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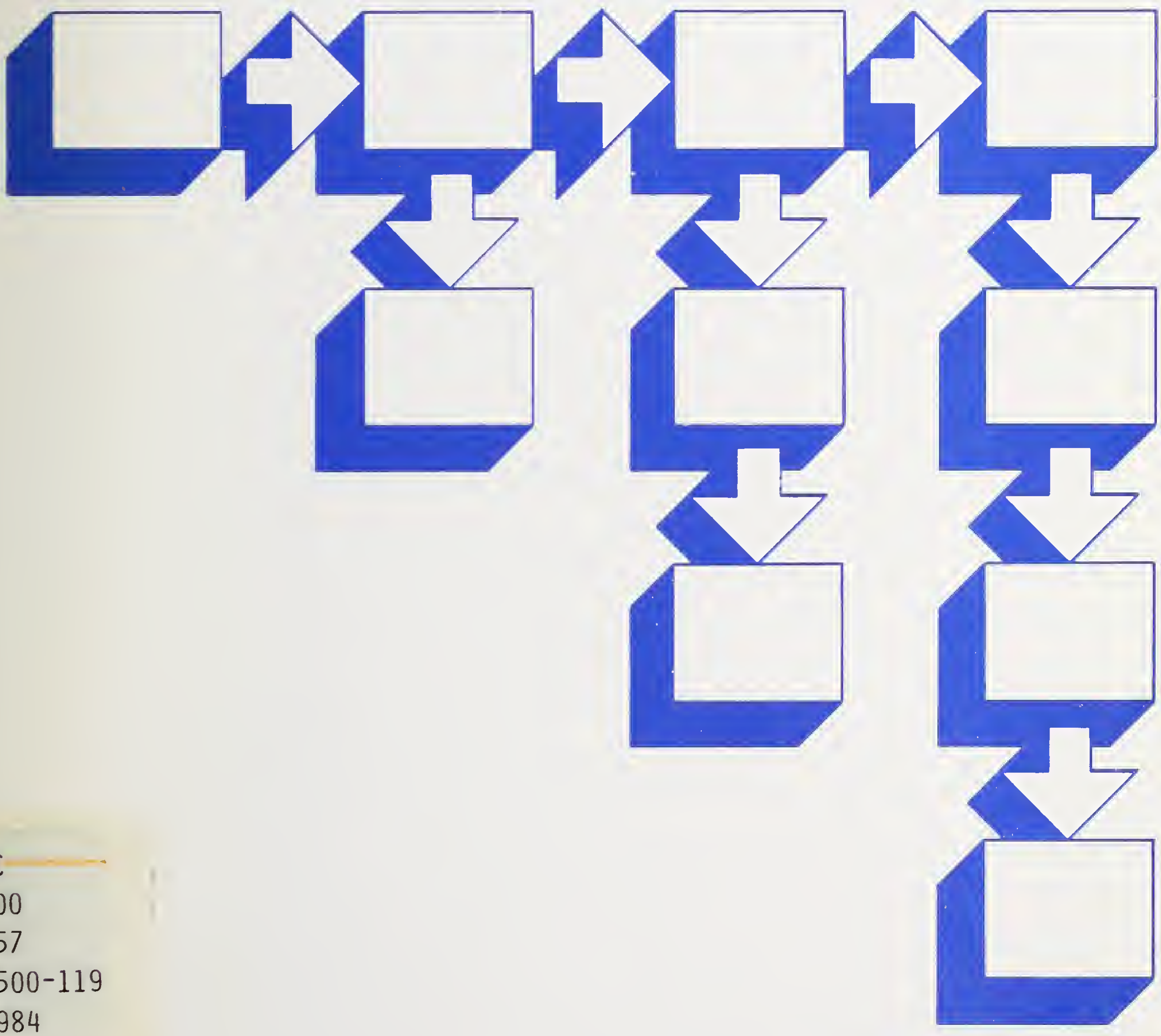
Future Information Technology-1984 Telecommunications



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[3] Located at Boulder, CO, with some elements at Gaithersburg, MD.

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Future Information Technology-1984 Telecommunications

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Institute for Computer Sciences and Technology
National Bureau of Standards
Gaithersburg, MD 20899

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ABSTRACT

This document, the second in a series, focuses on telecommunications technology and related areas in computer organizations. It contains four primary parts: the telecommunications forecast through 1999, three perspectives on the divestiture of AT&T, a discussion of the general impacts of technology on computer security, and the management implications of the trends in information technology. Additionally, it contains the summary of an industry workshop on this forecast, a brief update of the 1983 forecast, and a glossary of terms. This forecast is a companion to "Future Information Processing Technology - 1983" which contains fifteen year projections of computer hardware and software.

KEY WORDS: computer security; computers; divestiture; management implications of technology; networks; security of distributed systems; technology forecasting; telecommunications; trends in information technology.

ACKNOWLEDGEMENTS

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We would like to thank Warren G. Bender and Frederic T. Withington of Arthur D. Little, Inc. for their extensive contributions and the following Federal Agencies whose representatives served on the technology forecast steering committee: Defense Intelligence Agency, Defense Mapping Agency, Department of Energy, Department of the Army, Environmental Protection Agency, General Accounting Office, General Services Administration, Housing and Urban Development, Internal Revenue Service, National Aeronautical and Space Administration, National Security Agency, Office of Management and Budget, Office of the Secretary of Defense, Office of Technology Assessment, Smithsonian Institution, United States Department of Agriculture, United States Information Agency.

Our thanks also go to Nicholas P. Miller of Preston, Thorgrimson, Ellis and Holman, and John N. Rose of REA who prepared portions of Part II; Marco Fiorello of Titan Systems and Mark Samblanet of Aurora Associates, Inc. who prepared portions of Part III.

FOREWORD

The Institute for Computer Sciences and Technology (ICST) is responsible for the development of standards and guidelines which lead to "the economic and efficient purchase, lease, maintenance, operation and utilization of automatic data processing equipment by Federal departments and agencies" (Public Law 89-306). In order to fulfill its responsibilities, ICST gathers and integrates information needed for the timely selection of technical areas to be investigated and for monitoring and revising existing standards and guidelines. To those ends, ICST develops technology forecasts, gathers data relating to ICST product usage, and conducts studies on the costs, benefits, and impacts of its products.

While the information gathered and compiled is primarily used to help ICST guide its own program, certain studies are, we believe, of more general interest. When widespread interest is expected, ICST, through publication, disseminates the relevant documents. Our periodic technology forecasts are in that category. Our first forecast, in 1981, was published as a contractor's report. Even with limited dissemination, so much interest surfaced that in 1982 we "went public" for the planning of the subsequent document. That forecast, *Future Information Processing Technology - 1983*, was a joint effort by ICST, the Departments of Energy and Agriculture, the Defense Intelligence Agency, and the Environmental Protection Agency. A circulation draft was distributed throughout the Federal Government and 14 other agencies provided substantive contributions. In addition, a panel of industry ADP users and vendors reviewed the publication in a teleconference workshop. The document was published in the NBS Special Publications Series (SP 500-103).

Interest in technology forecasting continued to build and for this document we established an ad hoc steering committee comprised of representatives of 16 agencies to help guide its preparation. The 1984 edition, *Future Information Technology - 1984. Telecommunications*, is intended as a companion volume to the 1983 report. The recommendations of the steering committee are reflected in the content of the new forecast.

The steering committee -- now enlarged to include 24 agencies -- has already begun work on the next edition.

Part I, "Future Telecommunication Technology", was developed by Arthur D. Little, Inc., and was based in part on a point-of-departure draft prepared by Bob Sobecki of the Department of Agriculture. Certain sections are flagged by the words "staff comment". The flagged sections are keyed to comments submitted by knowledgeable staff members of Federal, State and local governments and comments from industry participants who attended the September 1984 workshop which is summarized in Part V. The comments themselves, contained in an appendix to Part I, either express divergent views from the material presented earlier or provide additional information.

Part II addresses the AT&T divestiture from three perspectives. Chapter 1 contains a technological overview developed by Arthur D. Little. Chapter 2 presents a summary of a teleconference held by ICST and ADP officials from various State and local governments. The material was developed by Nicholas P. Miller of the law firm Preston, Thorgrimson, Ellis and Holman. Chapter 3, prepared by John Rose of the Rural Electrification Administration, looks at divestiture from the perspective of rural telephony.

Part III discusses security issues in a distributed environment. Chapter 1 again contains a technological overview by Arthur D. Little. Chapter 2, a joint effort by Marco Fiorello, Mark Samblanet, and Peg Kay of Titan Systems, Aurora Associates, and ICST respectively, suggests a methodological framework for security analysis. As in Part I, staff comments are included in an appendix to Part III.

Part IV discusses the implications -- for management -- of the converging trends in ADP/telecommunications technology. This Part was prepared by ICST using point-of-departure material developed by the International Data Corporation. The chapter was jointly funded by the Department of Defense and ICST. Again, staff comments are included in an appendix to Part IV.

Part V summarizes the results of September 1984 workshops in which private sector participants reviewed the circulation draft of the forecast. The workshops were held at NBS at the request of the participants in the 1983 industry teleconference, mentioned earlier. The summary of the workshop dealing with Part I quite clearly indicates that private sector requirements for a most-useful technology forecast differ somewhat from those of the public sector. The public sector's major need is for information on which to base acquisition plans. While this is also of interest to private firms, they additionally need the forecasts as input to their strategic plans. That is, the future of the technology may very well influence what new areas the firms will explore as possible business-entry opportunities. Thus, a forecast prepared for the public sector will emphasize areas of stability; for the private sector, a more determinedly "futures" document is needed. As we noted in the first paragraph of this Foreword, ICST's primary obligation is to the public sector. However, it may be possible to jointly prepare a forecast -- or "companion" forecasts -- so as to satisfy both requirements. We are currently exploring this possibility with some of the workshop participants.

Part VI is a retrospective of this report's companion volume, the 1983 information processing technology forecast. It contains a summary figure and the table contents from that volume and a brief update of the 1983 material.

The glossary covers terms used in either the 1983 or 1984 documents.

We have been very pleased by the enthusiastic cooperation of the various Federal, State and local agencies. As you may infer from the paragraph discussing Part V, the private sector -- ADP/telecommunications vendors and users alike -- also did yeoman service and we are grateful. It is our intent to periodically update the forecast and we are looking forward to expanding the working consortium in subsequent editions.

We would very much appreciate comments and suggestions from our readers, addressed to P. Powell, Information Processes Group, Institute for Computer Sciences and Technology, National Bureau of Standards, Bldg. 225, Room B253, Gaithersburg, MD., 20899.

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PART I: FUTURE TELECOMMUNICATION TECHNOLOGY

Prepared by

Arthur D. Little, Inc.

Contract number
NB 80SBCA-0405
Institute for Computer Sciences
and Technology
National Bureau of Standards

PREFACE

Part I is a forecast of telecommunications technology, prepared for ICST by A.D. Little, Inc. The content of the forecast was suggested, in the form of a detailed outline, by the Department of Agriculture and agreed upon by ICST and the members of the ad hoc steering committee. A.D. Little's early drafts were extensively reviewed by knowledgeable experts in Federal, State and local government agencies. Despite that, when industry representatives met at ICST for a review workshop (See Part V), they identified digital bandwidth compression technology (which is expected to affect several types of telecommunications services) and infrared communication technology as two important areas which we have not covered. We apologize for the omissions.

The industry workshop participants strongly urged that they be involved at an earlier stage when next year's forecast is prepared. That is an offer we wouldn't dream of refusing.

Despite the omissions, the forecast covers an extensive amount of material. This material is summarized in the chart immediately following. Following the summary chart is a list of acroynms used in this part of the document.

SUMMARY OF TELECOMMUNICATIONS FORECAST

	1984-1989	1989-1994	1994-1999
OSI Model	Continued manufacture and sale of communication products that don't totally conform to standards	Compatibility problems will ease; but still there	Working OSI model universally recognized
Technologies			
LANS	Growing acceptance of standards; reduced cost; technology matures	Changes will be in component technologies, e.g., fiber optics; wide range of terminal interfaces available; system costs decline	
Digital Microwave Radio	Widepread application in short to medium-haul systems where need for digital capabilities and economies of digital termination will dominate decisions	Introduction of long-haul systems in 4-6GHz bands; expect 10bps/Hz and 45 percent cost reduction by 1999	
Satellite Communication	Expanded use of direct broadcasting and videoconferencing; development of higher frequency systems	Slow growth of application as optical fiber economies dictate optical fiber transmission	Growth limited to geographically dictated applications - e.g. transoceanic, archipelagos, etc.
Cellular Radio	Little change in concept and performance; wider use of portable phones; cost reduced	Saturation capacity being approached; costs decline; portables displace mobiles	Saturated market segment
Circuit Switching	Steady replacement of U.S. telephone switches with digital switches	Toll network all digital; digital switches begin to replace analog electronic switches as well as electromechanical; distribution of switches into subscriber plant	Incorporation of ISDN - New generation of modular distributed switches; few suppliers left.
PABX	4th generation widely used with voice and data; modest cost reduction	5th generation with distributed, universal modular blocks of hardware and software for voice and data; cost about half of 1984	Front-end processor, voice, data control completely merged
Packet Switching	Wide application for value added data services	Some packet switched voice in use; continues as data overlay switching method	Dominant data switching method
ISDN	First limited trial application definitions completed; regulatory considerations slow applications in U.S. since Bell Region. Oper. Co. are prohibited from providing enhanced service	Serious introductions of ISDN - oriented switches for business use	Business use of ISDN widespread; very small residential application

SUMMARY OF TELECOMMUNICATIONS FORECAST (continued)

	1984-1989	1989-1994	1994-1999
Devices & Media			
Microwave Semi-Conductors	Higher frequency, higher power, lower cost trend continues, circuit costs for DBS receiver will drop considerably	Low cost cellular mobile equipment will spur applications	Evolutionary rather then revolutionary advances continue
Optical Fiber	Rapidly gains acceptance as long-haul and exchange trunk medium.	Transoceanic systems in use; medium haul systems and trunks, including subscriber carrier, become widespread	Fiber to home installations start; fiber dominant transmission medium for all fixed applications
Optical Logic	Multimode switches being developed	Several input/several output multimode switches being developed; possibly some military applications	Integrated optical arrays made in small quantities; experimental switches put in operation in military labs
Coaxial Cable	This media is being replaced by other media; no further R&D in new versions carried out; continues as commodity item	Commodity item; some residual use for small system and expansion	
Input/Output			
Voice Synthesis	Word-to-phrase linking preferred over parametric synthesis; selected incorporation of speech synthesizers; integration with voice recognition systems	Human-like speech for unlimited vocabulary for text-to-speech transcription; synthesis to reach quality of recorded voice segments	Human-like two-way interaction possible
Voice Recognition	Limited complexity, continuous speech recognizers for commercial applications	Some task-oriented systems with vocabularies in range of 1,000 words for multiple speakers	General purpose systems available as out-growth of task-oriented systems
Character Recognition	Low-cost multifont readers for office automation; portable readers for stand-alone or mobile data entry terminals; omnifont readers for typed and printed fonts and hand-print for general text input		Possible systems for individualized connected handwriting
Facsimile	Group 4 becomes established; costs become lower	Lower costs lead to much more widespread application; functions will become integrated with terminals	
Terminals	Personal computer-based terminals enter general use	Voice, character and image functions converge	Conversational interaction; extremely user friendly terminals common
Teleconferencing	Telemeeting still in experimental developmental stage	Improvements in data transmission range and communication channels; increased resolution and use of color	Improvements in 1989-94 timeframe continues; use of blackboards in personal computer workstation; TV camera input for documents and faces

ACRONYMS

ANSI	American National Standards Institute
bps	Bits Per Second
CCD	Charge Coupled Device
CCITT	International Telegraph & Telephone Consultive Committee
CRT	Cathode Ray Tube
CSMA/CD	Carrier Sense Multiple Access with Collision Detection
DBS	Direct Broadcast Satellite
DNA	Digital Network Architecture (DEC)
DOMSAT	Domestic Satellite
ECMA	European Computer Manufacturers Association
EIA	Electronic Industries Association
FDM	Frequency Division Multiplex
FIPS	Federal Information Processing Standards
HDLC	High-Level Data Link Control
ICST	Institute for Computer Sciences & Technology
IDN	Integrated Digital Network
IEEE	Institute for Electrical & Electronics Engineers
ISDN	Integrated Services Digital Network
ISO	International Organization for Standardization
kbps	Kilo (thousand) Bits Per Second
LAN	Local Area Network
mbps	Mega (million) Bits Per Second
MIC	Microware Integrated Circuits
MICR	Magnetic Ink Character Recognition
NCS	National Communications System
OCR	Optical Character Recognition
OSI	Open Systems Interconnection
PABX	Private Automated Branch Exchange
PCM	Pulse Code Modulation
QAM	Quadrature Amplitude Modulation
SCPC	Single Channel Per Carrier
SNA	System Network Architecture (IBM)
TDM	Time Division Multiplexor
TWT	Traveling Wave Tube
VLSI	Very Large Scale Integration

1. NETWORK ARCHITECTURE

1.1 OPEN SYSTEMS INTERCONNECTION (OSI)*

1.1.1 Introduction and Background

Over the period 1960-1970, only computers or devices of the same manufacturer and model could communicate with one another, due to the unique signal structure and format built into each machine. Even with identical source and receiving machines, a "handshaking" routine had to be pre-established for proper communications.

