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STUDENT REPORT

AN INTEGRATED APPROACH TO AIR FORCE INTERPREMISE NETWORKING.

MAJOR BILLY G. THOMAS, JR 87-2485

"insights into tomorrow"

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The conventional Air Force interpremise communications approach involves dedicated, single media--voice or data--point-to-point communications links. However, the experiences of an increasing number of businesses point to a more efficient and effective approach for larger, heterogeneous networks like those in the AF. This approach, integrates different types of information into high capacity digital transmission lines and integrates automated network control. This study examines an integrated network architecture, shows how it would apply to one AF organization--Space Command. It concludes that integration could make AF networks more effective, responsive, coherent, and efficient.

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PREFACE

In the 1980s, information networks began to play an increasingly critical role throughout industry. Information processing was already important to the effective management of most corporations. But information systems also became increasingly important to the market strategies and capabilities of many companies--banks, manufacturers, service industries alike. Telemarketing, point-of-sale systems, automatic tellers, automated funds transfer, automated design systems, and remote job entry systems are just a few of the information based capabilities which emerged during this time. But since the mid 1980s the communications environment also changed in a number of other ways. Obviously, ATT was divested of its local operating companies. Until divestiture, most corporations could depend upon ATT to provide and manage most of their communications networking needs. But divestiture brought both competition and complications. Many corporations wondered how they could cope.

Divestiture, however, appeared to be only the birth process of changes for the better that had been gestating for some time. Many corporations had already begun to look at data processing and communications, not as separate entities, but as aspects of the same strategic resource--information. Divestiture simply motivated many businesses to look harder at the network achilles heel--the long haul or interpremise network. Businesses looked for ways to make their networks more reliable, responsive to dynamic market requirements, and more cost and manpower efficient. Many turned to interpremise networks which integrated all types of information, multiple digital transmission media, and intelligent network control into the same network infrastructure. Those who tried this approach were enthusiastic over the results.

During my assignment to the White House Communications Agency, I began to become keenly aware of the impact of divestiture on military communications capabilities. The experiences of this agency were similar to those I had observed during my time with industry. Planning lead times, costs, and complications of obtaining services all increased. The need to become as self-sufficient as possible in communications resources and management also became apparent. Although not a result of divestiture, the demand from customers for data communications began to grow as it had in industry--exponentially. Much of this growth resulted from the proliferation of individual computing systems, but the increased demand for high quality, non-synthetic sounding secure voice compounded it.

A very forward looking commander, Colonel (USA) Larry Schumann, put together a task force to see how industry had handled these challenges. One objective of the task force was to find a means of rapidly deploying and employing communications virtually anywhere in the world and connecting these capabilities back to Washington. Another objective was to enhance the overall survivability, reliability, quality, and security of Presidential communications. We had to accommodate the growth of data that had already taken place. But we also had to accommodate future growth and new capabilities such as secure video imaging if these became mission requirements. Reducing recurring costs was a final objective.

Some solutions--secure voice switching and conferencing, for example--required special developments. But commercial capabilities provided the majority of the solutions. Among these were a mix of commercial and military satellite systems, leased and military wideband facilities including fiber optics, and organic digital line-of-sight transmission systems. One of my major tasks as the network architect was to put these capabilities into a cohesive, easily managed, reliable whole. The whole not only had to satisfy the network requirements stated above. But it also had to interface existing gateways to other organizations and military systems supporting special missions. Integrated networking, which had proved useful for industry, also offered an ideal solution for the White House.

In pondering the worldwide communications network requirements of major Air Force organizations such as SAC, Space Command, MAC, and even the Air Force as a whole, I have made several observations. To begin, the Air Force has faced some of the same challenges as business. Just as in business, the ATT divestiture has not had the devastating impact many at first thought it would. It brought complications and complexities, most of which have been coped with. On the other hand, I do not believe that the Air Force as a whole has used the opportunities presented by divestiture, to the extent that industry has, to make strategic changes in its overall approach to networking.

Equally important, the Air Force will begin to face even more requirements for long haul digital communications. The interpremise networking impact of the proliferation of digital switches, secure voice command and control networks, and even personal computers are not yet fully appreciated.

I do not believe currently accepted Air Force networking technologies and concepts offer an effective or efficient means of satisfying current, much less, future interpremise requirements. Current methods are, I believe at a macro level, more cumbersome, unreliable, complex, inflexible, and inefficient than they should be. Off-the-shelf, state-of-the-art standard commercial integrated networking systems, with little modification, could make significant networking improvements now. But it might offer the best solution to future requirements as well. Realizing these improvements will require a proactive, possibly even a cavalier, decision to follow integrated networks as the the road map to the 1990s. The focus of this study is to bring about a keener awareness of what these networks are and their potential in the Air Force.

ACKNOWLEDGMENTS

My appreciation to Col Schumann, USA (Ret), who three years ago supported some risky innovations by the White House Communications Agency Network Planning Branch. Without this support I probably would not even be aware of integrated networking today, much less advocating it. Also my thanks to Col Ray French at HQ AFCC/AI with whom I share a common goal of supporting our customer's communications needs, smarter, better, and faster. I especially thank him for the requirements data used in Chapter Four and for sponsoring an opportunity to get on my soapbox. I especially thank my wife and family, who for several months may have felt neglected. But above all, I give thanks to God and to his son, Jesus Christ, without whom persevering over these past few months would have been more difficult.

> "Unless the Lord builds the house,
> its builders labor in vain..." Psalms 127:1 (NIV)

ABOUT THE AUTHOR

Major Billy G. Thomas, Jr is a 1972 ROTC distinguished graduate from Auburn University. He began his Air Force career as an Electronics Systems Officer in Berlin, Germany. During his Berlin tour, he attended Squadron Officers School in residence. His subsequent assignments have included Aide-de-Camp to the European Communications Division Commander, SAC Command Post Communications officer, and SAC Giant Talk Communications Detachment Commander. He has had operations, maintenance, and requirements programming experience in a broad range of communications systems, especially secure and nonsecure voice networks. Before attending Air Command and Staff College class of 1987, he was architect and builder of state-of-the-art secure emergency conferencing and integrated transmission networks at the White House.

Major Thomas has a bachelor's degree in Industrial Engineering. In 1978 he earned a Master of Science degree in Systems Management from the Air Force Institute of Technology, graduating with high honors. In 1982 he completed the Air Force Education with Industry program after almost a year with International Telephone and Telegraph (ITT) in New York City. His professional honors include the Air Force Communications-Electronics Professionalism Award in 1973. In 1983 he was recognized among the Outstanding Young Men of America. His professional interests include emerging, leading edge information systems technologies and concepts and how these might enhance Air Force capabilities.

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TITLE AN INTEGRATED APPROACH TO AIR FORCE INTERPREMISE NETWORKING

I. Problem: To determine if the Air Force might benefit from an integrated approach to its interpremise communications networks.

II. Objectives: The first objective of this study was to establish the qualities and capabilities Air Force interpremise communications networks should have. The second objective was to establish what integrated interpremise networks are, how they differ, technically, from conventional approaches, and how they compare with conventional networks vis-a-vis required qualities and capabilities. The third objective was to examine the benefits and constraints of integrated networking using the "typical" requirements of Space Command as an example. The final objective was to make some conclusions and recommendations about the usefulness of integrated networks to Air Force needs.

III. Discussion: Aside from providing communications connectivity, interpremise networks should have several important qualities. They should be effective, responsive to change, architecturally coherent, and efficiently use the resources committed to them. In addition to these strategic qualities, AF interpremise networks must transport increasing amounts of digital information in response to user needs. However, conventional AF networks do not transport digital information, especially large amounts, efficiently or effectively. Nor do they exhibit strategic qualities as they become larger and the information they transport becomes more heterogeneous. On the other hand, integrated networks do. Integrated networks replace the inefficiencies of single purpose, single channel transmission facilities with the economies of scale of information combined over high capacity digital facilities. They also consolidate and eliminate layers of communications equipment and substitute manual control with automated "intelligent" control throughout the network structure. Based on "typical" AF needs represented in Space Command, integration would fit these needs with few exceptions. Integration may be more costly initially to implement, especially where traffic volumes are low such as dispersed sites. But integration may offset these costs by reducing long term operating, manpower, facility, and engineering costs.

IV. Conclusions: Integrated digital interpremise networks should be both feasible and beneficial to the AF. The more extensively the AF implements these networks the greater the benefits would be. Trends in requirements and costs will eventually push the AF toward digital networks. Migrating to integrated networks now, using currently available commercial technologies, should enhance current network economies, quality, and performance while providing a proactive solution to future requirements.

V. Recommendations: The AF should disseminate this study and other integrated network literature to make more information systems planners aware of this emerging concept. The AF should establish integrated digital interpremise networks as near term planning priorities. It should perform a technology assessment of current systems. The Air Force should establish an organization wide integrated architecture model to complement current integrated models being developed for local area networks. It should establish an integrated network acquisition and migration strategy. Finally, the AF should assist the commands in establishing integrated networks and identify those inter-command requirements which would benefit from them.

Chapter One

INTRODUCTION
TO
INTEGRATED INTERPREMISE NETWORKS

Information, and systems which process and transport it, has become a strategic Air Force resource. Lt Gen Hughes, HQ AF/DCS Plans and Operations, confirmed this when he said, "never have information systems been as important to this nation's defense as they are today." (10:1) Yet, there are recognized shortcomings in some current systems. For instance, the President's Strategic Modernization Plan has made command and control communications network renovation one of its highest priorities. (21:4-16) Interestingly, network renovation has become strategically important for many non-Air Force organizations. Since the mid 1980s, integration has become an increasingly common way of accomplishing this. (4:30; 26:Ch 3; 28:23-24; 38:--)

Interpremise network integration has gone relatively unnoticed in Air Force planning. One study, Project Forecast II, has identified some features of integrated networks to be a part of future research and development. (18:31-33) The Local Information Transfer Architecture (LITA), under development at Air Force Communication Command, addresses some aspects of integration for on-base networks. (23:--) But no similar initiatives appear to be under way for current interpremise networks. This study attempts to redress this situation by examining how these networks might be renovated and improved with off-the-shelf integration concepts and technologies.

<u>WHAT ARE INTEGRATED INTERPREMISE NETWORKS?</u>

An interpremise network is a special class of communications system. Many organizations operate from multiple locations and may need many types of information among these locations. For example, members of an organization frequently need to talk to other members at different locations. A cluster of data users in one location might need information from a computer system elsewhere. Normally, users are local to the systems providing these capabilities, such as PBXs, Centrex, or Local Area Networks (LANs). Transmission facilities, communications interfaces, and transmission equipment allow these information systems and their users to communicate among distributed locations. (31:4-6) An interpremise network refers, collectively, to the equipments and facilities performing this function throughout an organization.

