digital conversions. Cryptographic equipment is capable of supporting 64 Kbps digital transmission. Low transmission rates over analog networks have been the motivating factor in the design and implementation of secure voice instruments to support low transmission speeds. An ISDN will allow users to take better advantage of developments in communication security, such as embedded cryptography in the user device, unclassified cryptographic equipment and advanced cryptographic keying. [Ref. 7:p. 46]

The BRI and PRI standard operating rates are adequate for providing digitized voice with recognition quality, high speed data, and slow-motion video. Although the performance rates of ISDN may not be adequate for every communications need, an ISDN will likely meet the requirements of a great many C^3I system users. [Ref. 28:p. 284]

Digital connectivity offers significant cost improvements over analog networks. The use of VLSI and VHSIC technologies and industry data networking standards will drive equipment costs down. A substantial network cost in providing the analog-digital conversion, e.g., channel banks, is eliminated.

The digital service offered by ISDN can be expected to reduce the number of dedicated leased circuits required to support users. Costs of circuits can be identified and allocated to specific users. [Ref. 7:p. 46]

The potential cost savings from the use of common facilities and standard equipment will be supplemented by additional savings achieved by improved maintainability, capability to buy off-the-shelf equipment and services, and improved acquisition times. [Ref. 7:p. 46]

ISDN technology facilitates the building of interfaces needed to integrate new equipments and services. For the C^3I system user, this means the network can evolve to support new technologies and requirements.

2. Integrated Services

Integration of user access to the network over one access medium may provide a number of significant benefits to the user.

The ISDN access standards define one subscriber loop for circuit, packet, voice and data services. This will provide the user with a tremendous capability to acquire network access in a shorter period of time. The standardized access also provides geographic and vendor terminal portability. [Ref. 32:p. 50.5.2]

Integrated access may improve and expand the information system services available to C^3I system users while decreasing the costs of providing this support.

[Ref. 26:p. 50.5.3] This may be achieved by the use of plug-in compatibility and use of in-house twisted pair wiring. [Ref. 32:p. 50.5.2] Sharing of the access medium among the different services made available by an ISDN may lower installation costs, a significant factor in providing new services to users. [Ref. 26:p. 50.5.2]

This ability to functionally integrate information from a multitude of sources--man, sensor and computer--and present the results in a suitable format that can consist of any combination of voice, data and image is one of the interesting aspects of an ISDN. This capability is a fundamental requirement for a C^3I system user and one that has not yet been adequately provided in current strategic networks.

Multimedia input/output reinforces the concept that humans perceive information about the outside world and attempt to communicate thoughts with their fellow human beings by utilizing the five senses. It is difficult to fully express human thoughts and ideas through information that can be conveyed only by a single medium. Using a combination of all media perceivable by humans to understand the thoughts and ideas of others is not only natural, it fits the very essence of human nature. [Ref. 19:p. 74]

Further elaboration on this concept is beyond the scope of the present discussion, however, it should be noted that an ISDN more closely approximates the needs of humans in expressing and communicating thoughts than other present-day telecommunication networks. Figure 6 is a graphical representation of a model