The problem of connecting machines of different manufacturers that used different formats, speeds, etc., remained an engineering research activity. Under the continuous pressure of increased data transfer requirements and higher speeds, development of worldwide standards for data transmission were initiated by several organizations. Much has been accomplished, and many manufacturers are attempting to make their equipment and devices conform to these rules, but standardization is still in an evolutionary stage.

1.1.1.1 Data Communications

Data communication takes place in two stages. The first is the communication between the user and the machine and is highly developed at this time. The second stage, which is the primary concern of this discussion, is the transfer of the data from machine to machine.

The original problem arose from the desire to interchange information between relatively large central site computers with their work station terminals, and other large computers. Although this was partially solved by modems and direct wiring, a strong trend has developed, sparked by the availability of small, programmable microprocessors, toward geographically distributed processing systems. These systems break up the many functions previously integrated in large CPUs into a network of small, special-purpose computers whose proper control and handling of data depend on strict adherence to a uniform code of data transfer standards.

1.1.1.2 History of Standardization

Standardization work began to focus on information systems and data communications during the early 1960s. At that time, the International Organization for Standardization (ISO) organized its Technical Committee 97 on Information Processing Systems and

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* This section draws heavily on the Proceedings of the IEEE, Dec. 1983.

several subcommittees, including Subcommittee (SC) 6 on Data Communications. The International Telegraph and Telephone Consultative Committee (CCITT) formed Special Study Group A (now called Study Group XVII) to deal with data transmission over telephone networks. In addition, the European Computer Manufacturers Association (ECMA) and many national organizations began to develop standards to deal with the newly emerging computer technology.

Progress was slow during the first 10 years but included the establishment of the widely used Electronic Industries Association (EIA) RS-232 and CCITT V.24 and V.28 physical services. Work also proceeded with the development of character-oriented protocols for transmission of data. These protocols are based upon the International Alphabet Number 5 (IA5) and the U.S. equivalent, ASCII.

In 1972, CCITT formed Study Group VII, Public Data Networks, to pursue telecommunications services specifically tailored for data communications. Activity proceeded with developing standards for circuit-switched networks, along with a vague consideration of the packet-switching technology that was then emerging.

At the same time, ISO was proceeding with the development of "bit-oriented" data link protocols to provide a more comprehensive and efficient mechanism for data transmission. ISO maintained close liaison with the CCITT Public Data Network activity, and ECMA and participating national standards bodies contributed to the work.

However, there was no "master plan" to assure that all requirements were being addressed properly, and many questions were left unanswered -- e.g., what was needed to make individual systems capable of communicating freely with others?

In 1978, ISO Technical Committee 97 established a new subcommittee, SC 16, on Open Systems Interconnection. SC 16's task was to develop a reference model whose architecture would serve as a basis for all future development of standards for worldwide distributed information systems. Once the architecture had been determined, existing standards were to be analyzed to determine whether they met the requirements of the reference model and, if not, what changes were needed to bring them into alignment. In addition, areas that lacked standards were to be identified and development action taken where appropriate.

In June 1983, the work finally resulted in the approval of ISO <u>International Standard 7498</u> and <u>CCITT Recommendation X.200</u>, which specify the basic architecture of Open Systems Interconnection (OSI). As these two approached publication, the texts were completely aligned. There are no technical differences and very few editorial differences.

In March 1983, the British Department of Industry announced its support for application of OSI as a national policy in the United Kingdom. In the U.S. the National Bureau of Standards has contributed to and supported the ISO Reference Model since 1979. France has adopted OSI as "ARCHITEL," and many other countries are pursuing similar lines.

In its Master Plan, the American National Standards Institute (ANSI) X3 Committee requires that all related standards work be based on the OSI Reference Model. Every related ANSI standards project must identify how it will ensure consistency with OSI.

The new work in CCITT for Integrated Services Digital Networks (ISDN) is also incorporating the principles of OSI. CCITT is developing standards for a worldwide switched digital telecommunications system that will support most of the familiar services (voice, data, facsimile, electronic mail, video, etc.). Newer requirements emerging from the ISDN work will be reflected back to the OSI architecture in the form of additions, enhancements, and adjustments to ensure its continuing evolution.

Transport and Session layers will be ISO Standard's pending publication.

1.1.2 Present Approaches - The OSI Reference Model

The OSI reference model is a layered hierarchical structure of communicating peer protocols. It is the base for coordinating future standards efforts. The model defines:

- o the functions of each layer,
- o interlayer communications, and
- o the protocols used for peer communication.

The approach is to use a layered architecture to break up the problem into manageable pieces. Three levels of abstractions are explicitly recognized: the architecture provided by the model itself, the service definitions and the protocol specifications.

The OSI Architecture defines a seven-layer model for interprocess communication that is constructed from the concepts of relations and constraints. These concepts are used as a framework both for coordinating the development of layer standards by OSI committees, and for the development of standards built on top of OSI.

The OSI Service Definitions represent a lower level of abstraction and define in greater detail the service provided by each layer. A service defines the facilities provided to the user of the service, independent of the mechanisms used to accomplish the service.

The OSI Protocol Specifications represent the lowest level of abstraction in the OSI standards scheme. Each protocol specification defines precisely what control information is to be sent and what procedures are to be used to interpret this control information. The protocol specifications represent the most stringent design guidelines placed on implementations built to conform to OSI standards.

Products can satisfy the much weaker constraints imposed by the Reference Model, but still may not be able to communicate with open systems. There can be many options at any layer that conform with the OSI model but may not allow intercommunication.

SC 16/WG 1 is charged with developing formal description methods for defining the protocols so that they could be implemented unambiguously by users all over the world. The method within WG1 currently being applied to 150 protocols was initially developed by ICST.

1.2 THE ELEMENTS OF THE ARCHITECTURE - PROTOCOLS AND LAYERS

ISO 7498, the document describing the basic OSI Reference Model, is divided into two major sections. The first of these describes the elements of the architecture; these constitute the building blocks used to construct the seven-layer model. The second describes the services and functions of the layers.

In the OSI Reference Model, communication takes place among application processes running in distinct systems. A system is considered to be one or more autonomous computers and their associated software, peripherals, and users that are capable of information processing and/or transfer. Although OSI techniques could be used within a system (and it would be desirable for intra- and inter-system communication to appear as similar as possible to the user), it is not the intent of OSI to standardize the internal operation of a system.

Layering is used as a structuring technique to allow the network of open systems to be logically decomposed into independent, smaller subsystems. A layer, therefore, comprises many entities distributed among interconnected open systems. Entities in the same layer are termed peer entities. Protocols are examples of peer entities.

The basic idea of layering is that each layer adds value to services provided by the set of lower layers in such a way that the highest layer is offered the full set of services needed to run distributed applications.

Another basic principle of layering is to ensure the independence of each layer by defining the services provided by a layer to the next higher layer, independent of the way that these services are performed. This permits changes to be made in the way a layer or a set of layers operates, provided they still offer the same service to the next higher layer. This technique is similar to the one used in structured programming, where only the functions performed by a module (and not its internal functioning) are known by its users.

1.2.1 Protocols

A protocol is the set of message exchange and format rules that the peer communicating layers use to control and synchronize their communication functions. The functions performed by a layer are reflected in the services provided by that layer. Functions may be either centralized, or they may be distributed, using the peer-layer protocol for communications and synchronization. A layer, therefore, need not have an associated protocol if all of its functions are local and its only communication is through its services to adjacent layers. Distributed functions, however, need a communication mechanism to transport their protocol messages between their peer-layer modules. Thus, each layer in the structure must present a communication function service to the layer above it.

The communication services capabilities discussed earlier will, therefore, become the concerns of the protocol supporting that communication mechanism, and the following protocol elements will appear in many protocols:

1. Addressing: The specification or representation of the name of the source and the destination of information.
2. Error Control: The detection and recovery from errors introduced by the lower-level communication mechanism.
3. Flow Control: The management of the flow of information from the source to the destination.
4. Synchronization: The control and/or knowledge of the state of each peer half-layer by the other half, so they may remain in a consistent state and avoid deadlock.
5. Circuit Management: The connection and disconnection of message paths or circuits in circuit-oriented communication mechanisms.
6. Sequencing: The management of an ordered, sequential flow of information.
7. Message Management: The segmenting and reassembly of messages and the management of buffers.
8. Priority: Providing differing grades of service through the communication mechanism.
9. Switching or Routing: The selection of a path from source to destination and the method for determining that path.
10. Security: Providing secure communications.
11. Accounting: Providing a mechanism for accounting for the use of network resources.
12. Performance: Achieving specified levels of performance, given the characteristics of the underlying available communication mechanism.
13. Robustness: Continuing to operate and being available when nodes, links, or other resources fail.
14. Information Representation: The management of the format, code set, size, etc., of the information transferred through the communication mechanism.

1.2.2 The Seven-Layer Model

The basic elements of the OSI Reference Model serve as the building blocks for constructing the model of interprocess communication. In OSI, interprocess communication is subdivided into seven independent layers. Each (N)-layer uses the services of the lower (N-1)-layer and adds the functionality peculiar to the (N)-layer to provide service to the (N+1)-layer above. Layers have been chosen to break up the problem into smaller problems that can be considered relatively independently. The seven layers are as follows (see also figure 1-1):

- Layer 1: Physical - transmission of bits over the channels.
- Layer 2: Data Link - creation of error-free sequential link.
- Layer 3: Network - reliable single-network logical channels.
- Layer 4: Transport - end-to-end reliable transport between source and destination systems.
- Layer 5: Session - management of sessions between communicating entities.
- Layer 6: Presentation - format transformations.
- Layer 7: Application - interstation dialogues.

1.2.2.1 Physical Layer

The Physical Layer provides the mechanical, electrical, functional, and procedural standards to access the physical medium.

1.2.2.2 Data Link Layer

The Data Link Layer provides the functional and procedural means to transfer data between network entities and to detect and possibly correct errors that may occur in the Physical Layer. Typical Data Link protocols are High-level Data Link Control (HDLC) for point-to-point and multipoint connections and IEEE 802 for local area networks. Data Link protocols and services are very sensitive to the physical transfer technology. In the upper layers, only a limited number of protocols are specified per layer, but this is not the case in the lower layers. To ensure efficient and effective use of various transfer technologies, protocols designed to their specific characteristics will be required.

1.2.2.3 Network Layer

The Network Layer provides independence from the data transfer technology and provides relaying and routing. It masks from the Transport Layer all the peculiarities of the actual transfer medium, so that the Transport Layer need be concerned only with the quality of service and its cost, not with whether optical fiber, packet switching, satellites, or local area networks are

APPLICATION LAYER (layer 7)

Layer 7 is the source of data, usually consisting of services which process data (i.e., data are combined, converted, calculated and processed to create new data). Airline reservations and on-line banking are just two examples of possible user applications.

PRESENTATION LAYER (layer 6)

Layer 6 provides data formats and data information, if needed. Examples of presentation layer services are data translation, data encoding/decoding, and command translation for virtual terminals.

SESSION LAYER (layer 5)

Layer 5 establishes, maintains, and terminates logical connections for the transfer of data between processes. Examples of session layer services are: dialogue control, message unit flow control, and segmentation of message data units.

TRANSPORT LAYER (layer 4)

Layer 4 provides end-to-end control signals from user terminal to user terminal across the network (e.g., network acknowledgment of received information).

Network Layer (layer 3)

Layer 3 provides the control needed for call establishment and clearing through the switching network nodes.

DATA LINK LAYER (layer 2)

Layer 2 protocols provide reliable transmission over a single data link including frame management, link flow control, and the link initiation/release procedures.

PHYSICAL LAYER (layer 1)

Layer 1 provides the mechanical, electrical, functional, and procedural characteristics needed to establish, maintain, and release physical connections between the network termination and the exchange.

Figure 1-1 The Seven-layer OSI Architecture

Source: Federal Communications Commission's notice of inquiry on ISDN, adopted August 4, 1983.

being used. The Network Layer also relays and routes data through as many concatenated networks as necessary while maintaining the quality of service parameters requested by the Transport Layer.

1.2.2.4 Transport Layer

The purpose of the Transport Layer is to provide reliable and transparent transfer of data between end systems, thus relieving the upper layers from the task of providing reliable and cost-effective data transfer. In some cases, the boundary between the Transport and Network layers represents the traditional boundary between the carrier and the customer. From this point of view, the Transport Layer optimizes the use of network services and provides additional reliability over that supplied by the Network Service.

1.2.2.5 Session Layer

The primary purpose of the Session Layer is to provide the mechanisms for organizing and structuring the interactions among application processes. The mechanisms provided in the Session Layer allow for two-way simultaneous and two-way alternate operation, the establishment of major and minor synchronization points, and the definition of special tokens for structuring exchanges. In essence, the Session Layer provides the structure for controlling the communications.

1.2.2.6 Presentation Layer

The primary purpose of the Presentation Layer is to make application processes independent of differences in data representation, i.e., syntax. The Presentation Layer protocol allows the user to select a "Presentation Context"; this may be specific to an application (such as a library protocol or virtual terminal), to a type of hardware (such as a particular machine representation), or to some standard or canonical representation. OSI users may use an existing context or define their own for registration with ISO.

1.2.2.7 Application Layer

As the highest layer of OSI, the Application Layer does not provide services to any other layer. The primary concern of the Application Layer is with the semantics of the application. All application processes reside in the Application Layer. However, only part of the Application Layer is in the real OSI system, i.e., those aspects of the application process concerned with interprocess communication (called the application entity). SC 16 is developing the Common Application Service Elements that provide common procedures for constructing application protocols and for accessing the services of OSI. SC 16 is also developing three application protocols of general interest (virtual file, virtual terminal, and job transfer and manipulation services), as well as OSI application and system management protocols.

1.2.2.8 Conclusions

The high cost of software production, the requirement that any system in the world potentially be able to communicate with any other, and the urgent need for open systems standards have caused the OSI effort to depart from the traditional mode of developing standards. It has been necessary to define standards that new systems could converge to, rather than to standardize procedures after the fact. SC 16 is now reorganized into SC5 and SC15 who together are now on a schedule that is producing new Draft Proposed Standards at a rate of around two a year. Groups that are developing standards for other areas or large corporate systems are expected to benefit from this work and to use the Reference Model for OSI and other Reference Models to organize and coordinate their work in communications, databases, and large application systems.