An integrated interpremise network has three salient features which distinguish it from other architectures. First, it eliminates conventional distinctions and integrates voice, data, or imaging information into a single infrastructure. (4:30) As Figure 1 shows, an integrated network consists of two common components--digital transmission facilities, capable of operating at 56 kilobits to 1.5 megabits per second and beyond, and integrated communications nodes. Together, these components form a simple, yet sophisticated, architecture. Secondly, unlike more basic digital architectures, it may provide end-to-end digital connectivity for any type of information or network topology. (25:--; 26:Ch 6; 36:5,10)

Finally, an integrated network is "intelligent." Microcomputers, embedded in each node, communicate with those in adjacent nodes. Individually, they control and direct the configuration and funtions of a node. Collectively, they monitor the performance and health of a network, automatically reconfiguring it or rerouting information as situations change. Moreover, through an interface to the microcomputers, network controllers can

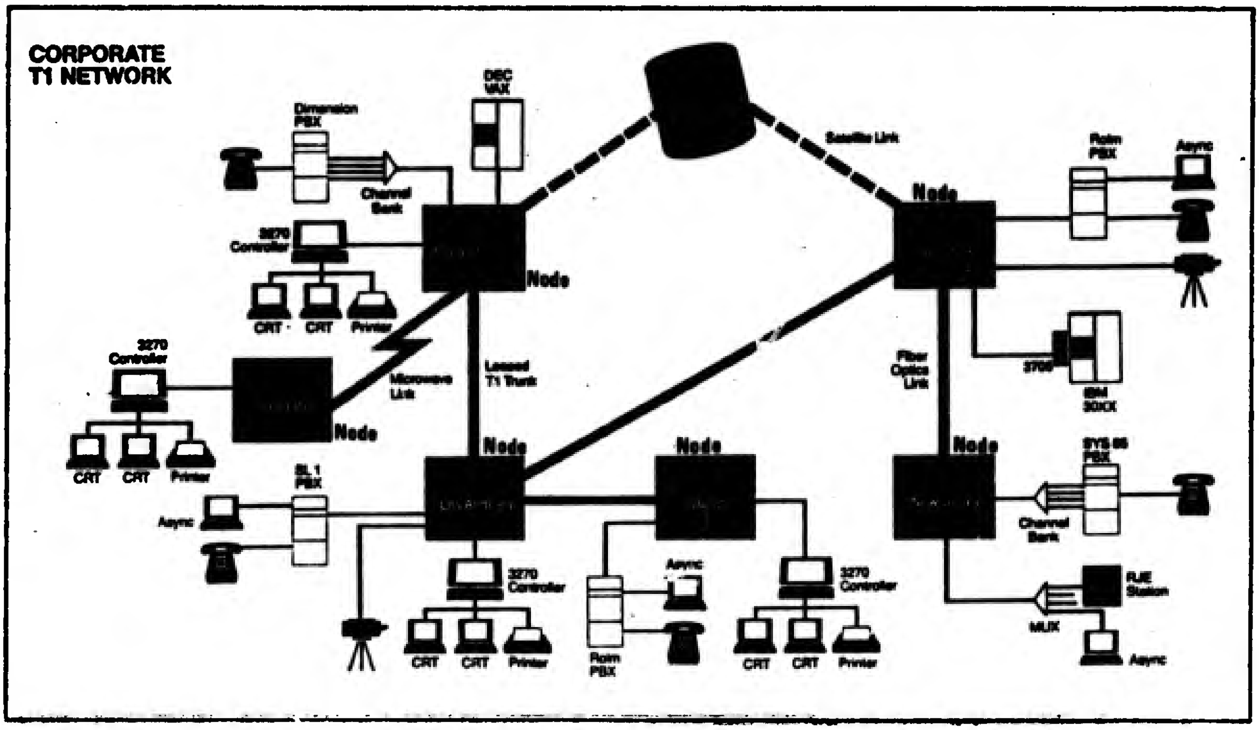


Figure 1. A "Typical" Integrated Network
Source: Network Equipment Technologies. Used by permission.

configure, diagnose, regulate, and manage the network. In other architectures, these are typically tedious, time and effort consuming, manual operations. (25:--; 26:Ch 3,6; 36:16-29) Intuitively, these are capabilities desired in many current Air Force interpremise networks.

INTEGRATED NETWORKS AND THE AIR FORCE

Integrated networks have been most feasible in heterogeneous--mixed voice, data, imaging--concentrated, multipoint communications environments. (26:3-10) Intuitively, Air Force networks typically have these traits. For instance, the Space Command communicates among approximately 30 locations world wide. There are at least 4 major concentrations of information users in the Colorado Springs area--Cheyenne Mountain, Peterson Field, Headquarters, and Falcon AFS. Moreover, the information covers the gamut from voice to several secure data systems. (22:--; 34:--) Assuming these traits are typical throughout the Air Force, integration might offer a feasible alternative to current networks. Although important, feasibility alone probably would not provide a compelling reason to begin migrating to this innovative technology.

Objectives

The central issue is whether integrated interpremise networks would currently benefit the Air Force. To answer this question, Chapter Two identifies the strategic requirements of Air Force interpremise networks. Chapter Three describes and compares integration with conventional and basic digital architectures. Chapter Four presents a conceptual model and practical considerations for integrating Air Force networks, using selected Space Command requirements as an illustration. Chapter Five discusses the potential benefits and limitations of integration and how to approach alternatives. The final chapter summarizes, concludes, and makes several recommendations.

Constraints

The analysis in these chapters is constrained in several ways. To begin, there is a paucity of primary data on operational integrated networks. Nearly all of them are corporate networks, the details of which are kept confidential for competitive reasons. The integrated architecture and model described herein synthesizes technical literature, observations of network consultants, and first hand experiences of the author. The study will not technically evaluate vendors nor will it address migration, acquisition, or implementation decisions. These are beyond its scope and purpose.

Assumptions

An important assumption in this study is that the Air Force has not previously rejected integration as a valid approach for its networks. The converse is more likely since several future plans include integrated concepts. Another assumption is that capabilities and limitations are presented without undue bias. Bias is minimized by the broad range of observations and opinions used in the analysis, including those from industry. Thus, the analysis also assumes Air Force and non-Air Force networks have comparable characteristics and requirements. This should not appear unreasonable since many Air Force networks currently use commercial facilities and equipment. A final assumption is that the requirements presented in this study represent those of the Air Force in general. It is beyond the scope of this study to defend this assumption, although the breadth of the testimony used in the study would imply it. Moreover, the intent of this study is not to show how integration would work in specific instances. Rather, it is to understand its generic applicability and potential benefits for the Air Force. This understanding begins with a comprehension of the more important capabilities an interpremise network should have.

Chapter Two

INTERPREMISE NETWORK REQUIREMENTS

INTRODUCTION

When network requirements are discussed, the focus is frequently on physical issues--what kind of information, where, when, and how much. Yet, more strategic considerations should precede these in network planning. (26:Ch 7; 31:4-6) Ideally, Air Force networks should have qualities which complement those of the forces they support. (21:4-16) For instance, timing and tempo, unity of command, and other principals of airpower described in AFM 1-1: Air Force Basic Doctrine rely on available, timely, quality communications. (20:2-6 - 2-8) Moreover, a network should be responsive to the changing needs of its users. It should be simple to employ and manage. Still, it should optimally use the resources committed to it. (16:47-48) These are the strategic requirements of interpremise networks.

NETWORK EFFECTIVENESS

Above all, a network should be effective. Lt Gen Randolph, HQ AF/DCS Research, Development and Acquisition has called networks the "central nervous system of an effective warfighting force." (16:47) Command and control, intelligence dissemination, support synchronization, discussing, and deciding at all levels rely on available and timely information. (21:4-17) To provide this, networks must rarely fail. But when they fail, they must also be quickly and easily repaired. Making them less sensitive to failures, for example with redundancy, might also enhance effectiveness. Forecast II foresees a more sophisticated method where networks function as "living mechanisms," autonomously recognizing and rerouting information around disruptions. (18:31) Another approach would be to make equipment and facilities more survivable against potential physical disruptions, such as nuclear effects. (21:4-16 - 4-18) All of these measures should help make information available, as General Herres, former CINC Space Command, expected, virtually 100 percent of the time. (7:1; 12:6)

A network may be most effective, though, when users are least aware of its presence. For example, placing calls over interpremise networks should not complicate user procedures, log-on, or other protocols. Likewise, networks should not induce errors, noise, or echoes. Resynchronization and timing operations should be virtually non-existent for the user. (32:1-3) Encryption and features which mask "the flow of operational communications" (18:35) should be a natural and inherent part of a network. The purpose of designing these capabilities into a network is not simply to avoid user annoyance and frustration. Rather, it is to complement, enhance, and protect the operations of network users, especially in a dynamic environment.

NETWORK RESPONSIVENESS

One certainty of the information environment is change. Lt Gen Randolph has said, operational flexibility. . . "is the keystone as far as air power is concerned. . . When you begin to lose flexibility. . . you have lost the real reason you have airpower." (16:48) Lt Gen Hughes, HQ AF/DCS Plans and Requirements, adds being "more responsive to requirements of the user" is one of the major challenges facing communications system providers. (10:1) Operational change most commonly affects quantitative aspects of a network, for instance, volume of information or location of users. Thus, a network may contribute to airpower in its own way when it can be quickly and easily adapted, reconfigured, and expanded to accommodate these changes. (16:48)

Air Force interpremise networks will progressively face qualitative changes also. By the 1990s, non-digital user devices should become an "anachronism." (5:50) Network experts today estimate 10 percent of transmitted information originates from computers and computer based systems. However, this amount is predicted to grow 35 percent a year until digital data transmissions comprise nearly half by 1991. (1:20) Air Force programs such as the Local Information Transfer Architecture (LITA) recognize this trend. (23:Ch 4) Similarly by 1991, the Air Force will have "digitized" nearly 50 percent of its base telephone switches with a goal of 100 percent by the end of that decade. (33:--) Future user capabilities, such as battlefield information management systems, "red" telephone systems, and imagery will require networks with high digital capacity. (18:31-33; 38:--) Clearly, the architecture of interpremise networks should reflect these trends.

NETWORK COHERENCE

An interpremise network can often appear as a blurred "impressionists landscape." (4:30) The complexity of many Air Force networks results, in part, from multilayered equipment and facilities supporting diverse media and users. (22:Ch 12) The divestiture of AT&T in the mid 1980s has added complexity by increasing the number of vendors involved with most Air Force transmission facilities. (9:7; 26:Ch 1,3,5; 28:--) Divestiture has also increased five-fold the lead time and effort of planning and implementing most networks. (9:7) Managing this complexity requires order in the way a network fits together and logic in the way it functions. (4:30)

Simplifying network architecture is one way of providing order. Consolidating communications equipment or replacing them with multifunction components are common simplifications. (3:97-99; 26:Ch 3) Consolidating media or bypassing commercial transmission facilities with organic capabilities are others. (26:Ch 7; 30:--; 38:--) Standardization may also add order. (1:26; 11:6; 8:60; 10:1) For instance, the Air Force Local Information Transfer Architecture (LITA) is an attempt to simplify and standardize local networks. (23:Ch 3) As Maj Gen Prather pointed out when he was AFCC Commander, however, the objective of simplification and standardization is not to over specify but to make architectures more interoperable. (14:54)

Four sets of standards are central to interpremise network interoperability. First is the military specification 188 series concerning physical interface standards for encryption and transmission equipment. (38:--) The second is the industry physical interface standards for data, voice, and transmissions media as defined by AT&T, Consultive Committee for Telephone and Telegraph (CCITT), and Electronics Industry Association (EIA). (38:--; 32:11) The third is emerging Integrated Systems Digital Network (ISDN) standards related to digital interfaces and network signaling and synchronization. (26:Ch 5) The last set of standards, is the International Standards Organization (ISO) Open Systems Interconnection (OSI) reference model for multivendor, multilayered, multimedia networks. (26:Ch 7) These standards should enhance interoperability and the physical coherence of a network.