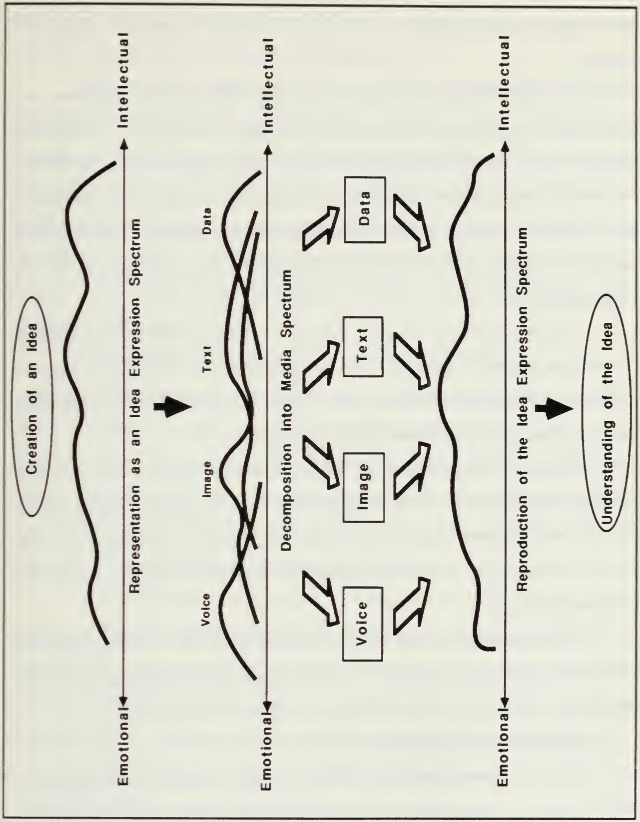

Figure 6. Idea Spectrum Representation
[Ref. 19:p. 75]

that relates idea expression to the multimedia aspects of the communications channel.

A C^3I system must be capable of relating information that varies along the idea expression spectrum from emotional (human) to intellectual (computer or sensors). The model stipulates that as information progresses from one state to another, the best means, in terms of media format, for representing the information also progresses. An ISDN may permit this decomposition and re-composition process to occur much easier than present network technologies allows. [Ref. 19:p. 75]

Finally, users can expect a synergy to develop from having multiple communications channels established at the same time. [Ref. 26:p. 50.5.2] Decision makers will, if desired, be able to more effectively manipulate the information gathering, processing, and dissemination processes.

For the C^3I system user, the integrated services feature of an ISDN will significantly enhance the commander's ability to execute his C^2 process in a more effective and efficient manner. An ISDN will allow the commander to seek, process, transmit and assimilate information in a more logical, planned and coherent manner.

The multimedia display will provide the commander with the opportunity to select the most suitable means for transmitting his ideas, thoughts and decisions and obtain confidence that they are properly received and understood.

3. Out-of-Band Signaling

Out-of-channel signaling or common channel signaling (CCS) means the user will have a communications channel with the network all the time, not just during call set-up. The provision of CCS in an ISDN provides a number of technical and functional advantages. [Ref. 33:p. 2]

The CCS will give the user access, on demand, to the network intelligence of an ISDN. On subscriber loops, CCS will use a message-oriented protocol which is easily adaptable to provide new service features. [Ref. 33:p. 2] This separation of signaling path from the user information path facilitates the specification of a flexible, universal signaling protocol, capable of supporting multiple services. It is the alternative to the "in-slot" signaling technique used in X.25 and X.21 access protocols where the signaling information is conveyed via the same path as user information. [Ref. 34:p. 17]

The availability of common channel signaling in both the network and the user-network link will allow users to exchange control/signaling messages without having to establish a circuit-switched connection. Particularly important is the ability to monitor and control services currently in progress on a two-way basis. This is contrasted with current in-band signaling where after call establishment, signaling and control capability are lost. This service will be available in the top four layers of the OSI based ISDN model. [Ref. 34:p. 21]

CCS will provide enhanced network management and control by the user. Network restoration and reconfiguration, if permitted, can be accomplished to support user requirements. [Ref. 7:p. 44] A commander can be alerted to high priority calls/messages and re-allocate or reconfigure network resources in real-time using CCS to support situation development. For example, CCS will permit the commander to screen/block network traffic at network nodes based on his own established priorities or other such factors.

4. Network Intelligence

The capability to integrate computers into an ISDN allows users to build a great deal of "intelligence" into the network. More direct user access to network intelligence, using CCS, will provide users with more control of their network resources. Users will be able to dynamically control and manage the network in a real-time fashion to support changing service requirements. [Ref. 32:p. 50.5.2]

This attribute of an ISDN offers the greatest potential for application in the C^3I area. Theoretically, an intelligent ISDN supporting a C^3I system can be designed to monitor network information flows and trigger alarms for anomalous events requiring a commander's immediate attention. For example, transmission of a flash priority message among users can automatically trigger the establishment of a voice with video call between designated commanders.