There is intense technological competition among these competing systems, and different vendors are backing different approaches. This point deserves to be highlighted because standardization plays an essential role even at this early phase in the evolution of local networks because the architecture of the network must be in the public domain if the network is to accommodate the equipment of multiple vendors.

IEEE Standard -- The first standard-setting activity to describe is that of the Institute for Electrical and Electronic Engineers (IEEE). The IEEE 802 technical committee is developing standards for the two lowest level protocols of the OSI model, i.e., the physical layer and the data link layer. This is the natural place to begin since it determines the physical basis for compatibility among equipment. The committee began its work in 1979, and the results are now emerging.

The committee found that it was not possible to develop a single standard for the various systems on the market. The two principal means for determining access to the transmission medium, contention and token passing, are incompatible. The committee therefore decided that the only feasible way to standardize LANs was to develop a family of standards. Consequently, standards are being developed for baseband and broadband bus media using CSMA/CD (IEEE standard 802.3), for baseband and broadband bus media using a token passing access method (IEEE standard 802.4), and for baseband media using a token ring system (IEEE standard 802.5). The first two standards have already been completed for baseband, and the third is expected next year.

In addition to local networks, the committee is developing a metropolitan area network (MAN) standard (IEEE standard 802.6). A metropolitan area network is a form of LAN that comprises a radius of up to 25 km.

All of the standards have been specified to work under a single logical link control standard (IEEE standard 802.2). Finally, a standard for layer three is being developed by ISO to integrate the various LAN technologies into a concatenated network architecture by specifying a consistent method for internetworking, addressing and managing local networks. This work is also beginning to be addressed by the IEEE 802.1 committee.

The timing of the IEEE family of standards is an important point worth noting. A standard cannot be developed before there is an adequate theoretical and practical knowledge base for developing it. On the other hand, if proprietary systems become too well established, there would be strong opposition to the development of standards that did not conform to the proprietary standards. Thus the timing of standards development is a critical matter.

1.2.3 Technological Evolution

o 1984-1989 -- The development of the OSI model and the general increase in data transmission utilization have accelerated the development of distributed processing networks and emphasize the need for universally accepted standards to facilitate their use. The current status in 1984 is that standards organizations, manufacturers, and researchers are beginning to bring accepted theory into real world practice. The progress already made in such elementary services areas as RS 232, RS 449, X.25, V.24, HDLC, etc., shows that enlightened self-interest plus a commitment by the major organizations such as IEEE, ANSI, CCITT, ECMA and ICST can bring changes to the marketplace and encourages optimism toward the future of universal standardization.

At present, most modern computer communications can be said to implement in some way the lowest five layers of the OSI model, the Physical and Data Link layers. Such issues as connectionless data transmission, security, and compatibility with other layered models are being addressed.

Of particular significance is the continued position of the industry leader, IBM, which supports its own System Network Architecture (SNA) model which has many similarities to the OSI system. Nevertheless, many new entrants in the Local Area Network (LAN) and Integrated Services Digital Network (ISDN) equipment fields will probably accept the IEEE, ISO, and associated standards as a cost-effective marketing and engineering approach.

During this time period, we expect the continued manufacture and sale of computer communication products that do not do so. This problem will encourage the design and manufacture of "smart boxes" (at least at the lower levels), that provide services compatibility of current products with standards or other widely distributed data transmission equipment. Cautious and discriminating procurement by users who wish to avoid equipment that could quickly become obsolete will also spur manufacturers to adhere more closely to universally accepted standards. [STAFF COMMENT 1]

- 1989-1994 -- This should be a period of great growth in both the standards area and in the design and manufacture of computer communication products. Extensive interplay between real-world demand and the development of standards should result in a new and improved equilibrium between users and suppliers.

  A number of layers of the OSI model will be well defined and understood by the community and will be implemented in the networks and equipment available. Protocols for the first four or five layers will be highly developed, while those for the remaining two upper layers will be under continued development. An appreciable amount of equipment or systems still in use are likely to have compatibility problems with the new systems, but smart-boxes will be designed to ease them. It is possible that IBM will modify its SNA model to conform completely to the OSI system or will market compatibility devices or systems to accommodate it. In all, 1989-1994 should be a major transition period during which standardization will begin to have a major impact on the industry. [STAFF COMMENTS 2 and 3]

- 1994-1999 -- This period should see worldwide standardization reach the initial stages of maturity as a set of standards for what we now define as data communications become firmly established. New standards will be under development to accommodate the variety of new data communications requirements expected from this dynamic industry.

  The OSI model will be universally recognized but will be continually evolving in anticipation of new designs and user requirements. The process is analogous to the development and growth of telecommunications under the impact of North American (Bell), European, and CCITT standards work over the past fifty years. Much has been accomplished, but much remains to be done to meet the demands and opportunities of new data communications technologies and users.

1.2.4 Computer Network Architectures

Every major computer manufacturer has a proprietary network architecture to interconnect its systems. These "closed" systems interconnection schemes enable the different equipment lines of the manufacturer to operate together.

These architectures are all more or less compatible with the ISO seven-layer Reference Model. IBM's Systems Network Architecture comprises seven layers, which provide services quite similar to the corresponding layers of OSI. A. D. Little believes that IBM's evolutionary strategy for enabling its users to access the OSI environment is through protocol conversion gateways, which map the SNA network protocols into the OSI equivalents.

DEC's Digital Network Architecture (DNA) is also based on a seven-layer model; it does not have a Presentation Layer equivalent, and its two upper layers together map into the OSI Application Layer, but otherwise DNA and OSI are quite similar. A. D. Little believes that DEC intends to migrate toward direct incorporation of OSI protocols into DNA as the standards become available, rather than adopt the gateway approach.

It appears clear, both from the widespread participation of all major computer manufacturers and network providers and from the similarity of existing proprietary vendor architectures to the ISO model, that the manufacturers and the network providers will evolve toward OSI product offerings as the standards become finalized and the user market develops. However, this may still not result in compatibility among manufacturers.

1.2.5 Cost Performance Trends

The design of new equipment that conforms to the OSI and associated standards will require considerable engineering development and research. Whether this equipment, once designed, will be significantly more costly to produce than the present devices and systems is debatable, particularly since the cost of making VLSI solid-state equipment is dropping.

Taking these basics as a starting point, we have postulated a set of trends (figure 1-2). The design and production of equipment conforming to current standards (ISO, IEEE, ANSI etc.) will drive costs upward, most notably in the 1984-1989 timeframe. Conventionally produced equipment, i.e., internally standardized only, is shown as rising slightly to accommodate the greater complexity undoubtedly required to meet new requirements; however, to make this equipment truly compatible on a universal basis will require the design and production of compatible "smart boxes," which will rise sharply in cost. [STAFF COMMENT 4]

These projections indicate that, for a given investment in a computer communication system, a buyer would be well advised to obtain OSI standard equipment to avoid "Band-Aid" solutions to incompatibility, outright obsolescence, and rapid replacement of systems. [STAFF COMMENTS 5 and 6]

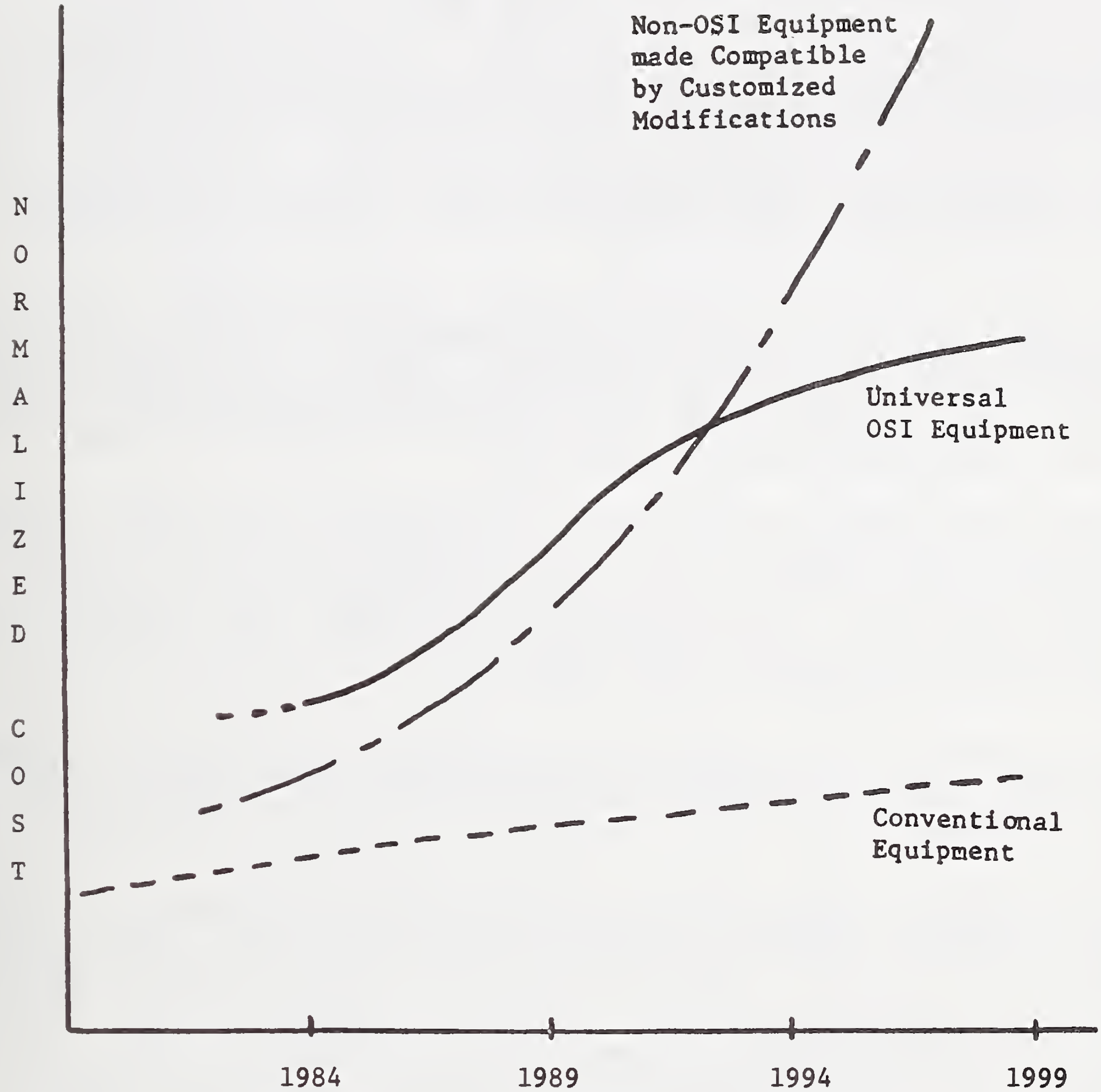

Figure 1-2 COST TRENDS FOR COMPUTER SYSTEMS 1984-1999

*1.2.6 Significant Current Developments**

The U.S. Government has implemented programs to develop and standardize OSI protocols. One of these is the Federal Telecommunications Standards Program, which is administered by the National Communications System (NCS). The program objective is to promote interoperability of the Government's telecommunication networks for both emergency and routine operations.

NCS participated with NBS in adopting CCITT Recommendation X-25 for Federal use. The resulting joint standard is designated as FIPS 100/Federal Standard 1041.

The Federal Information Processing Standards (FIPS) Program is conducted by the Institute for Computer Sciences and Technology/National Bureau of Standards (ICST). ICST has been very active in developing draft FIPS in the Network and higher layers of OSI, as well as in the lower layers for LANs, physical, link, network and internetwork protocols.

ICST has focused on working with industry and other federal agencies to develop commercial, off-the-shelf solutions to the problem of government systems incompatibility and to advance the state of the art in methodologies for formal description, computer-assisted protocol implementation, and automated testing and measurement of layered protocols.

Draft FIPS for LANs, Transport, Session, Internetwork, Message Systems, and File Transfer protocols were published in 1983 or are due in 1984. All these standards have been coordinated with the developing IEEE, ISO, and CCITT standards.

OSI has come of age. In six productive years beginning in March 1978, ISO has defined a Reference Model, services, and protocols for several layers of interconnection. Unprecedented cooperation among manufacturers, network providers, governments and users has permitted OSI implementation to begin to appear in 1984. By the end of the decade, most existing and new information systems will evolve into an OSI capability to exchange information easily and thus create a world information society.

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* This material has drawn upon: Young, John H, "Effect of Standards on Information Technology R&D", a contractor's report prepared for the Office of Technology Assessment Project - Information Technology Research and Development - Contract 33-8890.0 - November 25, 1983.

2. NETWORK MODELING AND MONITORING

2.1 NETWORK MODELING

2.1.1 Background and Present Approaches

Since the AT&T divestiture, users can no longer turn to a unified telecommunications supplier for their needs. From now on, they have no alternative to taking a more active role in controlling telecommunications. This will involve employing network planners for effective network design, procuring network testing systems to monitor performance, and considering new systems, media and carrier service offerings.

Planning for new systems is always important, but it is especially critical in the new communication environment. Network planning calls for modeling and optimization techniques. The success of a network plan requires an understanding of network performance with respect to user requirements and traffic.

Gathering good traffic information is generally the most difficult part of network planning. This process must be coupled with projections of user requirements. In general, an iterative planning process is required. After an initial basic projection is developed, it is refined into a performance cost analysis for the projected network architecture. It is customary for large networks to undergo many iterations of fine-tuning.

In view of the numerous design criteria, planning for all but the simplest networks requires a computer approach to ease the computational burden.

Network design begins with a model. Network modeling is a combination of art and science; it draws upon such disciplines as queuing theory, combinatorics, graph theory and nonlinear analysis.

There are two extremes to approaching network analysis:

- The first is to simulate a system and apply an iterative process to generate a network configuration. A statistical model of the expected traffic is then fed to that configuration. An iterative cut-and-try procedure is used to introduce changes in the network; this process continues as long as the changes decrease the cost of the network. When an apparent least-cost solution is reached, the analysis ends.

- At the other extreme is a purely analytic approach based on queuing theory. However, when the network exceeds a fairly small size, it cannot be manipulated by analytical approaches. This problem may be overcome by making simplifying assumptions that may or may not be valid in the real world.

The most logical approach to network modeling is based upon a combination of these two (simulation and analytic) methods. Some portions of a network may have straightforward analytic solutions, while others are exceptionally difficult and are best treated by simulation.

There are many vendors of network modeling and optimization software and services. Some network modeling is provided "free" by vendors, as part of a proposal or as part of the management of a network under contract. Two well-known providers of network models are Contel Information Systems (formerly Network Analysis Corporation) and AT&T Communications. Two sample programs from AT&T Communications indicate the range of programs that are available:

- Network Synthesis Module (NETSYN). This module allocates end-to-end blocking among trunks, access lines and off-net facilities for an electronic tandem network. It assists in selecting optimum switch locations and calculates approximate network costs. It prescribes routing and sizes of trunk groups for off-net facilities and determines the size of bypass access trunk groups. NETSYN can establish a two-level network hierarchy and can size intermachine and access line groups to handle predicted traffic.

- Network Service Evaluator Module (NETEVAL). NETEVAL prepares data from NETSYN, including user modifications, and calculates end-to-end blocking for on-net and off-net traffic as well as for inter-switch and intra-switch traffic for a specified hour. NETEVAL also prices the network and provides additional information useful for designing queues for off-net facilities.

Network optimization tools are available from many small software houses. One example is a product which is available for the IBM PC computer and can design up to 150-node networks. A smaller version for Apple II optimizes networks of up to 70 nodes. The software is packaged in a conventional floppy disk and accompanied by a self-help user manual.

2.1.2 Technological Evolution

The evolution of network modeling and optimization will go hand-in-hand with the development of increasingly sophisticated software for use on personal computers with continually expanding capabilities. It is unlikely that software costs will decrease significantly. However, the modeling process will be simplified and speeded up, increasing cost effectiveness and making the optimization of larger networks feasible in the future.