A coherent network also requires control. The control mechanism of a network monitors, regulates, and manages its performance. Although control is inherent in some form in any network, it is most cohesive when it integrates and permeates the architecture. It should be centrally coordinated, timely, and simple. Finally, it should facilitate accurate configuration management and record keeping. Clearly, control touches virtually every part of a network. As a result, control should be a prime consideration in network design, not only for the coherence it may bring, but also the impact it can have on the resources of a network. (3:97-98; 32:2,11; 38:--)

NETWORK EFFICIENCY

Air Force interpremise networks have significant resources committed to them. For example, fixed leased transmission facilities cost the Air Force approximately $450 million annually. (35:--) This amount does not include the investment and operation costs of organic communications systems and facilities. Over 2000 military members are involved directly with the operation of these networks and many more plan, design, and implement them. (17:4) It is no wonder that Gen Herres and others are concerned about the efficient use of these resources. (6:2; 11:6; 2:6) Consider a "small" network of 10 voice and 5 data lines between locations 500 miles apart. This network could typically cost as much as $120,000 per year without considering the manpower to control it. Increasing distances, numbers of locations, traffic volumes, and redundancy could geometrically increase network costs. (26:Ch 2)

Curtailing or constraining services is one approach sometimes advocated to deal with costs. (2:6) Replacing facilities with cheaper ones is another. Sometimes effective, these approaches are more often counterproductive and usually unsatisfactory to the user. Improving <u>cost performance</u> is a better approach. This means reducing the long term operating cost of a network while improving its effectiveness. It means reducing the incremental cost of changing service without sacrificing responsiveness. Finally, reducing the manpower needed to operate a network while maintaining control and performance is also a part of cost performance. The purpose, obviously, is to minimize future costs while maximizing return on current investment. (26:Ch 1)

OBSERVATIONS

Clearly, transporting information between locations is more esoteric than simply connecting users with widgets and wires. A strategic concern is how effective, responsive, coherent, and efficient a network operates once implemented. A panorama of criteria should be considered in the design of a network. Some criteria are more important than others. Decisions about some may affect others. But, the objective is to select technologies and combine them in a way that complements the operations of the users. The next chapter examines three of the more common ways.

Chapter Three

INTERPREMISE NETWORK ARCHITECTURES

An architecture defines the technologies and relationships used in a network. It describes what kind of communications equipment and transmission facilities will be used. It determines how information will access and egress, how it will be routed, and how a network will be controlled and managed. An architecture establishes how the signaling schemes, protocols, and electronic characteristics of information will be accommodated and matched to those of the transmission facilities. Unfortunately, voice, data--in its various forms--and imaging, each have different characteristics. For instance, voice requires idle-busy parameters to accompany it, whereas data does not. Obviously, complexities begin to emerge as the quantity of information, types, and user locations increase. This chapter examines the complexities of three main classes of interpremise networks. (31:4-6; 32:2-11; 29:--)

CONVENTIONAL NETWORKS

A conventional network is an aggregation of individual, point-to-point interpremise paths. Each path is typically dedicated to a single type of information--voice or data, for example--and normally carries one conversation or data transmission at a time. (See Note) As shown in Figure 2, each path has interfaces and communications equipment tailored to the information it carries. Transmission media are usually switched public telephone lines or private voice grade lines and, therefore, data are normally limited to 9600 bits per second or less. Moreover, modems must first convert digital data signals to an analog form suitable for transmission. Conventional network configurations are relatively static and most control functions are performed manually. A conventional network expands by adding more point-to-point paths, and therefore, more equipment and structural complexity. (22:Ch 12)

Note: There exist some schemes to transmit one voice and one low speed data call simultaneously over the same media. Statistical and time division multiplexers also increase the number of low speed data paths a media may carry. From the stand point of the communications equipment and transmission media, however, these look like one call.

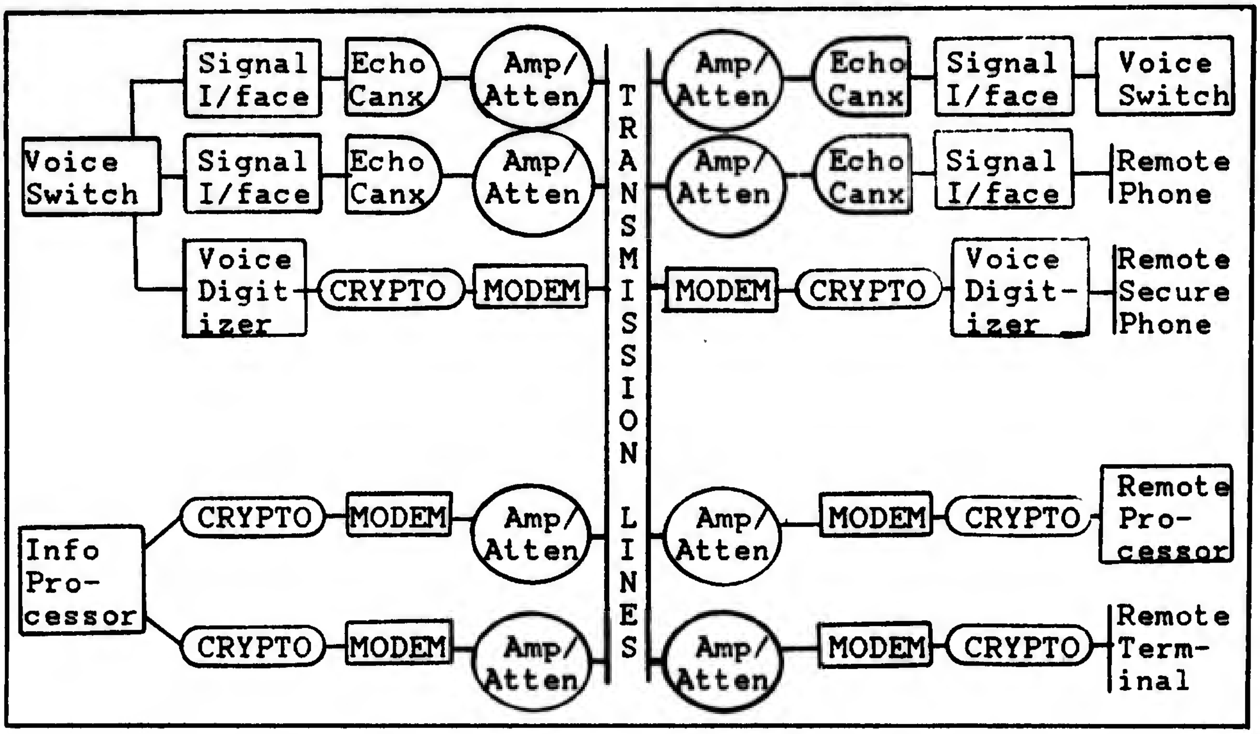


Figure 2. Conventional Interpremise Network Components (22:Ch 12)

BASIC DIGITAL NETWORKS

Basic digital networks are typically point-to-point architectures also, but with a difference. They combine several sources and types of information and simultaneously transmit them over high capacity digital transmission lines. They use high order technologies and methods traditionally used by telephone companies for interoffice trunk lines. (26:Ch 2) The move of private networks to high capacity lines--56 kilo bits, 1.544 mega bits (T-1), and higher--was sparked by the increased competition ensuing after the 1984 divestiture of AT&T. (11:26) Alternative communications companies and privately owned microwave, laser, fiber optics, and satellite systems have opened up a host of digital interpremise networking possibilities. (24:--; 30:--) User migration to digital networks reflects a general migration to digital systems throughout the communications industry. (5:50-51; 13:37-40; 26:Ch 1,5)

A basic digital network uses multiplexers to combine and transmit information. Figure 3 shows typical approaches. One obvious difference from conventional networks is that a multiplexer may replace many individual interfaces and communications equipment. (26:Ch 2; 30:--; 38:--) Another is

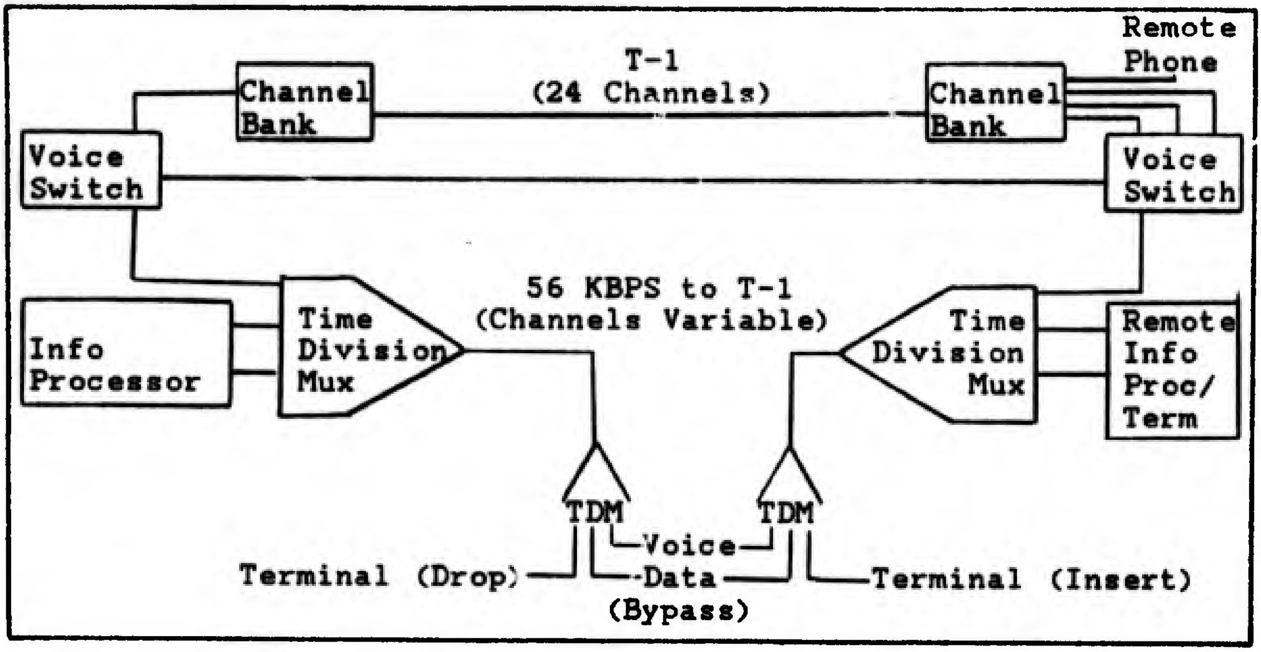


Figure 3. Digital Interpremise Network Using Standard Channel Banks and Time Division Multiplexers (26:2-15,6-6)

voice must be encoded to a digital format. The multiplexer commonly used by the telephone companies, called a channel bank, has made a 64kbps encoding scheme the most common. It encodes 24 "channels" from a voice switch or other voice system and multiplexes them into a T-1 compatible telephone company standard format (D3/D4). More recently, voice switch vendors have begun to build this multiplexer directly into their switches. Although channel banks may also multiplex data, each data path uses a full (64 kbps) channel even though it may only require, for example, 2.4 kilobits. In heavy data networks, a channel bank would leave much capacity unusable. Time division multiplexers (TDMs), on the other hand, can mix voice and data more freely and allocate only the amount of capacity needed by a channel. They also offer other, lower speed voice encoding schemes and formats, but at the cost of voice clarity. (27:--; 26:Ch 4)

Multipoint networking with basic digital architectures is similar to conventional methods. Most functions are manual, although some TDMs can be more sophisticated. Locations, redundant paths, and additional capacity may be added as needed. But as Figure 3 shows, some topologies may require dropping, inserting, and bypassing information between multiplexers, channel-by-channel. One difficulty with this is that voice degrades with each successive decoding and encoding. (27:--; 26:Ch 4-6)

INTEGRATED NETWORKS

Integrated interpremise networks provide several degrees of sophistication over basic digital networks. Although they use the same high capacity digital facilities, they are designed to make multimedia, multipoint networking "a breeze." (4:33) Two common components, integrated communications nodes and digital facilities, link together, somewhat like tinkertoys, into a simplified architecture. Integrated nodes, however, are far more robust than the multiplexers they replace. (26:Ch 2)

Node Attributes.