Network intelligence will also permit the network to directly link with information storage and processing facilities. Commanders may be provided the ability to query databases on an interactive basis, even while engaged on another communications channel and transmit the results to a distant party for further discussion. The implications on decision making productivity are clear; call-backs will be a thing of the past.

Perhaps the greatest potential for applying the ISDN network intelligence feature in supporting C^3I systems is in molding the telecommunications network services to the specific needs and desires of the commander. The commander, as an individual user, will be able to have the services of the network conform to his needs and desires. No physical re-engineering or reconfiguration of the network will be required.

Network intelligence will also provide real cost savings in its ability to dynamically allocate network resources to support user service demands. This will maximize the efficiency of the network facilities and services. Bandwidth can be assigned based on a user's immediate needs. Users will pay for bandwidth costs based on capacity used instead of connection time thereby eliminating the need for dedicated circuits and their built-in inefficiencies.

C. COSTS

There are essentially three categories of costs associated with adopting ISDN technology. The C^3I system user should be aware of all of them because they can substantially alter his perspective on the worth of the technology.

The first area involves transitioning costs. Implementing a full ISDN requires substantial capital investment in switch facilities and user terminals. For C^3I system users, there are the additional associated costs of transition, by network overlay or interface methodologies, with the current suite of installed networks and services.

The transitioning of bases and posts must be accomplished in a coherent and planned fashion. Otherwise, the military services will invest large sums of defense monies and accomplish little other than establishing islands of ISDN where the partial services available offer little functional value.

Commercial connectivity and service costs for ISDN must also be considered. Of importance to the user, is the fact that usage charges will, under ISDN, be based on capacity-used instead of connection time. Providing full ISDN service to all potential users could be many times more costly than under plain old telephone service (POTS).

Another cost factor will be the services defined and offered as "enhanced." It should be remembered that these are non-regulated services. Users can expect that tariffs for these services will be based on the carriers' perception of value. That is, those services that offer substantial value in increasing the productivity and hence profitability of a business will be priced accordingly.

Finally, the diversity of services offered by a multitude of carriers will create even further complexity in the pricing of telecommunication services.

VI. ISSUES AND ACTIONS

There are many issues that need to be addressed and actions taken before ISDNs supporting C^3I systems become a reality. ISDN is still in its development phase and there remain a number of substantive issues regarding its technical and functional implementation.

Many issues have been identified in the field trials and there are sure to be many that will yet surface. Users must, before plunging ahead in embracing an ISDN, appreciate the significant factors that must be considered in planning and implementing the technology. Some of the more relevant issues are discussed in the following sections.

A. POLITICAL AND REGULATORY

Chapter III introduced the ISDN concept and the fact that there currently exist two perspectives, the abstract one that calls for many ISDNs in the competitive environment of the U.S., and the monolithic perspective that views ISDN as the replacement for the current national infrastructure provided by the PTTs in many foreign countries.

The multiple ISDN solution is predicated on the concept of interworking. Interworking would allow ISDN users to select timing and routing options for their transmissions. Although the ability to specify and select carriers is included in current CCITT draft recommendations, interworking raises questions about a universal numbering scheme. If private networks, LANs or alternate competing carriers are to exist alongside the ISDN, the ISDN numbering plan must allow equal access to and from the ISDN. [Ref. 1:p. 119]

The single drawback to an interworking system would be its cool reception by foreign administrations. The PTTs prefer to connect with a single U.S. carrier rather than duplicate termination facilities. PTTs might refuse to interconnect their ISDNs with numerous U.S. ISDNs, thus undermining the worth of all systems and causing a significant policy and regulatory problem for the FCC to resolve. [Ref. 1:p. 119]

In the U.S., there exist two regulatory principles which will shape the implementation of U.S. ISDNs. The first is the Computer II dichotomy that requires clearly defined boundaries between the transport of information (basic services) and other kinds of information services (enhanced services). Additionally, a physical equipment demarcation exists between the network and CPE. The second regulatory principle encourages the competitive provisioning of information transport service. [Ref. 1:p. 86]