2.2 NETWORK TECHNICAL MONITORING

2.2.1 Background and Present Approaches

Most communication channels available from common carriers are analog in nature. That is, they respond to continuous signals in a limited frequency band that was originally intended for voice transmission. Terminals and computers communicate digitally using a discrete set of symbols, usually ones and zeros. For compatibility with analog channels, digital terminals and computers require a modem.

Different approaches can be used to locate faults in an overall connection. If the faults are in the analog channel, they are located by analog test instruments. If faults occur in the modem or digital services, they are located by data analyzers. A device called a protocol analyzer, which is more sophisticated than a data analyzer, may be inserted into a digital services to simulate the terminal for the network and/or the network for the terminal; in this way, end-to-end protocol compatibility, in addition to transmission, may be analyzed or diagnosed. In addition, ICST has recently developed a transaction analyzer (TA) which may be inserted into the network as a transparent monitor. Applicable to channel protocols and VLSI, the TA continuously tracks the state of electronic systems. Operating in real time, it is fast enough to keep up with the interface bus rate. Unlike the protocol analyzer, it does no simulations and thus can catch unpredictable errors.

At the present time, most networks have no built-in network control facilities. For small networks, or in the early stages of implementation, portable test equipment such as portable transmission impairment measurement sets and portable protocol analyzers are used. The use of portable test equipment generally requires that a technician be present at each end of a channel.

When a network grows beyond a fairly modest size, the savings possible by automation of network control facilities become worthwhile. Once this capability has been established, it provides automatic remote measurement of performance and reporting on trunks and data circuits throughout the system. Network technical control that is centralized and automated is a quality assurance system that will measure from one location the transmission quality of all circuits connected in the systems, reducing technician labor hours and providing cost-effective network testing.

If faults occur, a network technical control center is able to

- o detect that the trouble exists;
- o notify maintenance personnel of its existence and severity;
- o verify that the trouble persists and is not transient;

- o pinpoint the location of the fault by sectionalization and issue a dispatch notice to the correct person so that the fault can be cleared; and
- o indicate all is well once the trouble has been cleared.

2.2.2 Technological Evolution

Evolution of network control systems will follow two paths. One of them will be a more universal application of widespread automatic testing in user networks. These are now growing rapidly with the decreasing reliance on carriers to provide complete operating and maintenance services. At the same time, cost savings will result from diagnostics being built into processors and computers to exercise lines and pinpoint troubles. In general, the cost-effectiveness of separate network control centers is likely to remain constant for several years into the future as they are applied more widely.

3. UNDERLYING TECHNOLOGIES

3.1 SYSTEM TECHNOLOGY

*3.1.1 Local Area Networks**

3.1.1.1 Background and Present Approaches

A local area network (LAN) is a communications system used to interconnect computers, terminals and other peripheral devices within a building or campus. LANs permit work stations to be used for multiple purposes. A LAN may extend for as little as ten feet or, rarely, as far as tens of miles.

The term LAN embraces a variety of systems. Early local data networks were based on computer-terminal processing systems and were provided by mainframe vendors. Data switches and multiplexers were later introduced by communications component suppliers to provide cost-effective alternatives for the local interconnection of terminals and computers. Recently, PABX manufacturers have begun to introduce so-called third-generation PABXs capable of switching both voice and data (see section 3.1.6).

The LANs generating the greatest interest today are those based on the concept of distributed access of which Ethernet is probably the best known example. The most recent trend in LANs has been the introduction of hybrid networks consisting of distributed Ethernet-like access and centralized PABX switches.

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* A further discussion of LANs, from the management perspective, is contained in Part IV.

To assess the present role and future prospects of LANs, it is useful to take a brief look at the evolution of local networking in data processing. In the 1960s, an era of batch processing, the terminal and computer facilities were concentrated in a single building, often in a single room. The early 1970s saw the advent of remote terminal access whereby terminals accessing a mainframe could be distributed within a building. Communications between computers and terminals were managed by the computer teleprocessing system, which consisted of embedded communications and host application software. A characteristic of these early teleprocessing systems was that terminals were dedicated to a single application.

With the appearance of terminal-sharing in the mid-1970s, a single terminal was capable of addressing different applications on the same computer. The management of the communications function at the computer end was relegated to the front-end communications processor, an arrangement that tended to separate, both logically and physically, communications functions from the applications functions. This development was accompanied by the implementation of clustered terminal controllers, which, under the management of a central communications processor, could control local terminal clusters.

Two networking trends emerged in the mid- to late 1970s:

- o In response to the growing number of remote terminals that accessed a few computers, data switches with port-contention features were introduced. These gave added value to terminals by allowing them to switch among computers and applications, reduced wiring costs and, most importantly, reduced the number of expensive computer ports needed to support a large number of terminals.

- o Computer networking facilitated the sharing of both host and peripheral resources and provided a foundation and impetus for the new distributed switching LANs we see today. The networks that made computer networking possible are based upon the principle of a layered architecture (see section 1.2). The significance of layered architectures is that they logically separate the various communications and applications processing functions. In a sense, the acceptance of the layered architecture concept marked the end of a trend toward the logical separation of applications and communications processing, a trend spanning roughly ten years. This is not to say that the world now operates on the principles of a layered architecture; we mean only that the concept is widely accepted, even though its full implementation still lies far in the future.

In the 1980s the uses or applications of data and information processing developed in the 1970s or earlier, should be very widely disseminated. Long-standing efforts toward resource sharing networks (e.g., ARPA) primarily benefited a limited clientele, such as scientists. As LANs mature, this decade will also be a period of democratization of the workplace -- i.e., it will be commonplace for individual workers to be given extensive access to data and information processing resources. In sum, the 1980s will see greatly increased user-access and resource sharing requirements. The LAN response will be to provide wide-bandwidth communications media that offer easy access and low cost-per-access. This response is further explored below.

The present approaches to local area networking are mixes of old and new. By far, the most pervasive installed form of local area networks is application-specific. That is, each system or application has its own LAN, which is typically an integral part of a host teleprocessing system. Such a local area network application can be found in an IBM processing environment using 3270-type terminals connected to their cluster controllers, which, in turn, connect to the mainframe front end processor. Other application- or vendor-specific local area networks can be found in the systems of data processing equipment vendors such as Wang and DEC.

In addition to the vendor-specific networks are other application-specific networks not identified with any particular vendor's system architecture. In this area, we find a myriad of home-grown cabling systems that often provide simple point-to-point connections between communicating devices.

More sophisticated home-grown networks may include devices such as multiplexers and data switches. In environments with modest to large numbers of terminals, it is usually practical to concentrate traffic on a floor-wide basis, even within a small area, to avoid having to run many parallel wires to the host site. Small multiplexers are ideally suited and commonly used for this type of concentration.

At another level of sophistication in local area networking, "intelligent" devices are used to maximize the utilization of costly resources. In the examples just described, the thrust in local area networking was to economize and simplify wiring problems. In the present case, intelligent network devices such as data switches may be used to give large numbers of terminals access to smaller numbers of computer ports. The idea behind this networking technique, called port contention, is that all terminals do not usually communicate with the computer at the same time; therefore, a device that manages the "called" requests of the terminals can be used to economize on the number of expensive terminal ports that must be installed on the host. Data switches have been used for this application for approximately ten years, and they offer a relatively low-cost and proven technological solution to the terminal-host access problem.

More recently, we have begun to see application of the newest LAN technologies to the problems in the technologies we have just described. These new technologies are described by fourth-generation PABXs and cable-based local area networks.

- o The PABXs are identical with data switches in terms of their data and communications functionality. PABXs are, of course, designed primarily for voice applications; their use for local area networking is in its infancy (See 3.1.6).

- o Cable-based LANs are just beginning to come into use. There is, perhaps, only about $150 million of installed base of this technology. They are still regarded by many potential users as new and risky. However, they are growing rapidly and, with the acceptance of standards for this technology, will probably continue to increase at a high rate.*

With the exception of systems that are vendor-specific and homogeneous with respect to equipment type, protocols, etc., the systems served by the newer technologies (cable-LANs and PABXs) generally consist of relatively simple, asynchronous terminal devices. Until recently, one of the most intractable barriers to the widespread use of LANs to support factory automation has been the reluctance of manufacturers to divulge details of equipment operation. This problem has now been significantly reduced through the cooperative efforts of ICST, General Motors, IBM, Allen-Bradley, Concord Data Systems, Hewlett-Packard, Motorola, DEC, and Gould. System interoperability, using the new standard LAN protocols, was demonstrated at the 1984 National Computer Conference.

3.1.1.2 Technological Evolution

- o <u>1984-1989</u> -- We expect a number of important developments in the 1984-1989 time frame. In this period, we will see much more widespread acceptance of standards; a resolution of the competition among the various technological alternatives for LANs, accompanied by the emergence of widely accepted approaches to local area networking; and reductions in cost through the development of VLSI.

  Another very important approach to local area networking -- hybrid LANs employing both PABX and cable-type baseband LANs -- will, we believe, become established as the dominant technology before the end of this decade. The basic technology for hybrid networks is at hand, but

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* This does not imply ongoing R&D on coaxial cable for these LANs. This cable is a commodity item with no future improvement likely (See 3.2.4).

their development requires market commitment by the suppliers who are best positioned to provide them -- namely, the PABX manufacturers. We are increasingly finding that these suppliers are adding LAN capabilities to both existing and new PABX systems.

The technology development that is necessary for all LAN approaches is in the area of peer protocols and access methods, e.g., CMSA/CD. To date, as noted earlier, services available on the new LANs are limited to the most common types of applications. A wider range of options will be developed. This development will extend beyond the 1990 time frame, but the services needed to serve the most common types of equipment will certainly be available by 1990. Interface development is primarily software-based. Where the numbers justify it, custom Very Large Scale Integrated (VLSI) chips are being developed to handle services such as X.25.

- 1989-1999 --In the 1990s, we expect less significant change, primarily the maturing of some component technologies such as better fiber optic infrastructure to support LANs. [STAFF COMMENT 7]

  The ongoing development of the IEEE 802 standard for LANs will have, we believe, an accelerating effect on the development and user acceptance of LAN technologies. The current diversity of LAN architectures will decrease substantially as many suppliers simply fade out of the business and others attempt to realign their products with accepted standards.

  An important technological competition should be resolved by 1990 -- namely, the conflict between broadband and baseband transmission techniques for cable-based LANs. We expect this to be resolved in favor of broadband systems and that suppliers of baseband LANs will add broadband systems to their product lines. [STAFF COMMENT 8]

  For 1990 and beyond, we expect developments in LAN technology to be more evolutionary than revolutionary. With the acceptance of standards, more extensive use of VLSI technology should reduce system costs, primarily those of services. Developments in other areas will include further price reductions of fiber optical cable and the maturing of "infrastructure" techniques (e.g., fiber optical cable installation). These developments will give fiber a cost-competitive position with respect to other cabling alternatives such as coax and twisted pair. Low-cost means of accomplishing connecting and tapping functions in fibers will be needed to make this transmission medium cost-competitive. We expect these developments to be in place by the early 1990s.

3.1.1.3 Conclusions

Costs for all approaches to local area networking are decreasing, some more rapidly than others. Table 3-1 lists the approximate costs of three generic approaches to local area networking: data switches, cable-based LANs, and PABXs. [STAFF COMMENT 9] The most mature of these technologies, data switches, presently offers slightly lower cost, and least performance. Cable-based LANs are somewhat higher priced, but will experience a more rapid price decline than data switches because they are more amenable to VLSI cost reductions. Finally, PABXs, which are intended primarily for voice applications and are, therefore, subject to somewhat different economic considerations, will be very competitive with both data switches and cable-LANs on an incremental cost basis. The table summarizes these cost characteristics, along with other basic features of the three technologies.

One potential cost/performance benefit of LANs derives from savings on wiring costs and the elimination of multiport computer connections. The latter is illustrated in figure 3-1a which shows both a standard teleprocessing configuration and one in which the local area network becomes an extension of the computer teleprocessing system. [STAFF COMMENT 10]

In the standard configuration, each time a new terminal is added to the system, a communications port must be implemented in the front-end processor of the computer. Communication ports are generally expensive and require, in addition to the implementation of a port, dedicated wiring from the terminal to the computer.

When the computer has communications multiplexing hardware (figure 3-1b), several independent data streams can be transmitted by a single connection. These data streams can be addressed and sorted out by the local area network, to which many terminals may be connected. In this configuration, the local area network saves computer boards and the wiring cost for connecting each terminal with its dedicated line directly to the computer. These cost savings are weighed against the added costs of the intelligent multiplexing hardware and the processing service on the computer and the corresponding intelligence that must be implemented in the local area network.

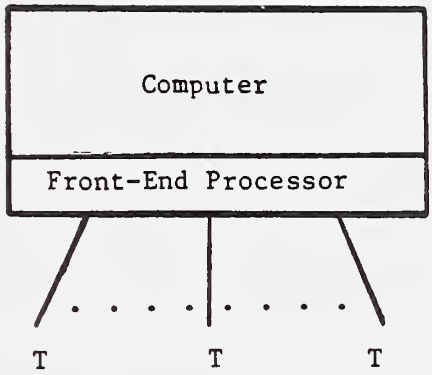
Figure 3-2 is a simplified illustration of the cost structures for various local network alternatives. The curves in this figure should be regarded as approximate. The specific cost assumptions underlying the curves are highly variable, depending upon the specifics of the physical installation and the teleprocessing system. The critical assumptions used in this figure are as follows:

- o <u>Wiring Costs</u>. We assume that the cost of cabling is approximately $30 per meter for baseband. This cost can easily double for certain installations, including broadband especially in metropolitan areas like New York City,