Physical Attributes. A node is the cohesive element of an integrated network. It is a modular, state-of-the-art, highly reliable electronic device. Although it functions as a multiplexer, it is much more. As shown in Figure 4, its main functional components are channel interface modules, trunk interface modules, a network bus, and a node processor. Channel interface modules are designed for various types of information and interface directly with the communications port of user information systems. They can manage the unique traits of these

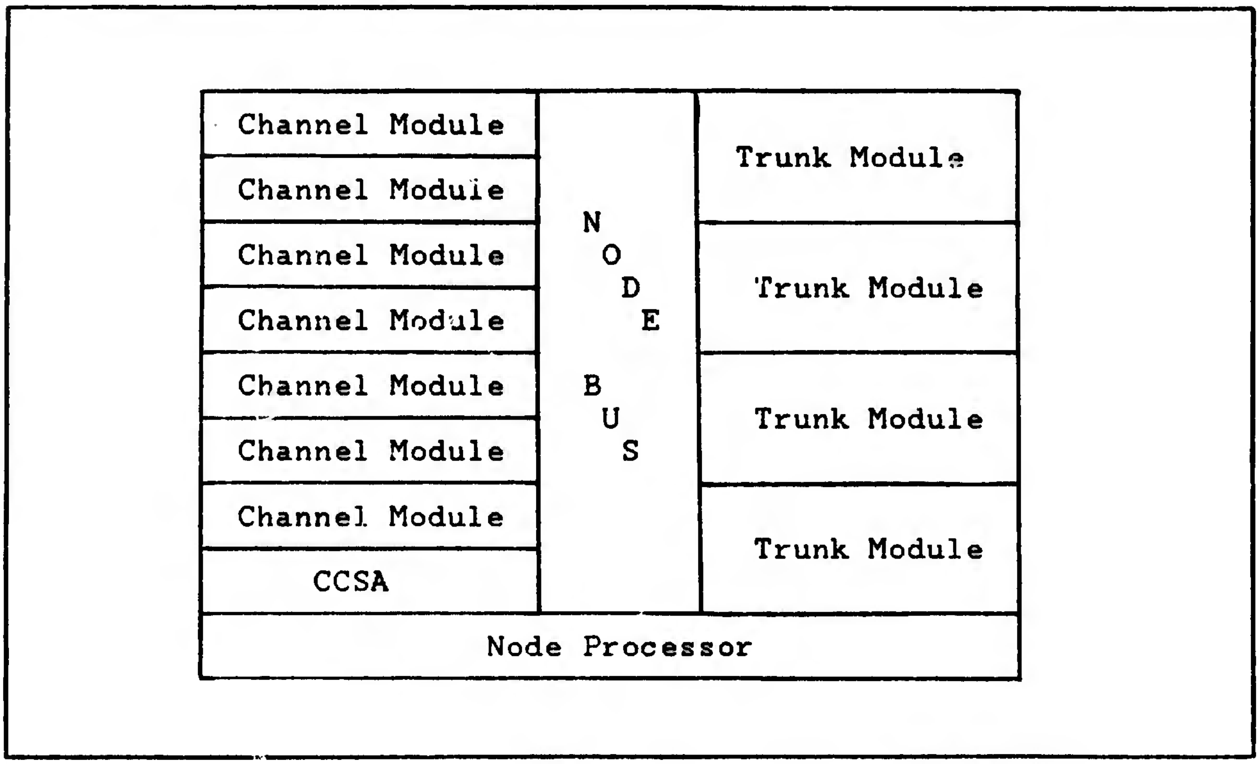


Figure 4. Integrated Node Model (36:7)
Source: Network Equipment Technologies. Used by permission

systems. Trunk modules connect to the transmission facilities and manage the nuances of various transmission media. A single integrated node may have as many as 50 or more trunks and 500 or more channels. (25:--; 36:--; 38:--)

Integrated nodes employ the major network standards. First, nodes are built around the physical layer requirements of International Standards Organization Open Systems Interconnect (OSI/ISO) and other vendor specific reference models. (37:15) This ensures a node remains transparent to user applications and protocols. Equally important, nodes incorporate industry and most military interface standards for voice and data systems, including emerging ISDN standards. (Figure 5) This ensures not only physical compatibility, but also signaling and

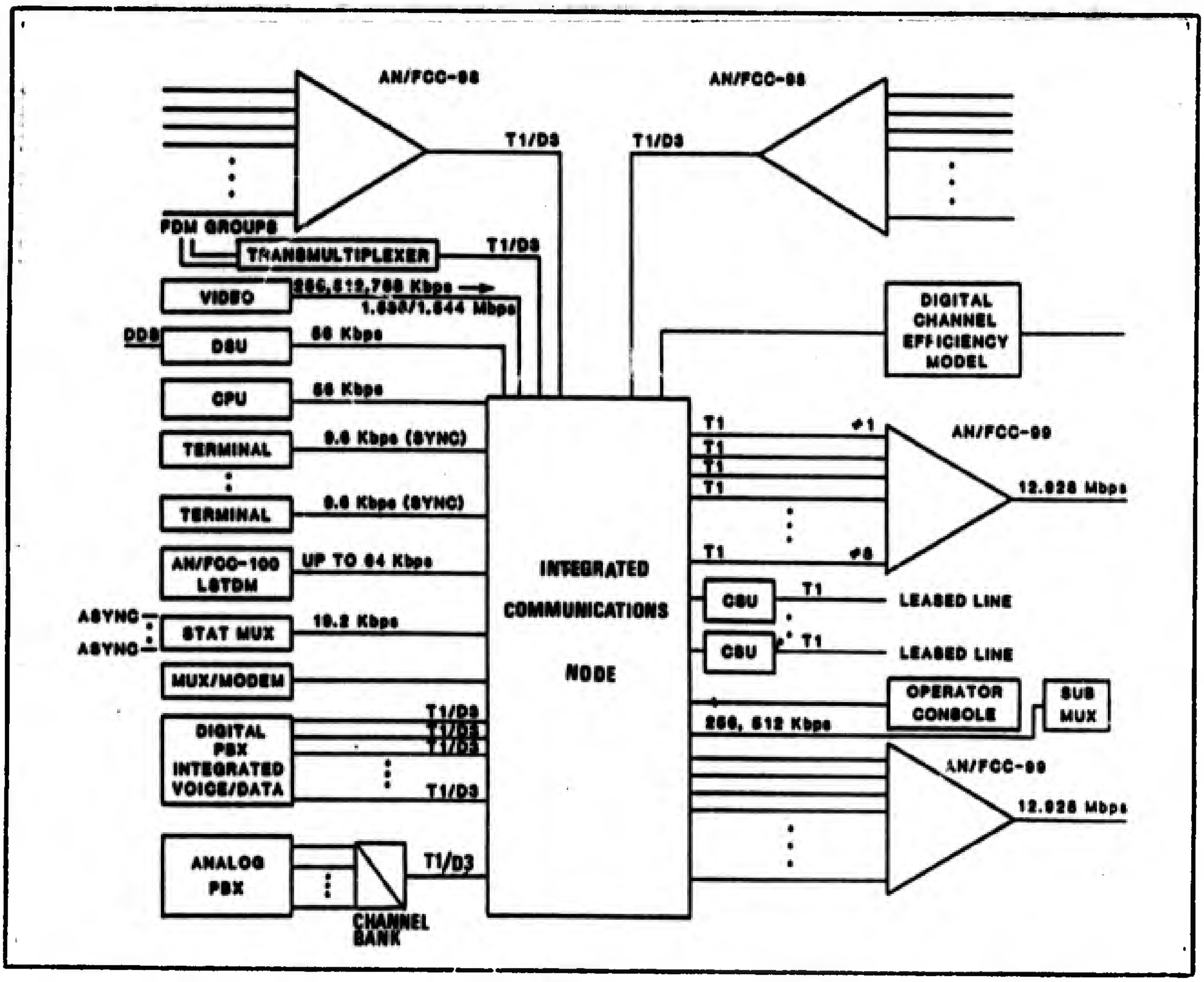


Figure 5. Integrated Node Standard Interfaces (37:14)
Source: Network Equipment Technologies. Used by permission.

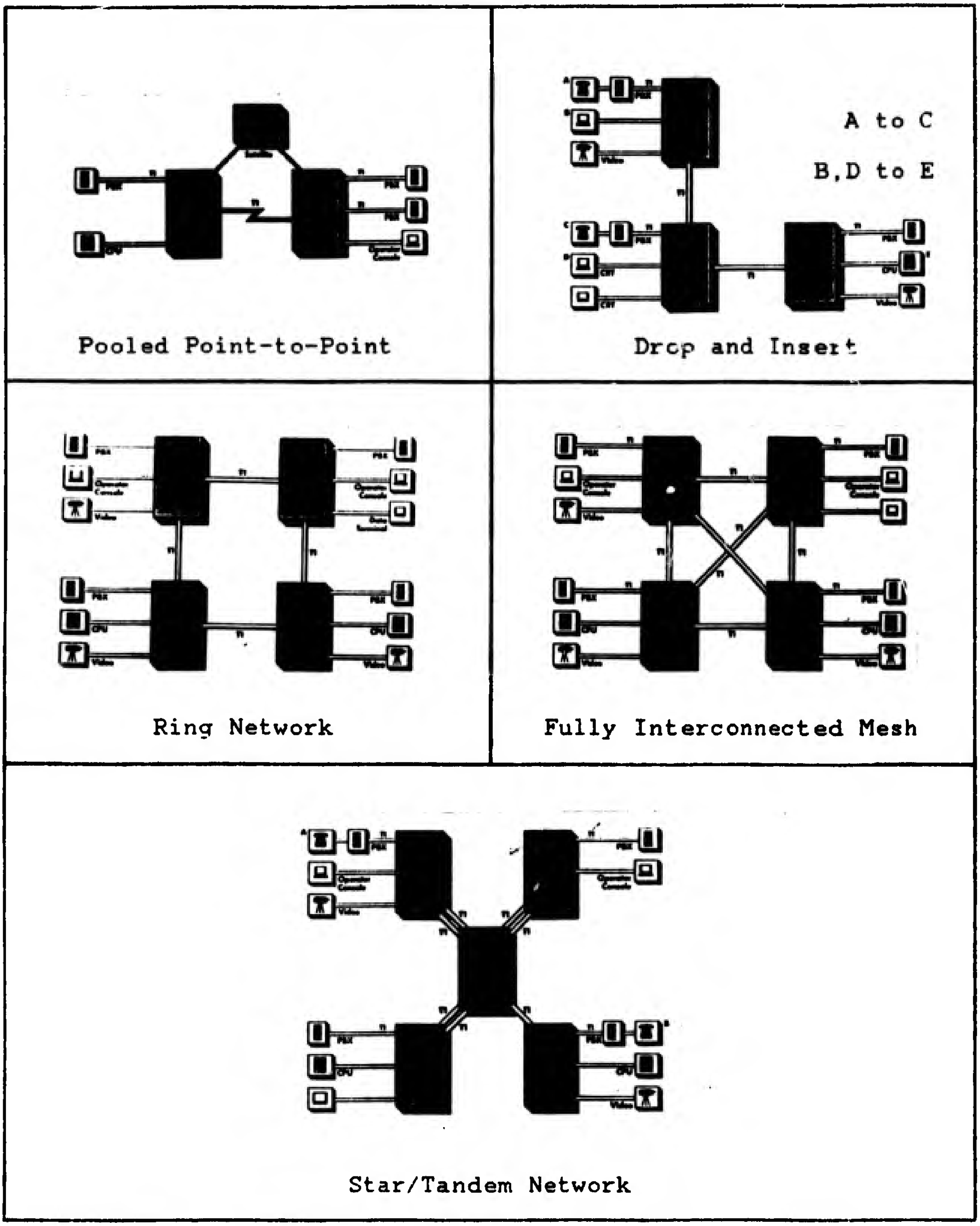
synchronization compatibility. Thus, these standards should allow an integrated network to interoperate with most existing, in place information systems. (25:--; 36:7-15)

Logical Attributes. Embedded processors give nodes logical attributes. A configuration database identifies each channel interface and its destination node/channel address. It identifies when an interface requires access to a trunk, for example permanently, on demand, or at a specified time of day. The database also includes what to do if there is contention for transmission capacity. Based on this information, a node processor can route information channel-to-channel, trunk-to-trunk, or channel-to-trunk. Because these routings are software-defined, rather than hardwired as in other architectures, they are easily changed by a deliberate database change. They can also be changed, dynamically, by performance algorithms in the processor. Similarly, since it is defined in the database, virtually any, equally dynamic, topology may be feasible. Figure 6 shows some of the topologies possible with integrated networks. These logical attributes are the basis for the sophisticated capabilities of an integrated network. (36:16-21)

Network Attributes.