Maintenance of a dichotomy between information services defined as basic and enhanced as well as between network and CPE equipment is supported by the ISDN architecture. This dichotomy, however, may serve to trade-off service efficiency so as to promote competition. For example, some enhanced services may be more efficiently provided by the network intelligence feature of an ISDN, yet the Computer II dichotomy would dictate a defined interface and transport of the information by an element independent of the network. In other words, the local telephone company would be prohibited from offering an information service as a feature of its ISDN. [Ref. 1:p. 92]

The advocacy of competition in the provisioning of information transport services will likely remain a U.S. regulatory goal. In addition to the interworking issue previously discussed, this policy can also be expected to trade-off efficiency in favor of competitive alternatives. [Ref. 1:p. 92]

B. PROTOCOLS AND STANDARDS

There are three categories in which standards today may be grouped: (1) voluntary standards, (2) regulatory standards, and (3) regulatory use of voluntary standards. [Ref. 1:p. 80] This last category has gained prominence recently and is, in fact, one of the methods that is being used by the government and DoD to impart some discipline in the procurement of communication and computer systems.

The regulatory use of voluntary standards has several salutary effects: (1) it reduces the burden on government to define standards and specifications, (2) it encourages cooperation between government and standards organizations to produce standards of broad applicability, and (3) it reduces the variety of standards that vendors must meet. [Ref. 1:p. 81]

ISDN standards are likely to be adopted by the DoD by regulatory mandate of the voluntarily drafted CCITT standards suite.

Standards development must involve the users yet, until recently, potential ISDN users--commercial and government--have not had the organizational vehicle to provide this interface with the national and international standards organizations. To address this problem, the National Institute for Standards and Technology (NIST) sponsored the incorporation of the North American ISDN Users' Forum (NIU-FORUM). The mission of this group is "to create a strong user voice in the implementation of ISDN and ISDN applications and to ensure that emerging ISDN standards meet user application needs." [Ref. 35:p. 1] The first meetings of this group have taken place only in the past year.

Although government users are included as a user sub-group in the NIU-FORUM, there is little, if any official military representation for the military user population. The author is not aware of any DoD level effort in the C^3I area intended to research and develop ISDN related C^3I user requirements and to gain visibility of these needs via the NIU-FORUM. It must be remembered that the DCA role continues to be one that focuses on the technical issues.

C. ARCHITECTURE

Although the ISDN provides economies and flexibilities that are attractive to telecommunication service providers, there is continuing industry debate on the benefits of an ISDN to large private network users. Many large data networks are dedicated to support well defined functions. The economies and flexibilities of an common-user ISDN are neither needed nor desired, especially when one considers the costs of implementation.

Other arguments are fashioned on the old debate of PBX versus LAN. For years there has been a continuing controversy on which would become the dominant premises data networking technology. "As the ISDN mythology has flourished, many PBX vendors are positioning themselves to ride its coattails." [Ref. 36:p. 225]

Telecommunication network users, in trying to develop a coherent network architecture, must try to understand how ISDN will impact PBXs and LANs. ISDN is promising to integrate the benefits of both packet (LAN technology) and circuit (PBX technology) switching into a single technology (ISDN). [Ref. 36:p. 225]

In general, users facing a decision now whether to embrace a LAN or PBX solution are advised to adhere to the following guidelines:

- procure a system that conforms to international standards such as X.25 and RS-232 and which will be supported in an ISDN environment;
- don't adopt a PBX, LAN or ISDN as a single technology but stay balanced in your network design. [Ref. 36:p. 224]

How rapidly ISDN is implemented in the commercial sector depends on a number of socio-economic factors. Many large telecommunication service providers are expending considerable capital resources towards implementing all-digital networks with the stated goal of implementing ISDN. Numerous field trials sponsored by the regional Bell operating companies and carriers are underway exploring the development of ISDN.

Generally, it can be anticipated that islands of ISDN functionality will first be implemented; these will be centered around large metropolitan areas where the economics and service demand justify initial capital expenditures. Eventually, these islands will be brought together to form a ubiquitous ISDN environment. [Ref. 37:p. 24] Many military facilities, usually in isolated communities, may be among the last communities to see commercial ISDN services offered. Although ISDN may be implemented in the base or post network, connectivity to the outside world still would entail connection through non-ISDN systems.