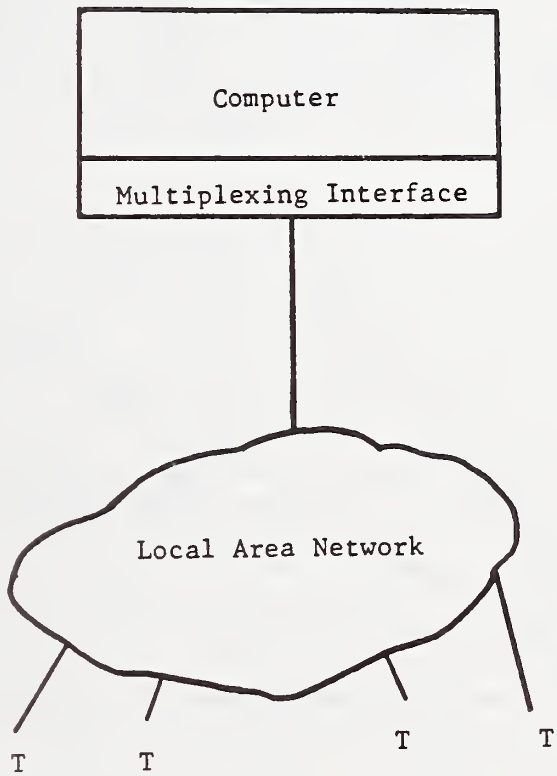
Table 3-1

COMPARISONS OF ALTERNATIVE LAN TECHNOLOGIES

Feature	Feature Importance	Data Switch	Cable-based Network	PABX
Price	High	$175 to $275/ Port + $250 installation (stable)	$500/Port + $100 installation -- (decreasing)	Installed prices 2nd generation $700/line 3rd generation $1100/line Data add-on $400 to $600 (decreasing)
Established Technology	High	Yes	Not Yet	Yes (2nd generation) Not yet (3rd generation)
Operational Features				
Connection Transparency:	Moderate	Yes	Yes	Yes
Wideband:	Moderate	Adequate	Yes	Adequate
Protocol Conversion:	Becoming high	Becoming available as add-on	Yes	Becoming available as add-on



a. Standard Teleprocessing Configuration



b. Local Area Network as Extension of Computer Teleprocessing System

Figures 3-1a & b LAN ARCHITECTURES

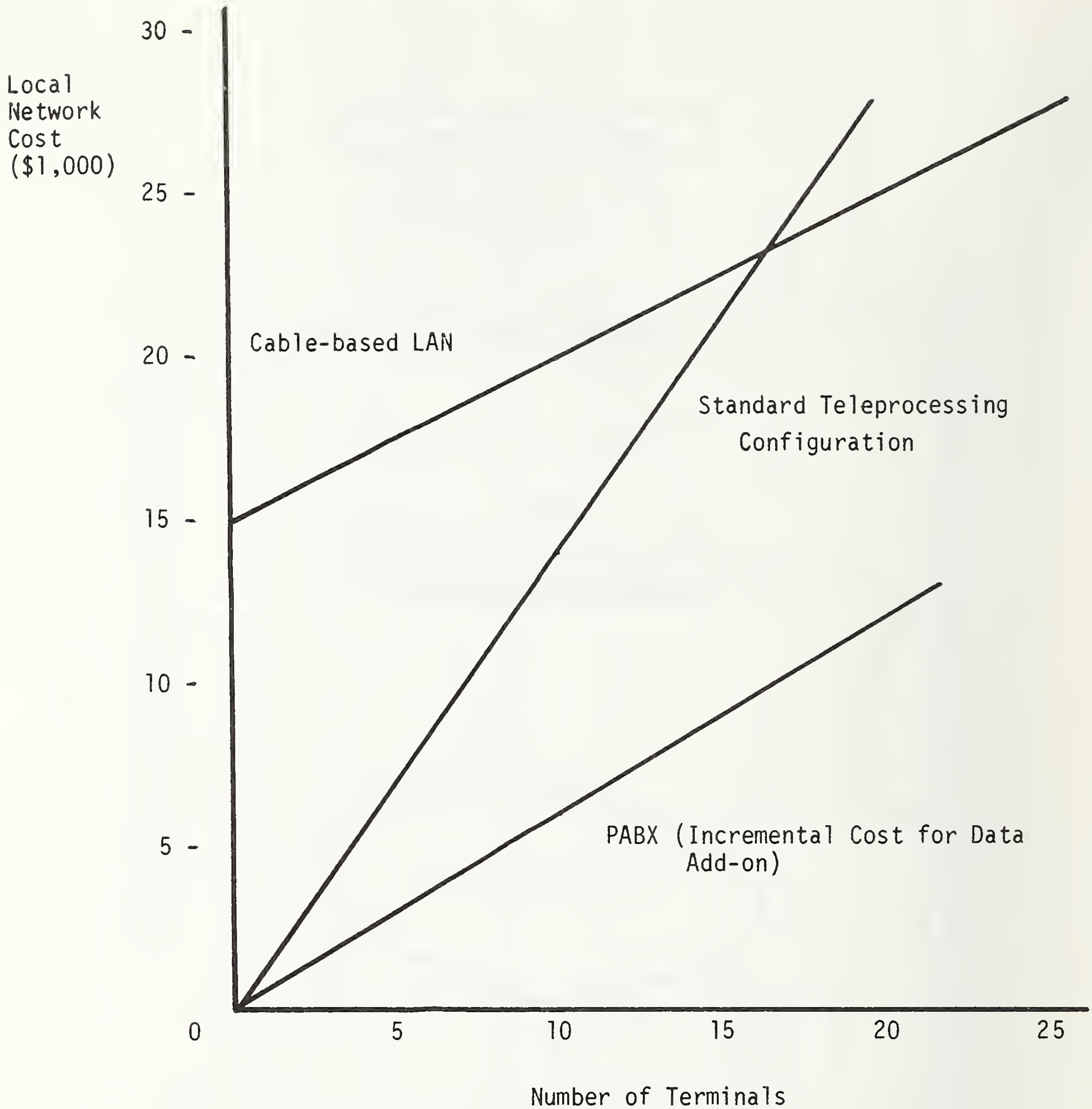


Figure 3-2 COST STRUCTURES FOR LOCAL NETWORK ALTERNATIVES

where tall buildings are commonplace and union wage scales are high. We also assume that the average length of the cable run from computer port to terminal is about 30 meters for the standard teleprocessing configuration. For the cable-based LAN, which may be either a ring or bus topology, the length of the bus or ring is assumed to be 500 meters, and we add $50-$150 to the wiring costs for each terminal-drop from the bus or ring. Finally, in the case of the PABX, we assume that the wiring costs have been covered in the telephone installation; that is, no additional wiring is needed to support a data device.

o <u>Port Costs</u>. The incremental cost for ports on a computer is assumed to be $300. The port costs for cable-based LANs are associated with the access devices to which the terminals connect. The port cost for a cable-LAN is assumed to be $500. This is an estimate based upon the prices of established LAN suppliers. In the case of the PABX, the incremental cost for providing a data connection is assumed to be $600 per port. These costs are in addition to normal communication processor front-end port costs.

Neglecting the fixed cost for communications software in the computer front-end processor, the figure 3-2 shows a sharply rising linear cost curve for the standard teleprocessing configuration. The slope of this curve is dominated by the wiring cost for each terminal. In contrast, the cable-based LAN curve exhibits a high front-end cost (attributable to the installation of the bus or ring) and a relatively moderate incremental cost for adding terminals, based on the cost of the wiring drop and the port access device required for each terminal. In this case, wiring cost is a minor portion of the incremental cost per terminal connection. Finally, the PABX-based network shows the least cost of all on an incremental basis. Here, it is assumed that the cost of the PABX installation has been justified solely on the basis of the voice service it provides and that we attribute only the incremental costs for providing data connections to the local area network. **[STAFF COMMENT 11]**

The curves suggest that if in fact a third-generation PABX can be cost-justified for voice service, it may offer the most cost-effective LAN solution of all. In applications where the PABX is not a reasonable alternative, the economics of the other two alternatives must be carefully evaluated. The qualitative behavior of the cost structures will remain as shown in figure 3-2, but the crossover point of the curves may occur at a different number of terminals. In any case, the cost must be weighed against the operational performance advantages already discussed that a LAN offers; for many users, these operational performance advantages may outweigh cost disadvantages.

The developments we have described will have several important impacts. First, the acceptance of standards and the later reduction of cost through VLSI technology will be major factors in stimulating the application of local area networks. These developments are coming at a time when the demands for local area networking are increasing rapidly. The proliferation of personal computers as desktop multi-function terminals and the general growth of sophisticated office automation systems will demand the communications features, resource sharing data base technology and ease of use offered by the new LAN technology.

On the supply side, as we have already suggested, new developments will soon establish the dominant LAN approaches. Currently, about 200 LAN suppliers are offering any number of approaches utilizing differing access methods, differing frequencies, differing topologies, and so on. The number of suppliers will drop dramatically as the market converges on the dominant approaches. As that occurs, standards will permit mixed-vendor systems. LAN ports will be bundled inside much equipment; in this case, LANs will not be an identifiable product. Because of their positions as large suppliers with established reputations, PABX vendors will, we believe, play a major role in the future of local area networking; the PABX will be itself in a natural position to satisfy many LAN requirements by virtue of its technological capabilities and cost-competitiveness. By providing LAN-like functions over twisted pairs or by incorporating cable-based networks into their product lines, PABX suppliers will be able to offer hybrid network solutions. These will satisfy a variety of local area networking requirements, such as broadband with data rates as high as the megabit range, to low- to medium-speed data to terminal to computer access, and inter-networking communications where the PABX itself serves as the hub for interconnecting other local area networks.

The benefits of local area networks are primarily those of operational convenience. Cost benefits, if any, can be assessed only in terms of very specific system applications and requirements. The significance of this technology lies in the following operational features:

- Adding New Devices. One of the principal benefits of a local area network is the convenience and the ease of attaching terminal devices as needed, regardless of whether a bus, star, or ring topology is used. With a bus or ring topology, the device may be connected by dropping a cable from the nearest point of the passing bus or ring; with a star topology, typically implemented with a PABX, the twisted pair cabling used for telephone sets may also be used for data devices.

- Moves and Changes. These are facilitated in the same way as the addition of terminal devices as noted above.

- Multi-Network. A LAN environment need not be homogenous. Isolated LANs may be implemented to support highly localized systems of processors and terminals. Where it becomes necessary to communicate off-network, gateways to other networks (local or long-distance) facilitate expanded access. Multi-network configurations particularly suited to this kind of requirement are based on the PABX; as a hub, the PABX can interconnect LANs with one another and with long-haul networks.

- Device Protocol Compatibility. This feature is presently less critical than the foregoing but may become more so. With homogenous data processing environments, problems of protocol incompatibility do not exist. However, as it becomes desirable to integrate different systems that may use different types of equipment, protocol compatibility is a serious problem. LANs are often promoted for their capability to link incompatible devices. This is not strictly accurate; LANs can facilitate the interconnection of otherwise incompatible devices. Incompatibility is a problem that frequently arises as data processing systems grow and the purchasers of these systems wish to retain flexibility with respect to equipment selection. With protocol conversion devices, which may be integrated with the LAN or installed as standalone equipment, the LANs provide a "universal" communications medium. This capability is significant, because it may free systems developers to choose systems on the basis of their suitability for new applications rather than their compatibility with existing systems or hardware.

3.1.2 Digital Microwave Radio

3.1.2.1 Background and Present Approaches

Microwave radio relay systems form the backbone of the national telecommmunications network. Approximately two-thirds of all toll telephone traffic in the United States is transmitted over microwave links. Despite the advent of satellites and fiber optic cables, microwave radio is expected to remain a major medium of transmission of all kinds, voice and data, for the foreseeable future.

An advantage of microwave is the ability to establish links quickly but it is limited to line of sight.

The main applications for microwave radio systems include:

- long-haul high-density telephone trunking
- short-haul and thin-route trunking
- metropolitan junction transmission
- private microwave systems
- broadcast and cable TV distribution
- portable and transportable TV transmission, including "electronic newsgathering"

Of the above, the first three categories account for the majority of installations (and investment). They are likely to remain the primary applications of interest, although fiber optic cables will become increasingly cost-competitive.

Microwave radio development began during the 1930s, but the first significant commercial service began in the late 1940s, when it was adopted as the primary common carrier transmission medium for distances longer than 25-50 miles, and for private communications systems by railroads, pipeline companies and electric power utilities. A vast proliferation of microwave systems continued well into the 1970s based mainly on analog frequency modulation (FM) and frequency division multiplex (FDM) technology.

A wide range of frequencies is used for microwave transmission -- from less than 1 GHz to over 40 GHz for commercial applications -- but the most widely used are in the range of 2-13 GHz for long- and medium-distance links. The higher frequencies, which are more subject to atmospheric propagation losses in rain and fog, are used for short-distance and single-hop applications.

An increasingly troublesome concern is congestion of frequencies, especially in larger cities.

FM microwave radio, the industry standard for over 20 years, was technologically mature by the early 1970s. Its position as the dominant backbone transmission technology was coming under competitive fire by then from newer technologies, such as satellite and long-distance waveguide transmission, as well as from improvements in older coaxial cable technology. Early research and development results on optical waveguide systems and fiber optic cables were beginning to attract attention. All of these alternative transmission technologies held out the promise of lower cost.

In addition, it had become evident that the telecommunications networks of the future would be based on digital transmission and switching, not the analog modulation used by FDM/FM microwave radio. The merits of digital technology compared to analog were already well documented. By the early 1970s, various types of digital microwave radio systems had been developed, and some had been placed in commercial service.*

Originally, digital microwave was of interest mainly because it promised a lower overall system cost; even though digital microwave radios were (and still are) more costly than analog radios, the PCM multiplex used with digital microwave is much less expensive than the FDM multiplex used with analog radios. In general, digital microwave is less costly on a system basis for relatively short, repeatered path lengths, where multiplex costs dominate; analog systems are cheaper for long path lengths with many repeatered hops, where radio equipment costs dominate.

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* The first instance was in Japan in 1962, the year the first T-1 digital cable conversion system was placed in service in the United States.

The economic cross-over path length for digital microwave over analog depends on many factors. It can vary from less than 200 miles to over 400 miles. Figure 3-3 illustrates the principles. Average cost cross-over distances are decreasing steadily as digital radio technology advances.

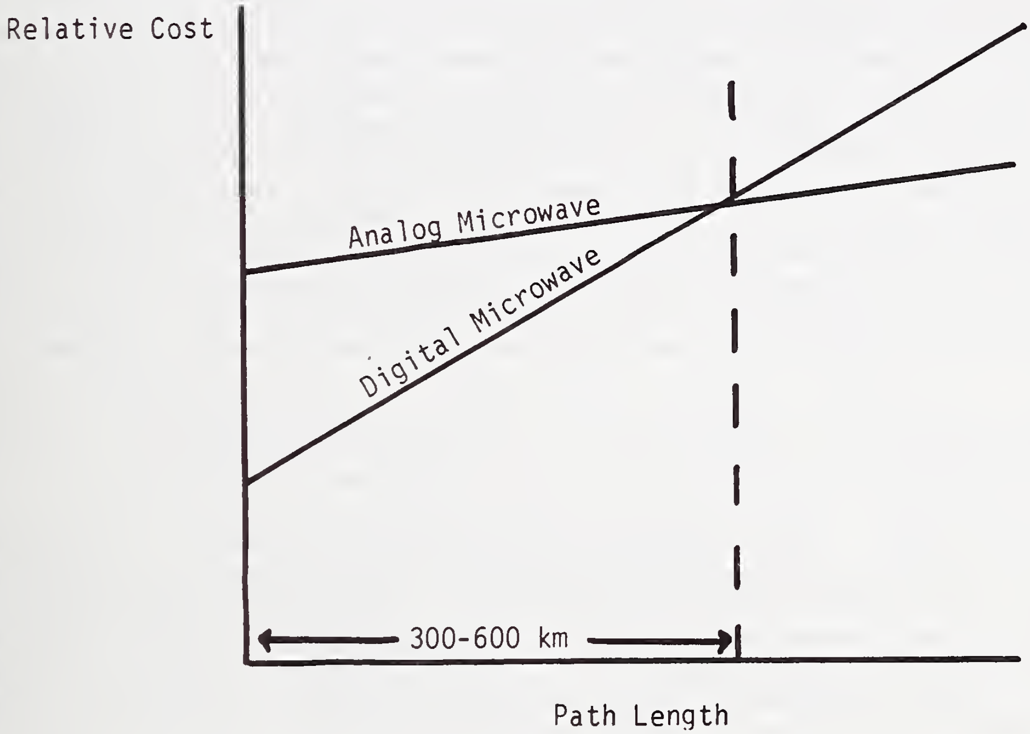


Figure 3-3 Relative Cost of Digital and Analog Microwave Radio Systems as a Function of Path Length

Digital microwave radios are more expensive then analog primarily because they are inherently more complex. By its nature, an analog modulation system is transparent to the modulation frequency, and the information-bearing signal is carried through the modulation-demodulation process without information state conversion. In contrast, most digitally modulated systems convert the digitally-encoded information-bearing signal into a different form for transmission (e.g., a three-level PCM-encoded signal may be converted into an M-ary phase-shift keyed signal by the radio system modulator). To recover the original information in the receiver, certain information must be precisely determined from the characteristics of the received signal itself, including the carrier frequency and the modulation rate.

These equipment functions, which require costly precision circuit components in the digital radio, are not needed in analog systems. This cost disadvantage is inherent in the digital radio technique, and comparatively little hardware cost reduction has been realized over the past ten years relative to the cost of conventional analog radio.