Virtual Networking. Although each processor is autonomous, it interacts with those in adjacent nodes. They do this, via the trunks, using a common channel signaling arrangement. This arrangement ensures that all nodes are synchronized and provides a means of monitoring the integrity of all transmission facilities. But more importantly, this arrangement allows nodes to inform each other of what information was routed to which trunk, where it is on the trunk, and where it is going. These routing parameters can be relayed through any number of intermediate nodes. Moreover, from origination to destination, connections are "virtual," using whatever media are available, not bound by any fixed routing. Information may transit a multinode topology end-to-end without being dropped and reinserted. (3:97-99; 25:--; 36:16-21)

Dynamic and Adaptive. One of the distinctions of integrated networks is their dynamic and adaptive use of transmission capacity. Regardless of the topology, the interconnecting transmission media are treated as a pooled resource. Network intelligence optimizes the use of this resource by dynamically allocating capacity to a call, only as needed and in the precise amount. (Figure 7) Because connections are virtual, the network may balance traffic across the pooled capacity. In a meshed network, processors can automatically reroute any connection around failed trunks or nodes, and reconnect the callers in a matter of seconds. If there is contention for capacity, the network reconnects calls, beginning with highest priority



Pooled Point-to-Point

Drop and Insert

Ring Network

Fully Interconnected Mesh

Star/Tandem Network

Figure 6--Possible Integrated Network Topologies (36:25-27)
Source: Network Equipment Technologies. Used by Permission.

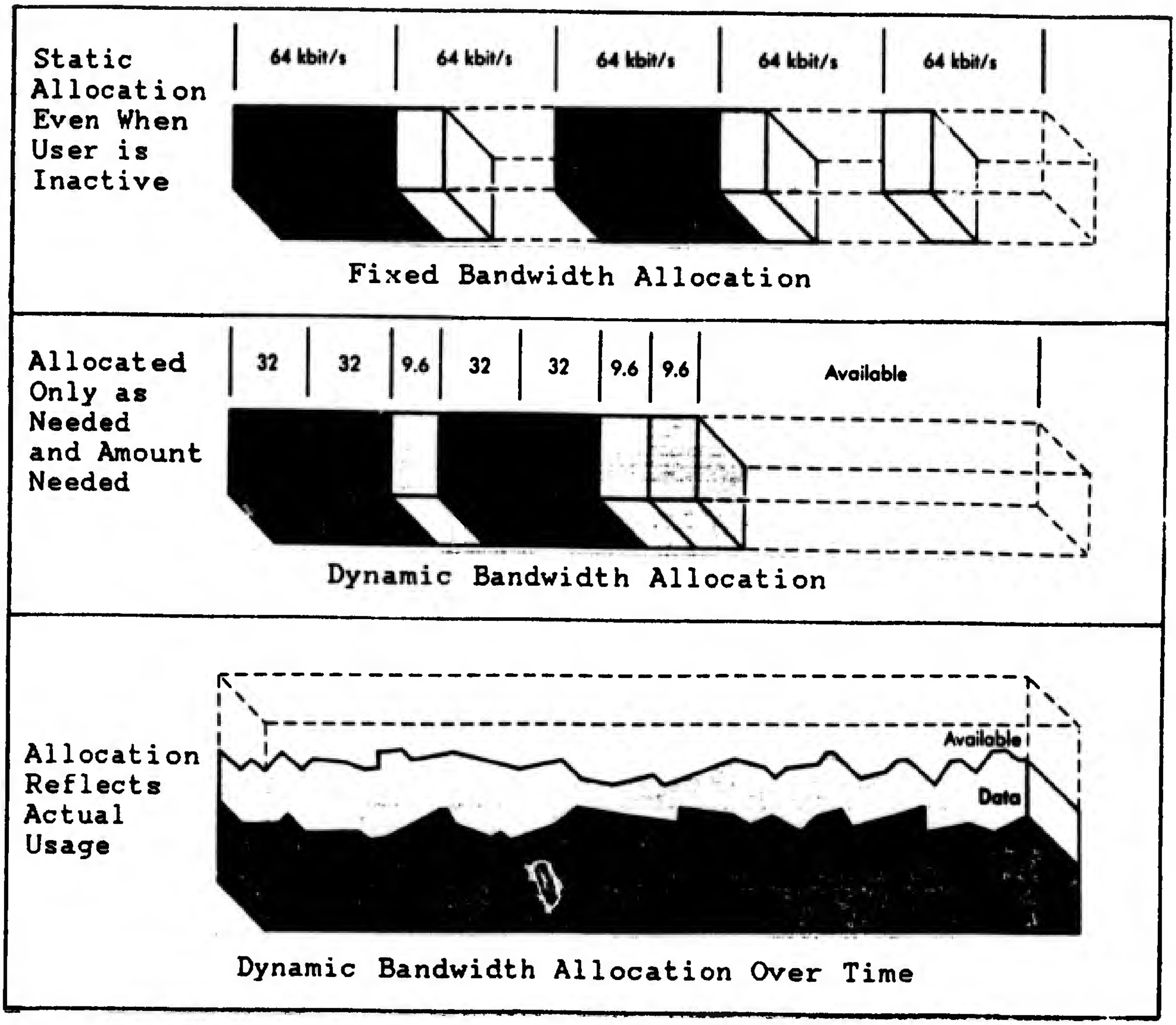


Figure 7. Dynamic Bandwidth Allocation (36:28)
Source: Network Equipment Technologies. Used by permission.

traffic, and continues until capacity is exhausted. This makes an integrated network, in a sense, self healing. Integrated networks also have dynamic voice processing capabilities which can optimize network performance in other ways. (4:32; 25:--; 31:28-29)

Voice Processing. Integrated networks provide several enhancements to voice networking. Quality voice transmissions begin by digitizing voice at the telephone company standard 64 kbps data rate. By maintaining this rate, end-to-end without repeated, degrading analog to digital to analog conversions along the way, quality is further ensured. (27:--; 13:37) The migration to telephone company standard format T-1 interfaces on most digital telephone switches capitalizes on this fact. In a typical point-to-point configuration, however, all 24 channels of a T-1 would be dedicated between two switches. Interfacing the switches to an integrated network, instead, would provide independent routing and control over each channel. (36:30-32)

Moreover, an integrated network may selectively, automatically, and dynamically "compress" a voice channel to 32 kbps or less in response to changing network loading. While maintaining end-to-end digital integrity with minor discernible decrease in quality, dynamic voice "compression" offers three important capabilities. First, it can provide a belt-tightening mechanism to get traffic through congested trunks resulting from failures elsewhere in a network. Second, it can provide a means to effectively surge and add network users beyond the "design" capacity of a network until trunks can be permanently added. Finally, it can provide a way to temporarily shift to lower (32 kbps) channel usage during transient peak busy periods, while providing 64 kbps voice rates at other times. Because most networks are statistically designed to handle these worst case periods, an integrated network, obviously, should require fewer trunks than a networking scheme fixed at 64 kbps voice channels. (36:30-32)

Control. The robust capabilities of integrated networks are the result of "intelligent" network control and management. Most of the routine functions of an integrated network are performed autonomously by node processors. The processors direct time sensitive functions in response to certain parameters. But some functions require human intervention. The configuration of a network may change, for instance, because nodes, user systems, or capacity are added, removed, or restructured. Network utilization rates, error rates, and other performance information are needed to plan, balance, and maintain a network. Problems must be identified, isolated, diagnosed, and repaired to keep a network performing optimally. An operator may perform all these functions through an operator interface at any node processor. But because the processors are linked, an operator may perform these functions, for an entire network, from any central location. Coherent, positive, dynamic control is an inherent quality permeating an integrated network. (25:--; 31:32-37)

OBSERVATIONS

Integrated digital interpremise networks have at least one thing in common with other approaches. They interconnect distributed locations of an organization with information. But the preceding discussion should make clear, although integrated networks perform many of the same functions, the way they perform these functions is fundamentally and qualitatively different.

They cope with the technical complexity of a large network using technical sophistication. Integration automates management, surveillance, and many maintenance functions of a network. Routine and time sensitive functions--things machines may do well--may be automated; those requiring decisions and judgments are left to operators. What emerges out of integrated networks are not just new technologies but new ways of conceptualizing networks. The following chapter examines how an integrated architecture might be applied to a "real world" networking requirement.

Chapter Four

APPLYING THE INTEGRATED INTERPREMISE NETWORK MODEL

Planning a network involving alternative architectures typically would follow four basic steps. (26:Ch 6,7) This chapter illustrates these steps using selected requirements of Space Command as an example. The first planning step quantifies the requirements. The requirements used in this analysis have been simplified to focus on the principles involved with integration, rather than to plan an actual network. No attempt has been made to identify all of the potential users of the network, their priorities, their characteristics, or their traffic patterns. This would require an effort at least as large as this entire study. Though required for actual architectural, acquisition, migration, and implementation planning, this detail is not needed here. The second step establishes a feasible topology. The third designs candidate architectures for this topology. Space Command communications planners have already decided to migrate to a digital network, although they have not determined its final architecture. Therefore, only digital architectures will be analyzed. The final step compares architectures and selects a target architecture which best satisfies the requirements.