Since ISDN is still under development, many of the communications standards related to packet switch support are still undefined. Initial implementations of ISDN by some carriers use proprietary standards that provide the functionality of ISDN. Although these proprietary standards were developed in consonance with the CCITT effort, there is no guarantee that they will be fully compatible.

Military users must also recognize that unique requirements including security, reliability, ruggedness and portability must be factored into ISDN in ways that have not yet been considered. The full implications of the ISDN architecture in these areas have not yet been studied. [Ref. 26:p. 50.5.3]

There is a large transition problem that must be considered in evolving to an ISDN. Although evolvability was a stated design requirement for ISDN, this objective was intended to address the evolution from the current telecommunication network and was not intended to address the factors--equipment and services--that are often the trademark of military telecommunication networks.

Satellite networks are a significant component in the world-wide U.S. military telecommunications architecture. ISDN and these satellite systems have developed concurrently but independently. Neither technology has considered the other and there exists a significant requirement to ensure they are compatible and that satellite networks can be integrated into ISDN.

From an architectural standpoint, satellites can serve as the transit network passing large amounts of traffic between major ground stations such as INTELSAT or can be used to interface with ISDN at the PRI. [Ref. 23:p. 366] The issue is whether it is better to interface with the ISDN through gateway stations and use protocols, interfaces, and bit rates optimized for the satellite network or incorporate ISDN protocols, interfaces and bit rates in the satellite network as a part of the satellite network design. [Ref. 23:p. 366] In addition to these architecture issues, there are the technical characteristics of satellite systems that must be considered, i.e., propagation delays, reliability rates, etc.

D. MANAGEMENT

Controlling network configurations and provisioning the network effectively and efficiently while managing its size and cost may provide the chief added opportunities and challenges for ISDN applications. [Ref. 38:p. 58]

A U.S. West company executive stated, "An issue that we must constantly keep in mind in the trial process is that implementation of ISDN applications may afford organizational change for our customers as well as ourselves." [Ref. 39:p. 56] This statement recognizes the fact that the technology of ISDN may induce changes on the organizations of those that use ISDN and those that provide the network and services.

The maintenance and management of an ISDN was a significant item for discussion at the January 1989 NIU-FORUM conference. CCITT Q.940 specifies the concept for user-to-network management in an ISDN. Network management is divided into:

- Fault Management
- Configuration Management
- Accounting Management
- Performance Management
- Security Management

Of concern to users of ISDN is the fact that only a limited sub-set of fault management is being considered by the ANSI T1M1 standards workgroup. No other standards bodies are considering the other aspects of user-network management. [Ref. 40]

There are three reasons why users must be concerned. First, ISDN is very complex in the technology and protocols it uses to integrate voice, data and video. Secondly, the ISDN environment will involve a wider array of equipment and service vendors. Finally, ISDN users will need a variety of automated tools to manage the operations and maintenance of the network and user interface. [Ref. 40]

Dr. Wiessberger, in his presentation to the NIU-FORUM, made the following comments on issue of user-network management:

- Existing ISDN standards in this area are primitive, exist only at the physical layer and are being standardized as an afterthought.
- The D channel and Q.931 like messages--logically the best means to implement maintenance protocols--will not be the initial vehicle for ISDN maintenance.
- User-to-network maintenance service between layer 3 peers will be based on proprietary switch functions recently proposed to T1M1.2 by AT&T and NTI.
- All maintenance information, alarms and actions are to be network controlled. Therefore, the user will not be able to access network statistics associated with its use, protocol abnormalities, etc.
- There is no provision for user-initiated fault isolation on the digital subscriber loop.
- There is no provision for user-oriented maintenance in the context of user-to-user, user-to-network, or user-to-maintenance service provider. [Ref. 40]

If Dr. Wiessberger is essentially correct in his judgments, then there are substantial network management concerns that must be addressed before ISDN can satisfy the requirements in a C^3I system.