A second disadvantage of digital radio compared with analog is lower spectral efficiency, as measured by voice channel capacity for a given radio frequency (RF) channel bandwidth. For example, a typical 6-GHz heterodyne FDM-FM microwave radio system can carry 1800-2400 4-khz voice telephone channels over a 30-MHz RF channel. In contrast, early digital radios carried fewer than 300 voice channels over the same RF channel. Because of this performance limitation, the FCC in 1973 mandated a minimum bandwidth efficiency requirement on digital microwave radios for use in common carrier systems of one bit per second (bps) per hertz of bandwidth. Since standard PCM-encoding of voice signals requires 64 kbps per voice channel, the FCC requirement technically implied a minimum of 469 voice channels in a 30-MHz RF band. However, as system capacities must be compatible with the standard PCM multiplex hierarchy, the ruling really implied a minimum of 576 channels (equivalent to 24 T-1 carrier channels).

From that time on, the emphasis in digital microwave radio development focused on increasing spectral efficiency through the use of higher level modulation techniques. While the FCC minimum of 1 bps/Hz presented a challenge to the industry in 1973, it was recognized that the theoretical performance limit was much higher. The well-known Shannon equation shows this limit to be, under ideal conditions:

$$C = W \log_2 (1 + S/N)$$

where: C is the signaling rate in bps
S/N is the signal-to-noise power ratio;
and W is the channel bandwidth in Hertz.

Therefore, assuming a signal-to-noise ratio of 27 decibels (dB) (a factor of 500), it should be theoretically possible to achieve a spectral efficiency of about 9 bps/Hz. In actuality, the Shannon limit cannot be achieved because of intersymbol interference, an impairment that varies with the form of digital encoding and modulation used as well as to the signal-to-noise ratio. In general, for a given type of modulation and a specified transmission error rate, the spectral (bit-rate) efficiency will increase as the number of modulation symbol states increases; however, the required S/N ratio will increase also, as shown in figure 3-4. The most spectrally-efficient digital microwave radio systems demonstrated to date have achieved 4.5 to 6 bps/Hz, using 64-level quadrature amplitude modulation (QAM). As spectral efficiency increases, overall system costs decrease, because additional channel capacity is made available at little or no incremental cost.

Early digital microwave systems often used simple phase-shift-key (PSK) or frequency-shift-key (FSK) modulations, the latter being used primarily to convert existing FM radio systems designed for analog transmission to digital operation. PSK modulation is more spectrally efficient than FSK, and early 4-level phase modulation schemes were able to meet the FCC's 1973 1 bps/Hz requirement. More modern equipment designs soon employed 8-level PSK, which is capable of 2-3 bps/Hz in practical systems. By the early 1980s, however, 16-level quadrature amplitude modulation (16-QAM) became the technique of choice for new equipment designs. QAM combines phase and amplitude modulation to create multiple signal states. It is capable of slightly higher spectral efficiency than PSK and is simpler to implement for higher level modulation schemes, because it is less critically affected by circuit and component impairments and therefore requires a lower minimum S/N ratio. Practical 16-QAM systems in use today have spectral efficiencies of 3 bps/Hz.

A natural extension of 16-QAM is 64-QAM. This modulation permits increasing the bit rate by a factor of 1.5 while maintaining the same baud rate. A spectral efficiency of 4.5 bps/Hz has been achieved in commercial service using 64-QAM. Digital radios operating in the 6-GHz band with a 30-MHz RF channel bandwidth and 135-Mbps information rate (the equivalent of 3 DS-3 multiplexed bit streams) represent the 1984 state-of-the-art in the United States. More efficient systems have been demonstrated in Japan, at up to 6 bps/Hz, but only through relaxation of filtering requirements below FCC limits, which are designed to prevent excessive adjacent channel interference.

- <u>Adaptive Equalization</u> -- Higher level modulation schemes such as 64-QAM are much more sensitive to dispersion due to multipath fading than are lower level systems or FM systems. Adaptive equalizers can greatly reduce the effects of such propagation path impairments, and their use has become standard in all modern equipment designs.

  The theory of adaptive equalization has been known and documented for many years. However, the importance of adaptive equalization has increased with the use of high-level modulation schemes, and the development of equalization techniques is probably the most dynamic aspect of digital microwave radio R&D today.

  The most serious problem in high-level modulation systems is caused by fading-induced amplitude response slopes over the signal passband, which can cause serious quadrature distortion in the demodulation process.

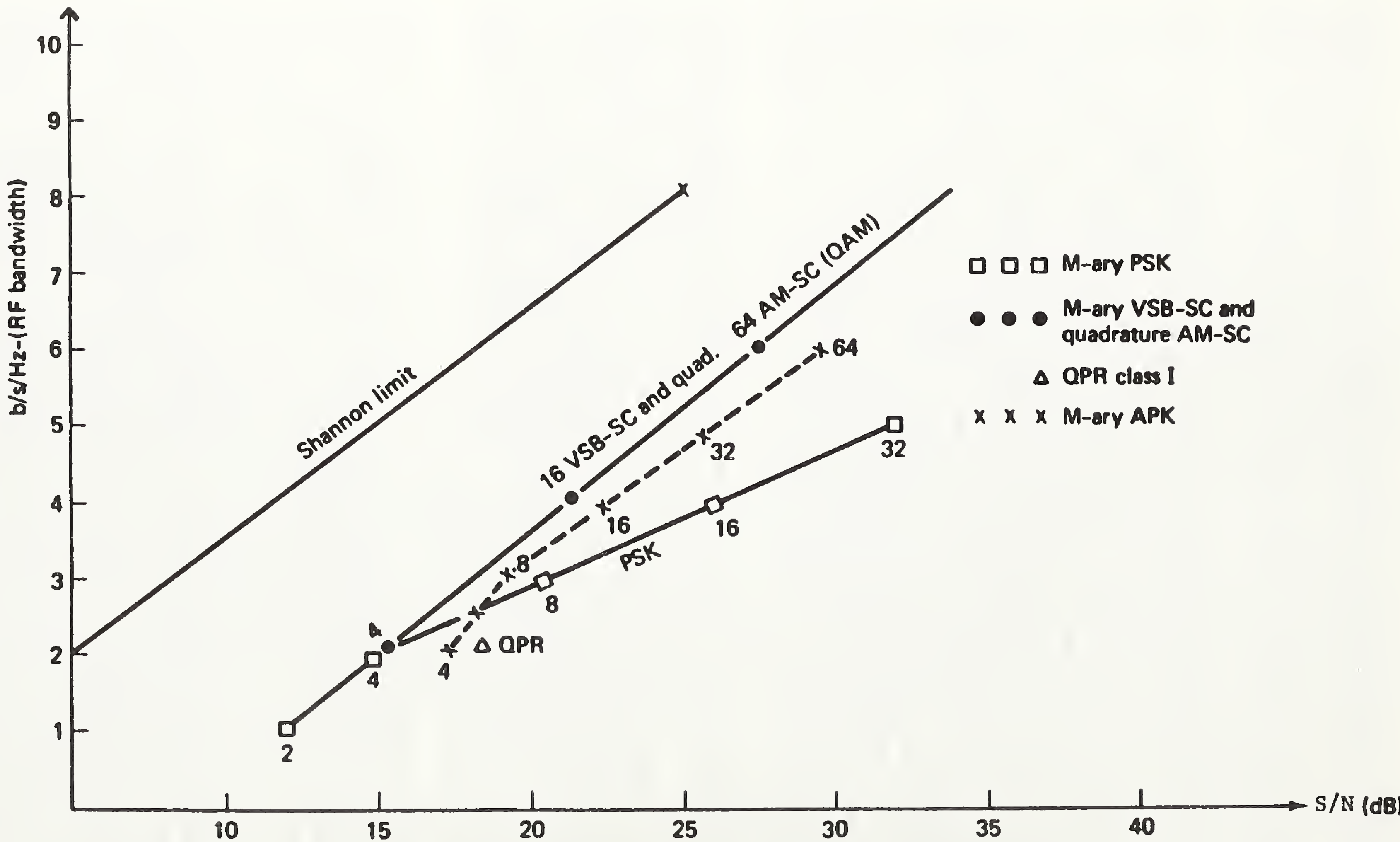


Fig. 3-4 Bit-rate efficiency (in b/s/Hz) of *M*-ary coherent PSK, VSB-SC, quadrature AM-SC, APK, and QPR systems as a function of the available S/N at a $P(e) = 10^{-8}$. The average S/N is specified in the double-sided Nyquist bandwidth, which equals the symbol rate. Ideal $\alpha = 0$ filtering has been assumed.

SOURCE: K. Feher "Digital Communications - Microwave Applications" 1981, Prentice-Hall

The earliest adaptive equalizers were circuits that simply sensed and corrected amplitude slopes in the receiver. More advanced forms of equalizers also correct for midband notch distortion. The most sophisticated equalizer in use today is called the baseband transverse adaptive equalizer, in which the in-phase and quadrature baseband signals are shaped by multitap transversal filters after being demodulated. These signals are then regenerated using the recovered timing waveform. The use of adaptive transversal equalizers has permitted higher-modulation-level 64-QAM systems to perform as well as, or better than, 16-QAM systems on the market today that are equipped only with slope equalizers.

Transversal equalizers for high-capacity digital microwave radio systems have become practical only with the development of thin-film integrated circuitry, miniaturized delay elements and advances in carrier and timing recovery circuitry. Further advances in these technologies will be needed to support the continued development of higher capacity equipment.

Table 3-2 summarizes the 1984 state-of-the-art in digital microwave radio technology, in terms of the spectral efficiency of the various types of modulation used. Phase shift key (PSK) modulation has been the most common modulation used in commercial equipment for the past decade, but QAM is clearly the choice today. Quadrature partial response (QPR), a variation of QAM used mainly in narrowband systems at 2 GHz, has not proven practical for broader bandwidth, higher frequency equipment.

Table 3-2

1984 DIGITAL MICROWAVE STATUS

Modulation	Frequency Band (GHz)	Spectral Efficiency (bps/Hz)
4-PSK	18	1.0
8-PSK	6,11	3.0
16-QAM	2,6,11	3.0
QPR-7	2	3.5
64-QAM	6,11	4.5

3.1.2.2 Technological Evolution

- 1984-1989 -- As digital radio technology advances, it seems certain that it will rapidly replace analog for almost all short- and medium-distance requirements (competing against optical fiber cables for some applications), while analog microwave will retain a gradually decreasing share of long distance requirements. For the highest density routes, optical fiber cables will often be preferred.

Special consideration will be given to upgrading and expanding the more than 100,000 route miles of existing long-haul analog microwave systems, most of which are owned by AT&T-Communications. Existing equipment can be upgraded at comparatively little cost by converting to single-sideband AM microwave. Using recently developed techniques, analog voice channel capacity per 30-MHz radio channel can be increased from the present average of about 1800 to approximately 6000, which would greatly reduce the cost per voice channel and extend the life of analog radio systems for many years.

On the other hand, it will become increasingly desirable to convert at least a portion of the existing capability to digital operation, to facilitate the expansion of high-speed data services and allow the evolution of a national ISDN. Significant introduction of long-haul digital microwave systems operating in the 4- and 6-GHz bands may be expected on existing routes as well as some new routes over the next 10-15 years.

The main thrust of future development will be toward higher spectral efficiency. Digital microwave is already approaching the efficiency of conventional FDM/FM analog equipment; on a total system basis, it may be substantially more spectrally efficient already, since the same frequencies may be reused in closer physical proximity -- i.e., on nearby parallel routes or on subsequent links in a tandem relay chain. Digital systems have inherently greater immunity to co-channel and adjacent channel interference. Nevertheless, further increases in channel capacity are possible, and digital microwave manufacturers have a strong incentive to achieve such gains to keep pace with competing technology.

- <u>1989-1999</u> -- The current practical spectral efficiency limit of equipment meeting FCC adjacent-channel filter requirements is about 4.5 bps/Hz. Improvements in filtering and adaptive equalization should allow an increase to about 6 bps/Hz for 64-QAM by 1989.

  Continued refinements to 64 QAM systems may yield a spectral efficiency of up to 7 bps/Hz, but still higher level techniques will be needed by 1994. Assuming that QAM remains the preferred format, we expect that 256-QAM will be used in commercial equipment, yielding efficiencies of up to 10 bps/Hz by 1999. Of course, it is possible that an entirely different technique may be introduced, much as QAM superseded PSK in recent years.

3.1.2.3 Conclusions

The projections discussed above are shown in Figure 3-5, along with projected proportionate decreases in cost per unit of transmission. The cost to transmit digital information by digital microwave will be reduced to about 45 percent of 1984 costs by 1999, based on improved spectral efficiency alone.

To achieve this cost/performance improvement, higher level modulation will be required, which implies a higher signal-to-noise ratio. This, in turn, implies more sophisticated adaptive equalization as well as improvements in solid-state microwave components such as gallium arsenide field effect transistors (GaAs FETs) and higher power solid-state transmitter sources such as high-power GaAs FETs. Particularly at 11 GHz and above, achievement of such improvements will also require continued advancements in microwave circuit miniaturization, mainly through further development of microwave integrated circuits of the thin-film hybrid and GaAs monolithic varieties.

The evolution of telecommunications networks will be based on further improvements in microwave radio technology as well as on newer fiber optic technology. Digital radio seems certain to replace analog for many short- and medium-distance routes, competing in individual applications with fiber optic cables. Digital radio will also be used in some long haul systems, particularly to upgrade existing routes; however, fiber optic cables are likely to be the medium of choice there.

3.1.3 Satellite Communication

3.1.3.1 Background and Present Approaches

The start of operations by INTELSAT in the 1960s enabled major industrialized countries throughout the world to communicate by satellite. By the mid-1970s domestic satellite communication was fully operational in Canada, the United States and the Soviet Union; other countries were initiating plans to install the necessary equipment.

The 1970s were marked by increased use of satellites for television distribution, business, and military applications. During this period, the C-band frequency spectrum was assigned to specific users, and the higher frequency Ku-band was opened up for satellite communications.

The technology of satellite communication has undergone rapid change in the past 20 years. The channel capacity of satellites has been increased dramatically by developments in power amplifiers, low-noise amplifiers and antenna structures, greater launch capability and space-proven prime power systems.