DETERMINING TRAFFIC REQUIREMENTS

"Who," "what," "where," and "when" questions are the first needing to be answered. The answers will identify the sources of information, types of information, traffic volume, and traffic patterns. For simplicity, only two applications are considered in this study. The first is a secure voice network. The second is a secure data network. Together these will form a "red" interpremise network among Colorado Springs locations and sensor locations. The product of this analysis will be a matrix of transmission bandwidth requirements. Other parameters, not considered here, would be needed for implementation planning. These would include time of day and class of service information, such as access and pre-emption priority. (38:--; 29:--)

Secure Voice System

The secure telephone switching system being planned for Space Command is depicted in Figure 8. It should consist of 5 "red" digital telephone switches at the main locations--2 switches in the Cheyenne Mountain Complex (CMC), one each at the Space Operations Center/Back Up Facility (SPOC) and Headquarters (SPHQ) at Peterson AFB, and one in the Consolidated Satellite Operations Center (CSOC) at Falcon AFS. The system requires tie trunks among the CMC and CSOC, the CMC and SPOC, and the SPOC and SPHQ switches. Moreover, 2 extensions will be remoted off the system to each of about 20 remote sensor locations. The system will also have trunks to switches of other commands. (19:--; 34:--)

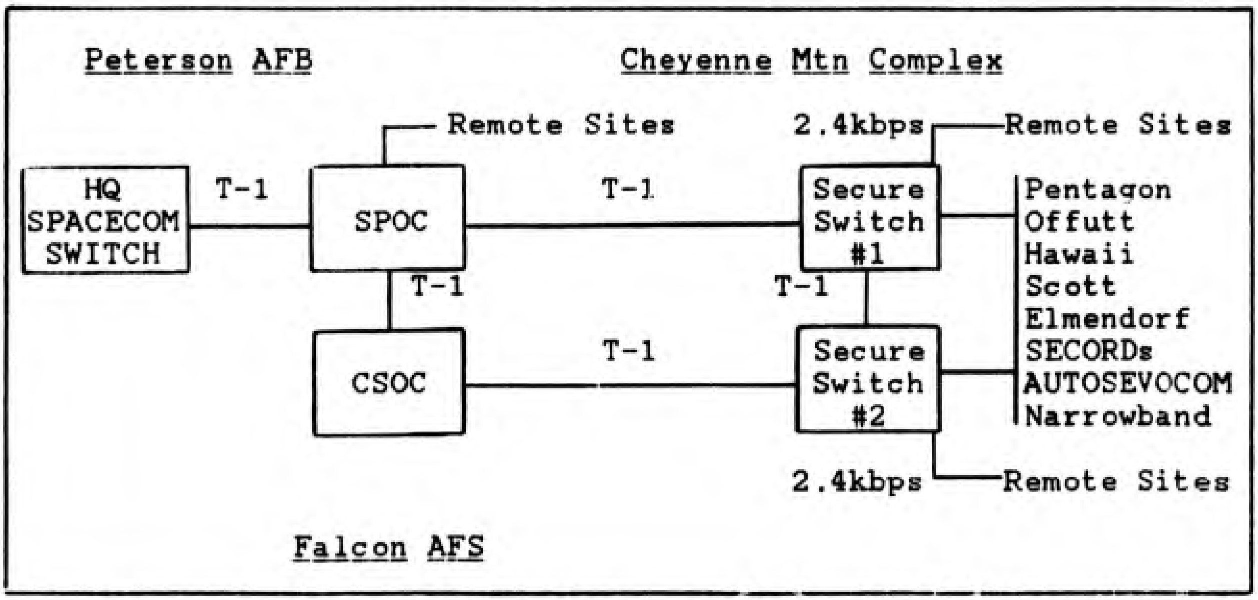
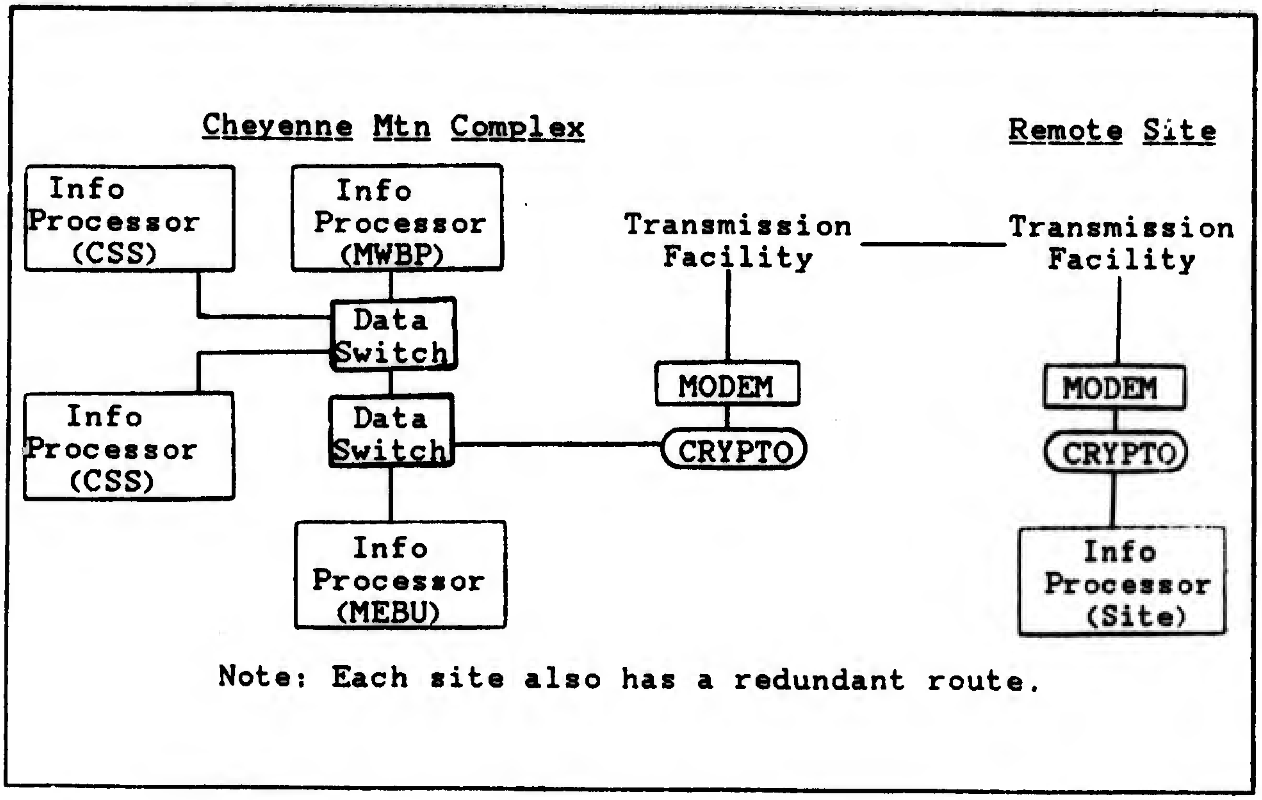


Figure 8. Typical Secure Voice
Baseline Connectivity for SPACECOM (19:65; 34:--)

The switches have two types of off-premise interfaces. The first is a single channel analog port. Signals from this port must be digitized, encrypted, and then transmitted. Single trunks to most locations use this interface with wideband encryption. One of the extensions to remote sites will use this interface and low speed (2.4 kbps) digitizers with modems over standard telephone lines. Another way to remote lines is through a digital T-1 trunks carrying a composite of 24 voice channels. Since the trunk is already digital, it needs only to be encrypted before transmitting it. Tie trunks and some remote extensions may use this method. (19:--)

Secure Data System

The second system examined is a secure data system. The planned configuration is shown in Figure 9. A 2400 bit per second (in some cases 9600 bit per second) data line has been planned from the CMC over digital satellite facilities to 20 remote sites. Each of these lines must be encrypted. Each is distributed in the CMC technical control facility to one or several computers. (34:--)



Note: Each site also has a redundant route.

Figure 9. Typical Secure Data Baseline Connectivity for SPACECOM (34:--)

ESTIMATING COMPOSITE BANDWIDTH

Once connectivity requirements are known, composite digital bandwidth requirements among premises may be established. (26:Ch 6) Matrices are one way of visualizing this. Table 1 shows estimated channel requirements for both voice and data. Table 2 shows the requirements in terms of bandwidth. A standard 64 kbps was used for most voice requirements. Each site was allocated 56 kbps. The reason is, this is the smallest bandwidth providing

	SPOC	HQ	CSOC	SENSORS "A"	SENSORS "B"	SENSORS "C"
CMC (Cheyenne Mtn)						
Secure Voice	11	23	8	1x2.4	-	-
Secure Data	*	*	*	2x2.4	2x2.4	2x2.4
Non-Secure Voice	*	*	*	*	*	*
Non-Secure Data	*	*	*	*	*	*
SPOC (Peterson AFB)						
Secure Voice	-	*	8	1	1	-
Secure Data	-	*	*	*	*	*
Non-Secure Voice	-	*	*	*	*	*
Non-Secure Data	-	*	*	*	*	*
HQ (Peterson AFB)						
Secure Voice	-	-	-	-	-	-
Secure Data	-	-	-	-	-	-
Non-Secure Voice	-	-	-	-	-	-
Non-Secure Data	-	-	-	-	-	-
CSOC (Falcon AFS)						
Secure Voice	*	*	*	*	*	*
Secure Data	*	*	*	*	*	*
Non-Secure Voice	*	*	*	*	*	*
Non-Secure Data	*	*	*	*	*	*

CMC (Cheyenne Mtn) to	Secure Voice		Secure Data
SAC	1x50 KBPS	1x2.4 KBPS	3x2.4 KBPS
NMCC (Pentagon)	3x50 KBPS	1x2.4 KBPS	3x2.4 KBPS
ANMCC		1x2.4 KBPS	3x2.4 KBPS
Los Angeles Secord	1x50 KBPS		
San Diego Secord	1x50 KBPS		
Sunnyvale Secord	1x50 KBPS		
Kelly Secord	1x50 KBPS		
Malmstrom Secord	1x50 KBPS		
Elmendorf Switch	1x50 KBPS		
Hawaii Switch	2x50 KBPS		
Scott Switch	1 **		
Buckley AFS	1 **	1x2.4 KBPS	*
Travis AFB	1x50 KBPS		
Fort Carson	1		
Lamar GEP	1x50 KBPS		

Note: * Requirements not identified but could be accommodated.
** Presently 50 KBPS. Proposal to replace with T-1.

Table 1. Partial Listing of SPACECOM Interpremise Connectivity Requirements (19:--; 34:--)

	SPOC	HQ	CSOC	SENSORS "A"		SENSORS "B"		SENSORS "C"	
CMC (Cheyenne Mtn)	704	1472	512	4.8	56	2.4	56	2.4	2.4
SPOC (Peterson AFB)	-	-	512	*	*	*	*	*	*
HQ (Peterson AFB)	-	-	-	-	-	-	-	-	-
CSOC (Falcon AFS)	-	-	-	*	*	*	*	*	*

Note: (1) Amounts are in KBPS.
(2) Total required pooled bandwidth CMC>SPOC(HQ)>CSOC 3200 KBPS = 2(+) T-1s.
(*) Amount not yet specified

Table 2. Sample Matrix of Composite Secure Bandwidth Between SPACECOM Locations

a "non-synthetic" sounding "compressed" secure voice channel combined with a data channel. It is also a standard satellite channel. (27:--; 38:--) From these tables, a feasible topology may be established.

ESTABLISHING A FEASIBLE TOPOLOGY

A feasible topology is one capable of satisfying connectivity and capacity requirements. Many topologies are possible--tree, star, ring, or mesh, for example. Several factors will determine the best topology--physical layout, interconnectivity needs, bandwidth requirements, and availability of facilities, and redundancy are some. Potential cost is another. A fully meshed network, for example, means that each premise is interconnected to every other premise by at least one path. Although more survivable, a mesh may also be the most costly. (26:Ch 6)

If this were not a simplified analysis, several topologies would have been evaluated before deciding upon a feasible topology. In this study a mesh is assumed for the Colorado Springs area. This assumption is based on a need to avoid catastrophic loss of information and to provide interconnectivity. (34:--) A star is assumed to the remote sites. A paucity of digital capacity and little requirement for site-to-site connectivity are behind this assumption. This proposed topology is shown in Figure 10.