The need for robust network management functionality in ISDN was highlighted by the results of the McDonalds Corporation ISDN field trial recently completed in August 1988. In this trial, 1300 BRI lines involving a mix of voice and data services were installed and supported by a 5ESS in a CENTREX configuration.

In a presentation at the NIU-FORUM, the Director of Telecommunications for McDonalds highlighted some significant user experiences in managing the ISDN.

The complexity of an ISDN link was an order of magnitude greater than in a typical non-ISDN connection. The number of components increased by a factor of four while the number of interface points and vendor equipments/software each increased by a factor of five.

The mean time to isolate faults and user dissatisfaction increased exponentially with the incremental increase in connection complexity. Trouble calls reached a maximum of 30 per day during the trial.

Of particular concern was the fact that 50% of the reported problems were not later found or were cleared while testing. Almost 35% of the problems were traced to plant wiring.

Finally, 45% of the problems required in excess of eight hours to clear despite the involvement of vendor representatives.

The results of the McDonalds field trial appear to reinforce the requirement for a well-defined network management system to support the ISDN environment.

The ISDN architecture, although well defined by its access points, is complex because of the ability to provide network intelligence and integrated services. This integrated network environment may not be amenable to the manner in which current DoD networks are operated and maintained. This is an issue that needs to be considered by the DCA and military services.

E. APPLICATIONS

One forecasted result of ISDN implementation is an explosion in the amount of data traffic as files are sent among a multitude of ISDN terminals. [Ref. 41:p. 24] ISDN will remove many of the physical and psychological barriers facing users in the sharing of data. Basing ISDN service on capacity used instead of connectivity time will also serve to remove many of the financial constraints as well.

In developing service applications, planners will have to consider questions such as:

- which personal computers?
- which telephones?
- what software tools and environment?
- what applications?

In answering these questions, organizations are going to have to confront the information management issue: They must understand what information they need and how this information is best used to support the organization's purpose.

Early ISDN applications are likely to mirror services already available in some degree on current networks. It is important to note that ISDN is being developed and implemented by the telephony industry and thus, many of the first applications will, and do, have a voice-based service orientation. This may be simple and harmless industry bias but it can also indicate the level of priority that data communications has in the development and implementation efforts of that industry.

At any rate, sophisticated multimedia applications won't be developed until users gain a deep understanding and appreciation for the esoteric features of an ISDN and how these can be applied to solve the information fusion problem.

Finally, the value of ISDN technology must translate into tangible worth to the users. Users must perceive that their decision making process is enhanced by the services offered by ISDN--not impeded by it. [Ref. 42:p. 51]

F. SECURITY

The ubiquity of ISDN presents a major challenge for meeting network integrity and security requirements and the protection of classified and sensitive information.

The ISDN architecture encompasses all the problems associated with the elements of communication security (COMSEC) and computer security

(COMPUSEC). In solving these problems, users will require a low-cost solution to protect the information transmitted through the network. Network providers and users with computers and associated databases must be concerned with maintaining their integrity against the proliferation of virus' and malicious entry.

Work in these areas has been initiated by the National Security Agency (NSA) and the National Institute of Standards and Technology (NIST). Although there is no explicit requirement for secure ISDN terminals, NSA intends to develop a comprehensive set of cryptographic standards and specifications for inclusion in the Commercial COMSEC Endorsement Program (CCEP). [Ref. 43:p. 3] Successful use of the CCEP will preclude industry development of proprietary, non-interoperable protocols and encryption algorithms. [Ref. 43:p. 5]

At present, there is no activity in providing secure capability for digital telephones. The STU-III secure telephone provides a narrowband analog output at a maximum rate of 4.8 kbps which cannot provide the improved voice quality, rapid call setup and ease of conferencing that a secure digital telephone operating at 64 kbps can achieve. Although STU-III may still be used in an ISDN, it will not provide the improved levels of performance that ISDN can support. [Ref. 43:p. 5]

Secure digital telephone for ISDN is only a small part of the security problem. Secure video and voice conferencing, interoperability with cellular telephones, secure voicemail and interface with tactical secure voice and data systems are additional dimensions that must be considered. [Ref. 44]

The solutions to the security problem for C^3I users must be cost effective and enable the transition to ISDN from present secure network implementations. Security is a difficult problem and may be one of the significant obstacles towards full-scale implementation of ISDN in the C^3I system environment.