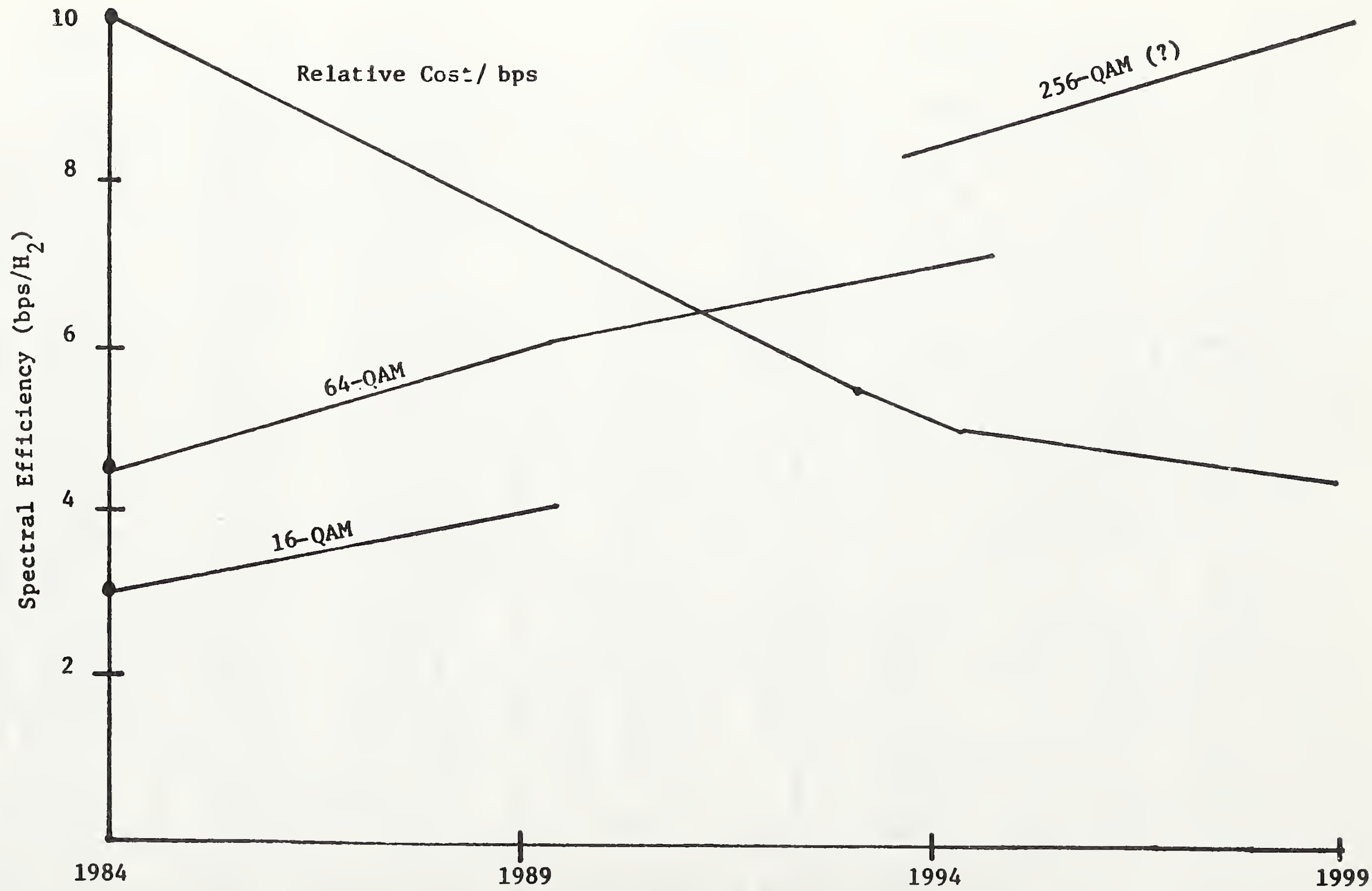


Figure 3-5 EXPECTED COST/PERFORMANCE TRENDS IN DIGITAL MICROWAVE

Furthermore, the cost of satellite systems has dropped greatly over the past 20 years: INTELSAT earth stations with 30-meter antennas sold for $10 million (U.S.) during the 1960s, while those now being placed in service for two-way communication (such as the INTELSAT B stations) sell for one-tenth as much. Receive-only stations for a single television channel are also dropping dramatically in price -- from $50,000 - $75,000 ten years ago to a few thousand dollars now.

Modulation techniques initially used for multi-channel voice systems on satellites relied heavily on the traditional FM/FDM channelization and had little flexibility in trunking and routing of channels. Today, numerous modulation and access techniques are in development or in use:

- FM message -- most economical for point-to-point trunking;
- FM video -- for network and cable video;
- SCPC -- most cost effective for thin-route communications, audio, video, and computer systems;
- TDM/FDM -- most cost effective for high duty-cycle point-to-point systems; and
- TDM/TDM -- most cost effective for large networks.

New developments require a wide variety of channelizations utilizing various data rates. For example, satellite systems will be using the following bit rates:

- 56 kbps for data systems;
- 1.544 or 2.048 Mbps for data channels;
- 6.44 or 8.448 Mbps for high-speed data channels;
- 16, 32 and 64 kbps for voice channels;
- 1.544 or 2.048 Mbps for one-way video conferencing; and
- 56 or 64 kbps for freeze-frame video.

An important consideration in the use of satellites is its vulnerability to jamming. Sensitive information transmitted by satellite must be encrypted along with satellite control circuits.

3.1.3.2 Technological Evolution

- <u>1984-1989</u> -- New services will require further satellite communication developments during this period. For example, direct broadcast satellite systems will require more powerful satellite amplifiers and improved antenna design for regional broadcasting. Direct broadcasting and videoconferencing will expand dramatically with the advent of better bandwidth compression techniques and utilization of lower bit rates (1.544 or 2.048 Mbps). Educational and medical information services will place additional demands on channel capacities.

The increased demand for communications services throughout the world will spur the development of higher frequency systems. The saturation of the 4/6 GHz region in the United States has already caused greater use of the 11/14 GHz spectrum. Systems are now being developed for the 20/30 GHz region, and their feasibility has been demonstrated.

Other technological developments in 1984-1994 will include multi-beam satellite antennas, on-board satellite switching, high frequency/high power systems, and lower cost earth stations to provide services direct to customer premises. Specific development areas include the following:

- The next-generation DOMSAT satellite system has been developed utilizing the C-band spectrum for transmission. This has been possible because of improvements in satellite and ground-station subsystems and the increased capacity and reliability of systems through the use of state-of-the-art, space-proven components.

  Systems that utilize the Ku-band require large downlink margins to overcome the fading that can be caused by precipitation in the transmission path; therefore, they will have to use high-power transmitters with traveling wave tube (TWT) amplifiers for the next decade. C-band amplifiers, on the other hand, can employ the more reliable solid-state technology of GaAs FETs.

  Ku-band station locations are not limited by the radio-frequency interference (RFI) and congestion of terrestrial microwave networks, but frequency coordination for C-band stations has been difficult in the past. It is now a less formidable problem, because interference levels can be precisely measured on-site, and natural or artificial shielding can be judiciously used.

- Design improvements and higher antenna gains can double the traffic capacity per transponder of current satellites. Receivers using GaAs FET in both the 6-GHz amplifier and 4-GHz receiver sections can reduce noise by over 3 dB.

- The replacement of traveling wave tubes (TWT) amplifiers by an all-solid-state GaAs FET power amplifier in all frequency bands will significantly improve both the linearity and reliability of the final amplifier. For a given signal quality, the input back-off required is approximately 5 dB less than that for a TWT amplifier. This will result in greater channel capacity for the same signal-to-noise ratio. Further, the elimination of the hot-cathode life limitation of the TWTAs will enhance the probability that the amplifier will meet a 10-year mission requirement.

- Along with improvements in the satellite power, amplifier linearity, and channel response, enhancements of terrestrial equipment will permit a doubling of traffic capacity per standard 40-MHz transponder channel. For example, the figure of merit (G/T) of the receiving earth station in the DOMSAT system has been improved by the use of recently available thermoelectrically cooled low-noise amplifiers (LNAs) providing noise-temperature performance on the order of 35 degrees K. These LNAs are replacing cryogenically cooled amplifiers because of their inherently superior reliability, performance and reduced maintenance expense.

Table 3-3 shows a projection of growth in equivalent standard 40-MHz transponders:

Table 3-3
GROWTH IN CAPACITY
(Equivalent 40-MHz Transponders)

Year	World	U.S.
1980	426	156
1985	1,410	478
1990	3,100	756
1995	5,580	1,135
2000	9,870	1,655

Source: IEEE Communications, May 1984.

The capacity of the DOMSAT systems has been increased from 1,000 to 2,000 circuits per transponder by the use of compandors. These enhance the signal-to-noise ratio in a channel by compressing the dynamic range of a voice signal prior to transmission to the satellite channel and expanding it to its original range at the receiver. The S/N ratio can then be reduced to the original value by decreasing the per-channel FM deviation, allowing more channels in the baseband with no perceived loss in quality.

To further improve signal quality, DOMSAT systems are utilizing adaptive echo cancellers. These devices are significantly superior to conventional echo suppressors, because they estimate the echo level on a given path and exactly cancel it.

Provision has been made for the transmission of wideband 56-kbps data to dedicated 5-meter duplex earth stations on customer premises. All data carriers will use forward error correction codes with expected performance of a data channel equal to a bit error rate of one error in ten million bits transmitted at an availability of 99.95 percent.

- For some time, INTELSAT has offered a wide range of digital services via dedicated PCM-PSK (pulse code modulation-phase shift keying) channels, providing transmission at speeds of 50 and 64 kbps and 1.5 Mbps and, by submultiplexing, meeting current international data needs. INTELSAT is now changing to time division multiple access (TDMA) techniques, which will be the operational method of the future. TDMA is required to meet the vast communication requirements now on the horizon; dynamic satellite-switched TDMA (SS-TDMA) systems, operating to multi-beamed satellites, are essential to achieve future effective reuse of frequencies in satellite systems. On-board regeneration and processing techniques will also be utilized in future systems.

  The INTELSAT VI satellite, scheduled for launch in 1986, incorporates a 6 x 6 satellite switched matrix. This switch provides for full interconnectivity between two hemispheric beams and four overlaid zone beams, two in each hemisphere. Frequency reuse with the overlaid zone beams is achieved by orthogonal polarization to the corresponding hemisphere beams. In addition to the six beams at C-band, there are two steerable Ku-band spot beams, normally one in each hemisphere, and two global 4/6 GHz beams. The spot beams can be interconnected to each other or to the 6/4 GHz hemispheric transponders via a static switch. There is also full interconnectivity between the two 11/14 GHz spots and the six 4/6 GHz beams.

- Home reception of microwave signals transmitted from a direct-broadcast satellite (DBS) is now becoming a reality with the authorization by the Federal Communications Commission in the United States to several corporations and with the development of a number of European and Japanese systems. Consumer acceptance of the DBS concept will largely depend on the size of the equipment and its cost. Present system concepts call for an antenna size of one meter and the use of monolithic microwave components for the 12-GHz receivers. Several recent developments in antenna structures, and electronic equipment for proposed DBS systems are aimed at minimizing the equipment size and reducing costs.

Developments in Japan have produced a monolithic microwave integrated circuit using gallium arsenide for the down converter-receiver. These subsystems have an adequate (3.6 dB) noise figure over a 500-MHz bandwidth. The intermediate frequency band (821.4 MHz) will require further conversion to TV-set frequencies. In the 400-800 MHz range, field-effect transistor amplifiers can be used in the first stage with a gain of over 40 dB. Bipolar transistor amplifiers are used for the second and third stages.

Scientific Atlanta, in the United States, has developed a down converter from 12 GHz to 2770 MHz with a noise figure of 3.1 dB and a gain of 56 dB. This unit can be mounted directly on the antenna. The intermediate frequency (IF) signal is conveyed to an indoor unit via a low-loss cable. The indoor unit is designed to perform an additional frequency conversion, signal demodulation, video and audio processing and remodulation to produce an output compatible with existing television sets.

- The use of thin-route satellite systems has increased in several countries. For example, in Alaska and the sparsely populated northern sections of Canada, thin-route systems provide private two-way telephone communication for remote villages and access to the main telecommunications network. Continued development of these systems and the reduction in equipment costs will permit their economic implementation. An important feature of these systems is the increasing application of demand assignment multiple access (DAMA) to reduce costly space-segment bandwidth and power utilization. Centralized control and mesh rather than star configurations improve performance and decrease the probability of double-hop (i.e., earth-satellite-earth-satellite-earth) connections.

o <u>1989-1994</u> -- There will be slow growth in applications as optical fiber economies cause displacement of satellite transmission.

o <u>1994-1999</u> -- Growth will be limited to special geographical applications such as trans ocean and archipelagos.

3.1.4 Cellular Radio

3.1.4.1 Background and Present Approaches

Nearly fifteen years after the invention of the cellular mobile radiotelephone by Bell Laboratories and significant development efforts, principally by Motorola, the first commercial systems are now being installed. Cellular radio technology is principally used to provide common carrier switched mobile radiotelephone service interworking with the public switched telephone network.

Cellular radio is one of a class of system approaches for better utilizing the scarce natural resource of the frequency spectrum. Previously, radiotelephone systems were implemented using high-power transmitters that saturated an entire metropolitan area. Because of the limited frequency spectrum and competing demands for other uses, only a limited number of frequencies were available for mobile radiotelephone use. This had the impact of limiting mobile radiotelephones to only several hundred users per major metropolitan area.

Present commercial systems are being implemented with narrowband FM transmission in the 800-MHz microwave mobile radio band. A maximum repertoire of 300 channel-pairs is allocated to any one system. These frequencies, in turn, are zoned into hexagonal cells that form a blanket network covering a metropolitan area. The cells are extended as necessary and adjusted in radius to cover geometries of various shape. Cells may be sub-divided into smaller cells within a group. Within any one zone, or cell, frequency assignments are chosen which are not used in adjoining cells. Frequencies are re-used at a predetermined distance measured in number of cells from a cell of interest. In this way a large geographic area can be covered with a small number of frequencies without interference.

When a mobile unit passes over a cell boundary, a centralized control system dynamically reallocates the mobile unit to the frequency of the adjacent cell and simultaneously switches the wireline public switched telephone circuit to the new cell base station.

Current FCC regulations and posture require nationwide compatibility so that service will be available anywhere within the nation. All products now being marketed are of the mobile (vehicle-mounted) type. However, portable (hand-held) units the size of a standard brick have been demonstrated and will be commercially available soon.

3.1.4.2 Technological Evolution [STAFF COMMENT 12]

- <u>1984-1989</u> -- During this time period, products presently on the market will proliferate with little change in the basic systems concept and performance. More widespread use of portables may be expected toward the end of the period; higher degrees of semiconductor integration and the learning curves associated with volume will permit cost reduction. Of particular importance in this application will be monolithic integrated circuits employing gallium arsenide front ends. Cost reductions in high-power silicon radio-frequency devices will result from increased yields. Battery technology developments, in the form of rechargeable lithium and possibly zinc/air technology, will make portable operation more feasible.

- 1989-1994 -- Toward the end of this time frame, systems will begin to reach saturation capacity of some 200,000 to 300,000 users per system. Costs will decline to a point where upscale consumer demand (as opposed to business demand) will begin to develop, and technologies will begin to be investigated that have a potential for increasing system capacities up to tens of millions of subscribers per city.

  During this time period, hand-held portables will proliferate widely and begin to displace vehicle-mounted mobiles, since cells will have split into smaller cells that do not require high-power mobile transmitters. System technologies will have to provide upward compatibility with frequency assignments, since nearly all the reserve frequency spectrums will have been utilized and no additional room for growth will exist because adjacent frequency segments will also have been allocated.

- 1994-1999 Spread-spectrum modulation technologies along with digitized, efficiently coded audio will be utilized to provide cellular radio-type structures on the same frequencies currently used for the conventional FM non-spread-spectrum system. In this way, both upward and downward compatibility can be provided as cellular systems develop.

  Field tests of the spread-spectrum, high-capacity mobile radiotelephone system will begin during this period. While the technology will be ripe for exploitation by then, the government might well delay its implementation for as much as 10 years. The history of similar developments indicates that cellular technologies will develop most rapidly where regulatory structures are more conducive to industry/government partnership, such as in Japan and Europe.

3.1.4.3 Conclusions

Present mobile radiotelephone systems are priced in the $2,000 range, and portables are expected to be introduced in the $2,500 range. These costs should rapidly but asymptotically approach

$300 per unit by the 1999 planning horizon. Improvements in the performance will be limited; instead, technology improvements will be channelled into cost reduction.

With cost reductions, the utility of personal and mobile radiotelephones that provide functionality similar to that of land-line telephones will arouse widespread consumer demand. We do not expect, however, that even high-capacity, spread-spectrum technology will increase cost performance to the point where cellular telephones displace conventional ones. While cellular radio systems may become theoretically capable of serving all residences within a metropolitan area, they will simply not be cost-competitive. **[STAFF COMMENT 13]**

3.1.5 Circuit Switching

3.1.5.1 Background and Present Approaches

The basic function of a circuit switching system is to interconnect two or more ports on demand. Traditional switching systems consist of three basic functional building blocks:

- The <u>port services</u> examines the ports for request for services, <u>provides</u> ringing and signaling, and connects the ports through the switching network;

- The <u>switching network</u> provides paths between the ports through the port services; and

- The <u>control system</u> (or intelligence) recognizes subscriber needs and organizes all the portions of the switch to effect the connections in the network as required.

By 1979 it had been agreed by all switching manufacturers that the future of digital switching lay entirely in stored program controlled digital networks. All manufacturers have introduced first-generation digital switches, and these are being installed almost universally throughout the world in new switching offices.

Table 3-4 lists currently available, important digital central office switches and their principal characteristics.