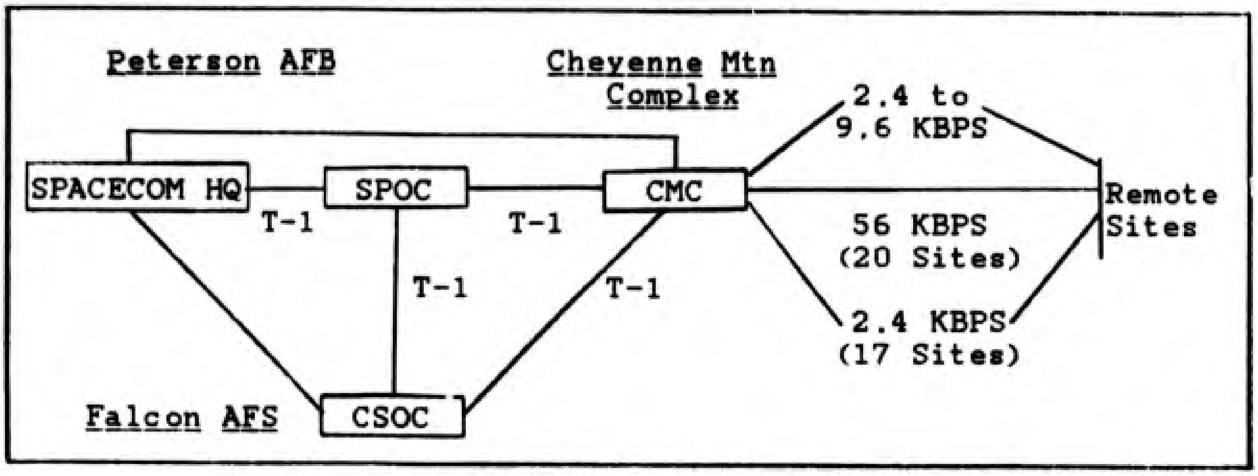


Figure 10. A Feasible "Red" Network for SPACECOM Based on Composite Bandwidth Table

EVALUATING POSSIBLE ARCHITECTURES

Establishing candidate architectures would be the next step. As discussed in Chapter Three, three typical architectures are possible--conventional, basic and integrated. A conventional network was not considered for reasons already mentioned. Moreover, integration is not practical in two areas. The first are gateways to other organizations, such as SAC. The second are the low rate voice paths to each site. Even so, integrating most of the network should be feasible. Figures 11 and 12 show a possible integrated architecture. A basic digital architecture would look similar except time division multiplexers would be use instead of integrated nodes. Integration might provide some immediate operational improvements such as consolidating the cable pairs between computer facilities and the patch and test in the CMC. It could reduce the number of T-1s needed for full mesh interconnectivity among the dispersed secure switches. It could provide an automated patching and testing capability. There are two options for sites. Option A would use an integrated architecture. Option B would use a basic TDM architecture. The former would have the advantage of a common, coherent architecture. The latter would cost less, initially.

The main drawback of integration is its cost. A fully integrated network for Colorado Springs and the sites would cost on the order of $1.5 million. This is based on 8 nodes at $100 thousand each and 20 site nodes at $35 thousand each. Using option B for the sites would reduce the cost about $300 thousand. (32:29-33) The cost of a comparable basic digital architecture would be on the order of $800 thousand. This is based on $20 thousand for each remote site, $60 thousand for each T-1 link and

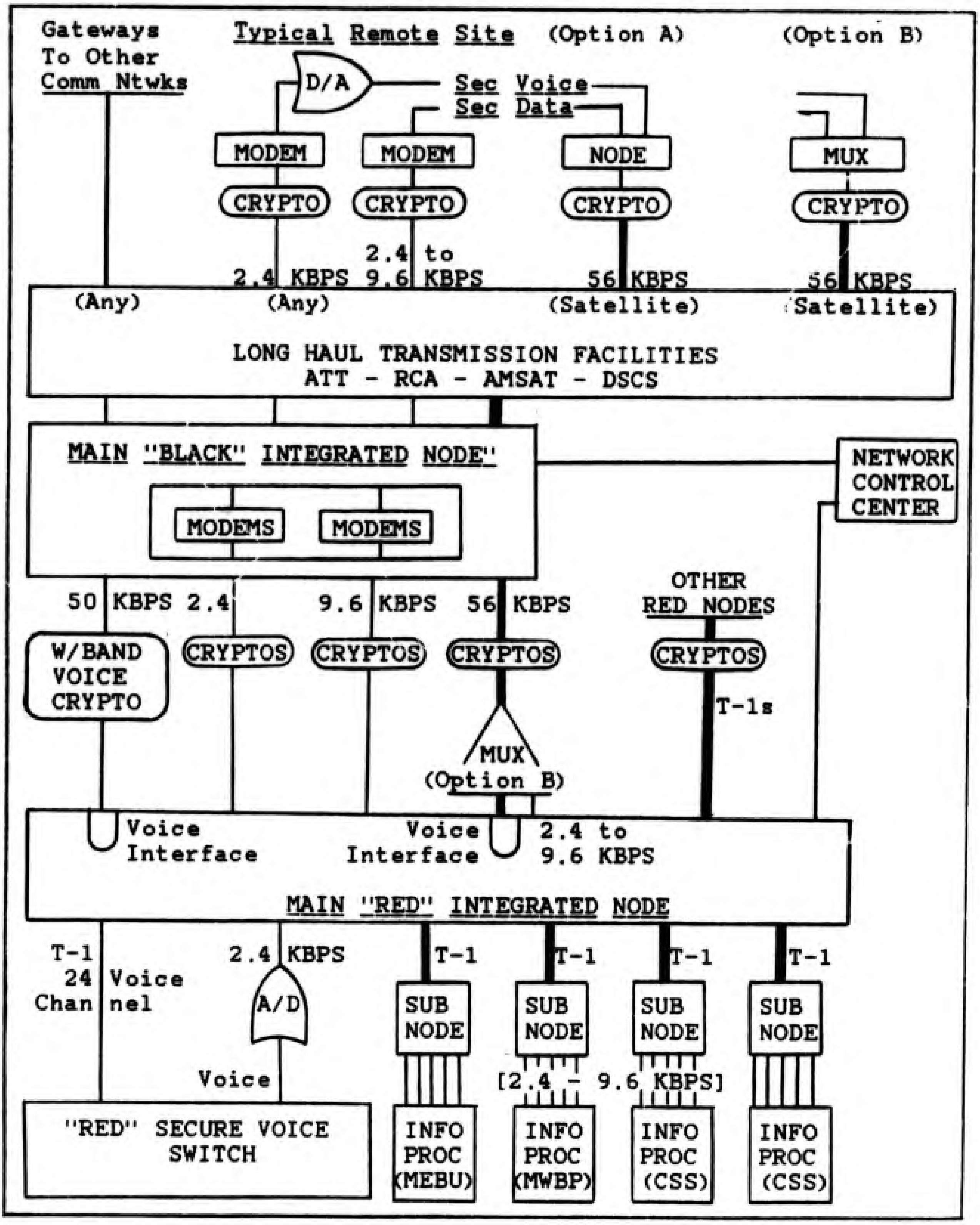
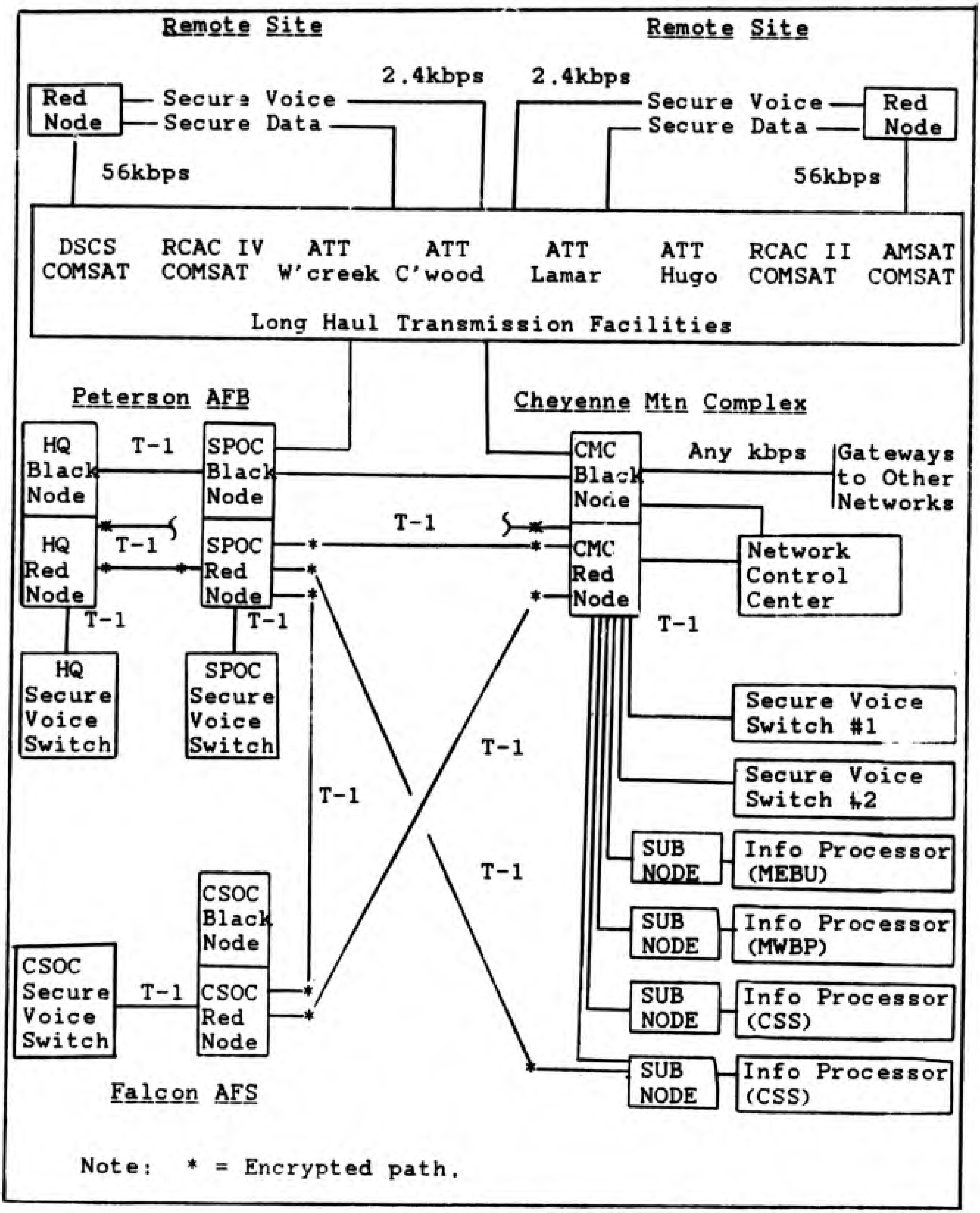


Figure 11. Integrated Network Architecture
Cheyenne Mountain Complex to Remote Site/Gateway



Note: * = Encrypted path.

Figure 12. Recommended Overall Target Integrated Architecture for SPACECOM

$80 thousand for automatic circuit switches. (29:--) Other assumptions and configurations could be examined. However, integration has paybacks which would offset these costs, for instance better use of facilities and reduced manpower.

OBSERVATIONS

This chapter has used a purposefully simplified methodology to illustrate how Space Command's interpremise network might be integrated. The illustration showed that there are factors which limit integration. For instance, integrated digital facilities to dispersed locations may not be practical or possible. A network may require gateways to other organizations which do not employ either digital facilities or a compatible integrated architecture. Integration may be undesirable for parts of a network for operational reasons. But these issues do not mean integration should be abandoned as a goal. They simply mean choosing a target architecture involves practical considerations. Even with these limitations, integrated digital interpremise networks are obviously applicable to a large portion of Space Command requirements. Clearly, a more detailed requirements analysis could change, or strengthen, this conclusion. This analysis would be needed if an integrated architecture were seriously considered for the Space Command, or any other command.

The obvious resistance to integration, as shown here, may be its relatively high initial cost. At this point, based on expected costs, a choice between an integrated or a basic architecture, would favor the latter. There is one set of requirements, not yet considered, affecting this decision. These are the strategic requirements. The following chapter will examine how these architectures compare against these requirements.