G. COST

There is presently no cost model available for users to analyze the economic and performance benefits of ISDN. Until such a model is available, potential subscribers to ISDN must perform a crude and laborious analysis of ISDN using present voice or data-based system models.

A great deal of the difficulty in determining ISDN costs will depend on the manner in which the telephone companies file tariffs for the service. Illinois Bell, the first to file a BRI tariff, used a complex process that breaks service costs down by number of lines (2B+D), installation charges, capacity used (switch and trunks), circuit or packet-switched data service, etc. "Many subscribers may really not know how much ISDN will cost until they get their first bill." [Ref. 45:p. 106]

Finally, military as well as business users might benefit from a cost model that weighs the productivity enhancements that might be realized from ISDN services. The ability to interact using voice, data, and video may serve to lessen the number of trips required by personnel thereby decreasing travel costs and increasing the amount of productive time the worker may spend on the job vice traveling.

VII. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

In the long term, ISDN is likely to fulfill its promise to the C^3I system user of providing greater integration of voice and data services than is currently available. It will bring the sophistication of data communication protocols to the world of voice, driving down network maintenance costs and increasing the number of sophisticated tools and applications available to support the commander's decision making process.

ISDN appears to offer great potential for solving many of the problems that have plagued C^3I systems for years. ISDN standards will increase the compatibility and interoperability of our C^3I telecommunication networks. The limited set of standard interfaces and the use of in-house wiring will improve service provisioning times. The network intelligence of an ISDN will provide greater flexibility and adaptability in the network and give the user greater control over network resources.

The digital technology of ISDN will provide the inherent cost and performance benefits associated with this technology.

There are however, significant obstacles that must be overcome before ISDN is integrated into the C^3I system environment. Network management and security standards require further research and continued development.

B. RECOMMENDATIONS

The following recommendations were developed based on the experience gained by the author in conducting this study:

- DoD planning activities that involve enhancements or new acquisitions of C3I systems should consider and, when applicable, adhere to the standards of ISDN.
- DoD should, through the DCA, continue to influence the standards development process to ensure that unique C^3I system technical requirements are considered and solutions adopted.
- The DoD should consider increasing the management role of the DCA in the military transition to ISDN. The current pragmatic approach where each service is expending substantial capital resources in technically and functionally evaluating ISDN lacks a coherent, planned approach. The field trials being conducted by each service and the procurement of new and replacement digital switches should be part of a DoD level transition program. In the commercial sector, ISDN upgrades will be driven by the marketplace. In the military, ISDN transitioning should be driven by a joint service plan based on user requirements. It makes little sense for each service to squander its precious capital funding resources on independent upgrade programs.
- The DoD should start focusing on the applications side of an ISDN. The applications of ISDN in C^3I systems needs to be studied along with the organization changes that may be required as a result of its implementation.
- DoD communications and information system planners need to get educated on ISDN and stay abreast of technical, functional and implementation proceedings.
- The DoD should re-evaluate future LAN and PBX acquisitions to ensure the meet the guidelines offered in Chapter VI. The transition to ISDN will be most easily accomplished if current LAN and PBX acquisitions take into account the future implementation of ISDN by the commercial and military sectors.
- DoD organizations should have a clear concept of information management principles. Organizations will have to identify user information needs and what ISDN services will be provided to support these needs. Not all workers will need full ISDN connectivity and services: The DoD cannot afford to acquire and install ISDN terminal sets and applications in a fashion that has occurred with personal computers.
- Potential ISDN applications in C^3I systems will be complex and unique to the military. The DoD should consider using the rapid prototyping concept. This will speed development time and ensure the user's needs are perceived by him to be fully satisfied.

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