Chapter Five

SELECTING AN ARCHITECTURE: A PROACTIVE APPROACH

The challenge a network planner may face is how to choose the most effective, flexible, coherent, and efficient network. The choice is made more difficult when firmer criteria, such as acquisition costs, suggest one choice and these soft, subjective criteria suggest another. A "proactive approach" has been suggested by Maj Gen Prather, retired Commander of AF Communications Command, to guide the selection of communications systems under similarly ambiguous circumstances. (15:2) This approach is, first of all, anticipatory--it favors a long view solution, one with the greatest potential to satisfy both quantitative and qualitative needs even before the user has recognized them. Moreover, it is holistic--it favors a solution with the broadest application and the greatest combined effect. It should also provide the greatest hedge against uncertainty, although this does not mean the solution cannot be innovative. On the contrary, the proactive approach is biased toward the innovative. (1:28; 5:52) With this approach, this chapter evaluates conventional, basic, and integrated architectures for Air Force applications.

CONVENTIONAL NETWORKS

Conventional, dedicated, point-to-point interpremise architectures predominate in the Air Force. Granted, they have provided usable networks for many years and will continue to do so. But, they have had shortcomings, even before viable alternatives existed. (22:Ch 12) Performance monitoring, diagnostics, coordination, and other control functions tend to be reactive, labor intensive, and imprecise. (3:97) They usually have no inherent mechanism to quickly reroute information or to use idle resources for other than their dedicated purposes. Finally, limited data capacity generally makes them unsuitable for many applications. Accordingly for volume, heterogeneous, multilocation applications, one network professional has called them, "unwieldy, unresponsive, inefficient, costly, and generally a pain." (1:28)

BASIC DIGITAL NETWORKS

Basic digital networks may improve performance and cost. To begin, their components fail less often than conventional ones. Moreover, by eliminating or consolidating most interface and communications equipment, normally there is less to fail. (4:29-30) Digital facilities have become increasingly simple to install and virtually maintenance free. (24:--; 30:--) They have characteristics which inherently improve data accuracy and voice quality. (13:37) Because digital networks use bulk transmission facilities, the cost to implement or expand them is 5 to 10 times greater than that of a single conventional facility. But their capacity is 20 to 50 times greater, depending on the mix of voice and data. At approximately 20 percent to 40 percent capacity, digital networks may break even with conventional ones; at full capacity, the price per unit of information is one fourth to one seventh of conventional costs. (26:Ch 2) Consequently, one appeal of digital architectures should be their long term economies of scale.

The main shortcoming of basic digital architectures is, like conventional ones, their general lack of sophisticated, network wide intelligence. Accordingly, they remain relatively unwieldy and labor intensive to control. (1:20) Moreover, with many communication eggs in the same facility basket, so to speak, any failure might be catastrophic. External matrix circuit switching and automatic, redundant facility switch over appliques may be added. But these would be costly band-aid fixes for multipoint networks. (29:--) Aside from being awkward, tandeming circuits through multipoint topologies also degrades voice quality, due to repeated recoding. (26:Ch 6) Yet with these limitations, one networking guru still believes now is the time to begin the migration to digital networks. (5:50)

INTEGRATED NETWORKS

Once committed to a digital architecture, integration is the next logical step. The reason is that network intelligence is inherent in integration. (1:19-21) Intelligence improves operator, or "tech control," functions by automating most routine, repetitive, or error-prone operations, such as performance monitoring and circuit patching. It also helps avoid critical loss of connectivity, without operator intervention, by rerouting and reconnecting calls over alternate facilities. (4:32) Most remaining functions are as simple as a few keystrokes on an operator terminal. Decision aids, alarm displays, event logs, and on-line record keeping further enhance operations. (31:21-35) Thus, controlling a network may become less tedious, more precise, and more timely, requiring as little as a tenth the time and effort of other networks. (22:63) Regardless of the size or complexity of a network, a small cadre of controllers at a central location may perform most control functions for an entire network. (25:--; 31:31) Other architectures may require operators at virtually every site. Clearly, integration may drastically reduce operating costs while improving performance.

An integrated network should also provide a better use of network capacity. Allocating only the amount needed for calls maximizes the number who may use the network at one time. More important, allocating capacity only when needed statistically increases the number who may use it over time. (4:32) By compressing voice calls, the effective number of users may be further increased, with a nominal effect on voice quality. Compression may be especially useful to temporarily handle a surge in requirements or congestion resulting from a failed link. (31;30-37) Furthermore, these enhancements can be balanced across the pooled capacity of a network. As a result, a given topology may require fewer facilities to support a given number of users. It should also absorb more users before additional facilities may be required. Hence, integration may make a network even more economical.

Finally, integration improves an architecture in almost every way. It consolidates or eliminates much of the infrastructure--patch bays, interequipment wiring, layered interfaces--which make other architectures so unwieldy and unresponsive. It provides transparent, tandem routing and end-to-end digital quality to virtually any user information system. (31:1-5) Standardization and an open ended structure can make any complex network easier to conceptualize, plan, and implement. Virtually any topology should be possible, subject to facilities and equipment being available. A topology can be easily changed. Most changes are as simple as changing a few records in a database and connecting a user to a module. (31:30-31) Unlike conventional facilities which must be engineered for each user, integrated networks only engineer facilities when expanding topologies or when additional bulk capacity is needed. Recalling that integration may reduce the need to add facilities, when added their cost may be spread over many users. (4:32; 1:26) Coupling this with interface modules, costing one to two thirds comparable communications interfaces, may make the incremental cost of change a fraction of that for other architectures. (32:31-33; 29:--) Clearly, integrated networks offer a degree of flexibility and cost control "impossible to achieve with non-dynamic systems." (1:20)

Integration also has drawbacks. First, with integration comes the burden of network management. Thought must be given to optimal topologies, configuration management, resolving contentions among traffic, and tracking the performance of the network. This should not be a problem, however, for the Air Force because of its in-place communications staffs. Secondly, recognizing the full potential of integration requires a change in the way networks are planned and conceived. It requires a strategic, organization wide--rather than parochial--approach. Information must be treated as a singular resource, not as voice, data, or other distinctions. (4:30-33)

Finally, integration has a high initial infrastructure cost. This primarily reflects the cost of network common equipment and intelligence. Although integration may reduce operating costs 10 to 15 percent (28:--), the economies of integration depend upon spreading infrastructure costs among a number of applications. Obviously, the fewer the applications, the less the cost benefit of integration. In general, conventional networks would be most practical for simple networks with only several information paths. Basic architectures would be suited for simple networks with no drop/insert/bypass requirements, a few digital lines, and enough traffic to use approximately 30 percent of facility capacity. Integration should be economical in most other applications. On the other hand, in some applications, the proactive solution--integration--may be the most costly, initially, yet the most economical to operate in the long run.

OBSERVATIONS

With few exceptions, integration emerges as the proactive interpremise networking solution. An integrated architecture is designed around the understanding that information is strategically linked to the success of an organization. It anticipates that systems fail--so it provides the mechanism to minimize the impact of those failures. It anticipates that users' needs change--so it provides an infrastructure that can be quickly tailored to those changes with minimal sunk effort. It anticipates systems will be managed by humans--so it includes the tools to do this accurately and timely. It anticipates that the world is becoming digital--so it provides a concept to manage that migration and use it to the best advantage.

One appeal of integration is the holistic way it approaches the strategic challenges of interpremise networking. It can transparently interface virtually any existing user information system. Accordingly, these systems can become more reliable, survivable, dynamic, and precise without being replaced or redesigned. Current off-the-shelf integrated network systems have such a broad range of applications and capabilities, yet such a simple and cohesive architecture, that they should not quickly become obsolete. Even when an investment in integration may not be quickly recouped, integrated networks should be the proactive solution. This innovative approach has proven to provide more effective, responsive, coherent, and efficient interpremise networks, than other architectures, in applications similar to those of the Air Force. There is every reason to believe integrated networks would benefit the Air Force also.

Chapter Six

SUMMARY AND CONCLUSIONS

The purpose of this study has been to determine how the Air Force might benefit by integrating, now, its interpremise networks. In attempting to answer that question, this study has examined three types of architectures, the qualities they should have, and the applicability of these networks to the Air Force.

Integrated interpremise networks should be feasible for many Air Force networking needs. This is a somewhat panoramic observation from Chapter One based on similarities between the Air Force and those organizations which have migrated to these networks. Both operate from distributed locations and must communicate among them using a diverse mix of media. Most major Air Force organizations have these traits. But feasibility alone is not a compelling reason for integrating their networks.

Chapter Two examined the strategic qualities interpremise networks should have. Of obvious concern in the design of a network are its physical requirements. But of more strategic concern is how effective, responsive, coherent, and efficient it will be. These are strategic issues because of the essential and complementary role interpremise information networks, play in applying airpower. Reliability, transparency, flexibility, interoperability, simplicity, control, and cost performance are among the design criteria which contribute to this role. Moreover, Air Force networks must be increasingly capable of interfacing high volume digital user information systems.

Chapter Three examined characteristics of three of the more common interpremise architectures. Conventional ones typically use telephone lines dedicated to a particular information type. They are built piecemeal from these individual point-to-point lines. Basic digital architectures replace individual telephone facilities with digital ones. They take advantage of economies of scale of digital lines by simultaneously transmitting many types of information over a single, high capacity digital facility. Integrated networks are sophisticated digital networks. Their unique component is an integrated node. In addition to performing more basic multiplexing and switching functions, nodes make intelligent networking possible. Embedded microcomputers in each node provide automatic routing, control, performance monitoring, dynamic bandwidth management, and other network wide, software defined, robust features.

Chapter Four showed how the Space Command interpremise network might be integrated. The Space Command has decided to migrate to a digital architecture. It has not yet chosen an integrated one. Based on a sampling of the command's secure voice and data requirements, the high volume Colorado Springs network would benefit from integration. However, integration would provide lesser benefits beyond Colorado Springs due to the low traffic volume to dispersed locations. A basic digital approach would cost less but would also fragment architecture and control. Moreover, the Space Command has numerous single path gateways to other locations which further complicate integration efforts. Similar situations would probably occur throughout the Air Force. None of these factors of themselves should obviate the potential overall benefits of integrated networks; they should only complicate the planning and implementation of them.

Chapter Five takes a proactive approach to evaluating the benefits of integration. Current Air Force conventional networks will progressively provide less than satisfactory solutions. These networks tend to be unwieldy, error prone, and resource intensive compared to other approaches. By necessity, the Air Force should implement digital interpremise networks to satisfy a growing demand for digital communications. Digital networks also offer a way to lower the cost and improve the quality of information transmission. Given this move toward digital networks, integration is the next logical step. Automation, inherent with integration, enhances control and gives a network self healing attributes. For many volume networks, integrations should offer the most effective, flexible, coherent, and efficient approach.

The conclusion of the author is integrated digital interpremise networks are not only feasible and generally applicable to the Air Force, but would also be beneficial. The larger the base of integration in the Air Force the greater the benefits would be. Trends in requirements and costs will eventually push the Air Force into digital interpremise networks. When this happens, the Air Force will face the issues of how to most efficiently use and manage them. Beginning the migration to integrated networks now rather than later will put the Air Force in the best position to proact rather than react to these eventualities.

RECOMMENDATIONS

The author makes the following recommendations:

--The Air Force should disseminate this study and other integrated network literature to make more information systems planners aware of this emerging concept.

planners aware of this emerging concept.

--The Air Force should establish integrated digital interpremise networks as a near term planning priority. It should perform a technology assessment of current off-the-shelf systems.

--The Air Force should establish an organization wide integrated architecture model to complement current integrated models being developed for local area networks.

--The Air Force should establish an integrated network acquisition and migration strategy.

--The Air Force should assist its commands in establishing integrated networks and identify those inter-command requirements which might benefit from them.

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