3.1.5.2 Technological Evolution

- <u>1984-1994</u> -- There are now indications of what succeeding generations of digital switches will be like. The key technology trends that will affect the next generation of switching systems include the following:

- <u>Much larger memory</u> will reduce the cost and simplify the structure of the time division switching portion of the switch;

Table 3-4

TECHNICAL CHARACTERISTICS OF TODAY'S MAJOR DIGITAL SWITCHING SYSTEMS

Manufacturer	CIT-Alcatel			L.M. Ericsson	Fujitsu	GTE		Hitachi
System	E-10B	E-10S	E-12	AXE-10	PETEX-150	GTD-3EAX	GTD-5EAX	HDX-10
Type of Exchange	Local/Toll	Local	Transit	Local/Tan/Toll	Local/Tan/Toll	Toll/Tandem	Local/Toll	Local/Transit
Max. No. of Lines	50,000	16,000		100,000	240,000	–	150,000	240,000
Max. No. of Trunks	11,000		42,000	65,000	60,000	61,440	25,000	57,000
Busy Hour Calls	150,000	50,000	450,000	N/A	N/A	480,000	N/A	N/A
B.H.C. Attempts	190,000	62,000	520,000	700,000	700,000	600,000	360,000	720,000
Total Capacity (E)	4,000	2,000	15,000	25,000	24,000	27,000	N/A	20,000
Assumed Holding Time (sec)	120	120	150	90	100	180	N/A	100
Call Loss Prob.	0.02	0.01	0.01	0.0001	0.1	0.1	N/A	0.1
Max. Traffic/Line (E)	0.1	0.5	–	0.23	1.0	–	N/A	0.24
Max. Traffic/Trunk (E)	0.8	0.7	0.95	0.8	1.0	0.9	N/A	0.80
Switching Matrix	T-S-T		T-S-S-T	T-S-T	T-S-T	S-T-S	T-S-T	S-TS-ST-S
Remote Line Unit	Yes		No	Yes	Yes	No	Yes	Yes
R.L.U. Max. Size (Lines)	1,000		–	2,000	1,920		3,072	5,000
30 Chan. PCM (CCITT)	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
24 Chan. PCM (Bell)	Yes	Yes	W/Converter	No	Yes	Yes	Yes	Yes
Common Control	Multi-Proc	Dist-Proc	Pair	Paired-Proc	Multi-Proc	Multi-Proc	Dist-Multi	Dist-Proc
Loading: Prog. & Data	Tape	Disk	Tape	Tape	Tape	Tape	Tape	Disk
Progress Language	ASSEM/HLL	HLL(PLM)	HLL	HLL	HLL	N/A	PASCAL	HLL(PLM)
Obj. Downtime (20 yrs)	0.76	0.75	0.2	1.0	1.0	1.0	1.0	0.5
MTBF Large/Smallest	100-22 yr	400-25 yr	200-50 yr	$(2.7\text{-}0.44)\times10^{6}$ hr	N/A	350-26 yr	N/A	N/A
Loop Resistance (ohm)	2,200	2,200	–	2,500	1,900	–	1,800	1,700/3,000
Lines/CODEC	128/256	1	–	1	1	–	1	1
Tandem Hierarchy (CCITT)	Yes	–	All Levels	All Levels	All Levels	No	No	All Levels
Tandem Hierarchy (Bell)	5,4	–		No	All Levels	Yes	Yes	All Levels
Integr. Opr. Position	No	–	Yes	Yes	Yes	No	No	Yes

continued

Table 3-4 (cont'd)

Manufacturer	ITT	NEC	Northern Telecom		Oki	Siemens	Western Electric	
System	ITT-1240	NEAX-61	DMS-10	DMS-200	KB-70	EWSD	No. 4ESS	No. 5ESS
Type of Exchange	Local/Tand/Toll	Loc/Tan/Toll	Local	Toll	Local/Toll	Local/Toll	Toll/Tandem	Loc/Toll/Tand
Max. No. of Lines	100,000	100,000	6,000	–	57,700	100,000	–	100,000
Max. No. of Trunks	60,000	60,000	–	60,000	28,000	64,000	107,520	50,000
Busy Hour Calls	N/A	N/A	10,000	–	N/A	N/A	550,000	400,000
B.H.C. Attempts	750,000	700,000	13,000	350,000	292,000	750,000	616,000	500,000
Total Capacity (E)	25,000	22,000	1,000	22,700	9,600	25,000	47,200	30,000
Assumed Holding Time (sec)	N/A	120	N/A	160	100	150	N/A	200
Call Loss Prob.	0.005	N/A	4	0.5	0.1	0.01	0.05	0.01
Max. Traffic/Line (E)	0.275	0.30	0.2	–	0.5	1.0	–	0.25
Max. Traffic/Trunk (E)	0.80	0.90	–	0.78	0.8	1.0	0.44	0.86
Switching Matrix	Combined T/S	T-S-S-T	T-S-T	T-T-T-T	T-S-T	T-S-T	T-S-S-T	T-S-T
Remote Line Unit	Yes	Yes	Yes	–	Yes	Yes	–	Yes
R.L.U. Max. Size (Lines)	480	2,000	420	–	2,000	976	–	4,000
30 Chan. PCM (CCITT)	Yes	Yes	No	No	Yes	Yes	No	Yes
24 Chan. PCM (Bell)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Common Control	Distributed	Pair & Multipair	Pair Proc	Pair Proc	Pair Proc	Multi/Distrib	Pair & Distrib	Pair & Distrib
Loading: Prog. & Data	Disk	Tape	Tape	Tape	Mag. Bubble	Tape/Disk	Tape/Disk	Disk
Progress Language	CHILL	HLL & ASSEMBL	HLL	PROTEL	CHILL	CHILL	ASSEM & EPL-X	C-Language
Obj. Downtime (20 yrs)	1.0	1.0	4.0	2 hr/40 yr	1.0	3.0	1.0	1.0
MTBF	0.5 yr	N/A	N/A	400 yr	N/A	10^6 hr	N/A	N/A
Loop Resistance (ohm)	1,900	1,900	1,900	–	2,000	2,000	–	2,000
Lines/CODEC	1	N/A	1	–	1	1	–	4-8
Tandem Hierarchy (CCITT)	All Levels	All Levels	–	No	Yes	Yes	Yes	Yes
Tandem Hierarchy (Bell)	All Levels	3,4,5	–	1,2,3,4	Yes	Yes	Yes	Yes
Integr. Opr. Position	Yes	Yes	–	Yes	Yes	Yes	No	Yes

- Higher speed memory will provide faster access and increase the size of the switch that can be implemented entirely using time division digital techniques without resorting to intermediate analog switching stages;

- Cheaper memory promises to reduce the cost of circuitry;

- Improved microprocessors promise more effective control and the opportunity to distribute increasing capability at minimum cost throughout a switch. Increased capability includes operation with more digits, more memory and more flexible application opportunity;

- High-voltage semiconductors are finally permitting the replacement of all iron-core components such as relays and transformers in subscriber services circuits. This offers the promise of much more compact line circuits of greater reliability and lower cost;

- Architecture is becoming more refined as digital switching develops, permitting increased cost-effectiveness; and

- Distribution of intelligence is a corollary of improved architecture, and its effects are profound.

Figure 3-6 shows the traditional distribution of functions in a stored program controlled analog or first-generation digital switch. With the advent of incredibly inexpensive and capable intelligence, control is being distributed as shown in figure 3-7. This approach has several important advantages, including graceful cost-versus-growth functions and a high degree of flexibility and reliability.

Switches are beginning to operate more in the way that biological systems operate, i.e., with the intelligence being distributed and duplicated throughout the system. A new-generation switching system may have literally thousands of microprocessors; in fact, the ultimate will probably be to have one or more microprocessors for each incoming line. Since a given call may encounter only a few of these microprocessors, the failure of any one part will not result in an emergency situation. If a microprocessor fails before a call is set up through it, a distributed system is generally able to ignore that microprocessor and find an alternative set of processors and routes to establish the call. A conversation may be lost if a microprocessor fails, but the low probability of this should be acceptable.

One of the benefits of the new technology in switching systems is the modularity of approach, leading to more powerful switches with distributed intelligence (which includes distributed logic and memory); these can be configured to perform local or transit (toll or tandem) and remote switching unit functions, as illustrated in figure 3-8. The elements of the concentrated switch shown in the upper diagram can be separated and put in different

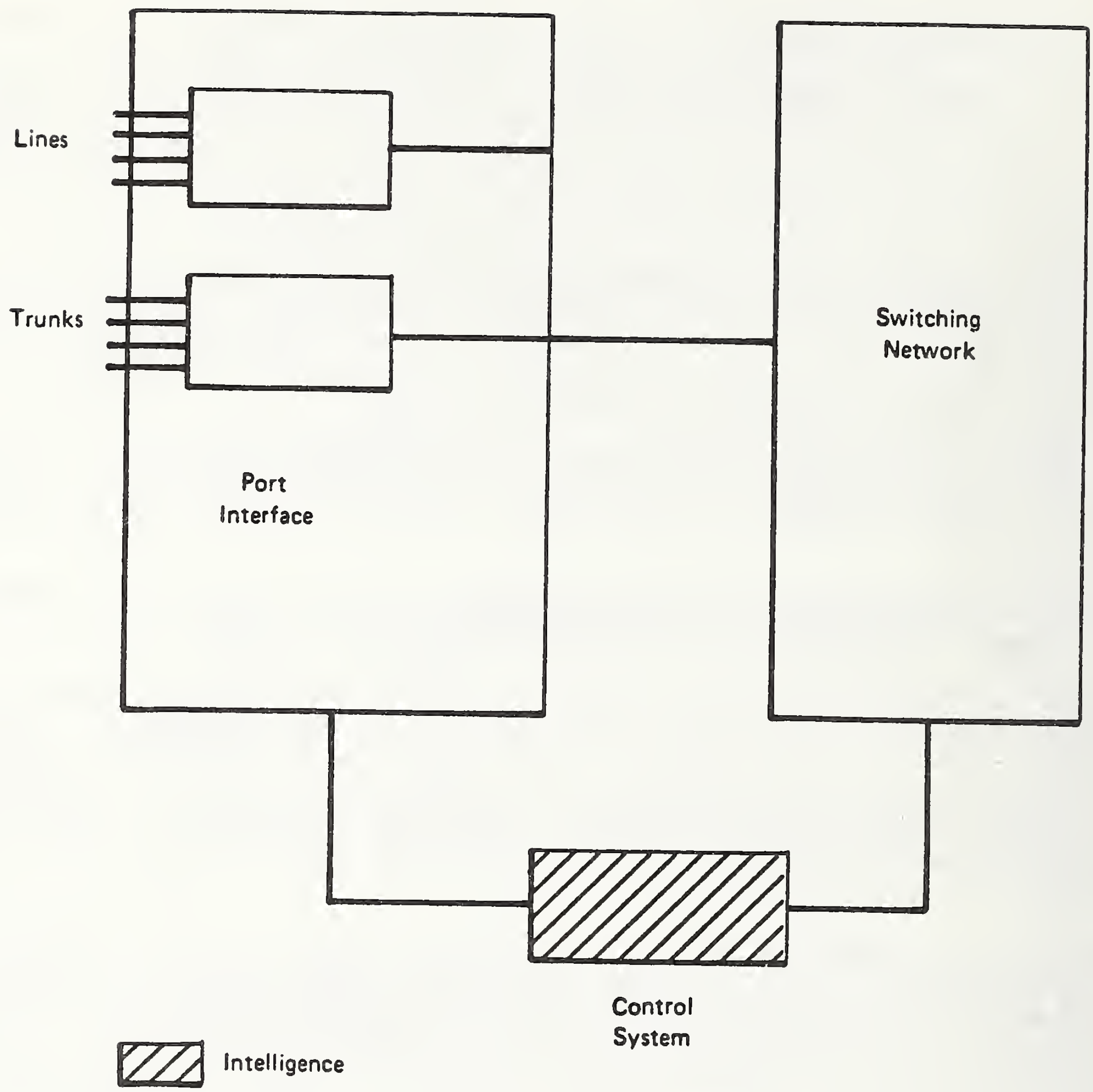


Figure 3-6 TRADITIONAL ARCHITECTURE: CENTRALIZED INTELLIGENCE

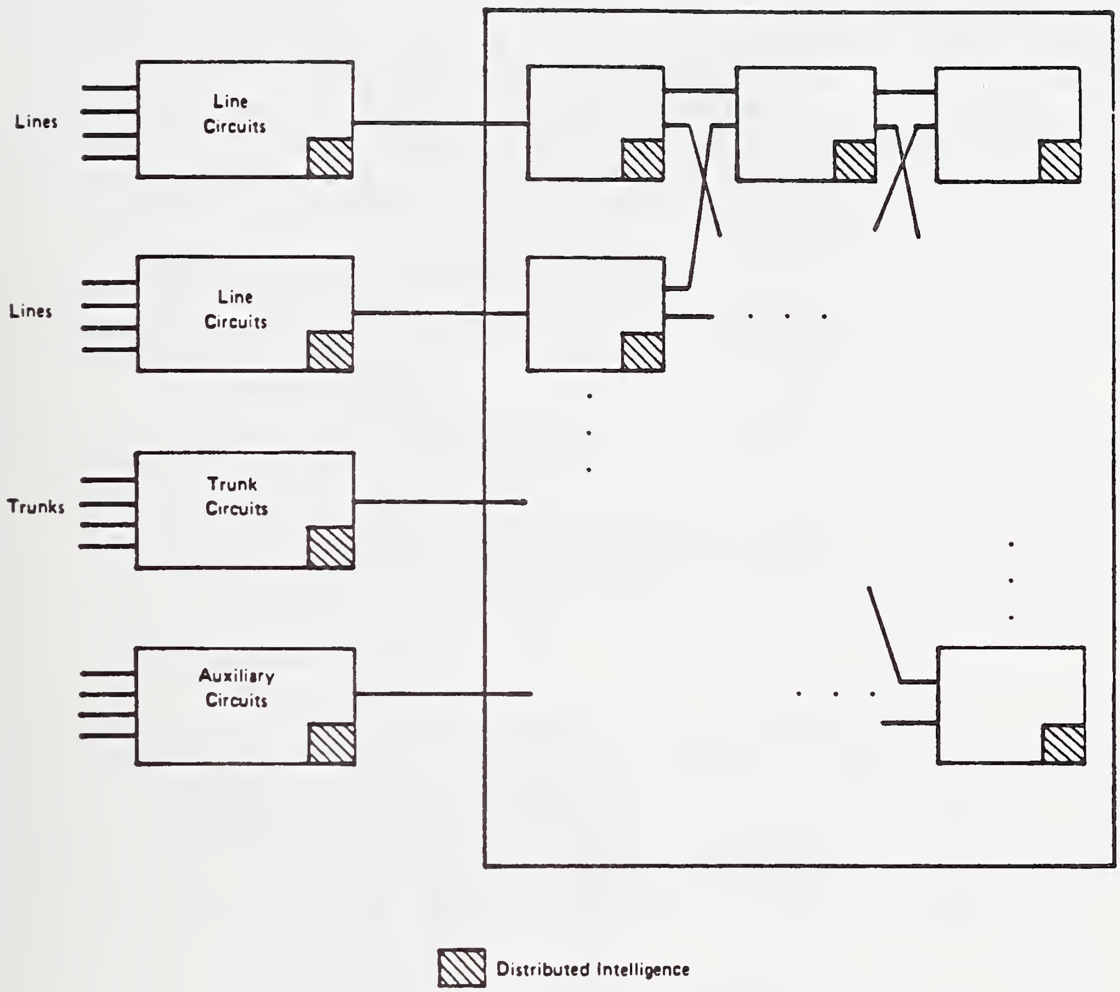


Figure 3-7 NEW ARCHITECTURE: DISTRIBUTING THE INTELLIGENCE

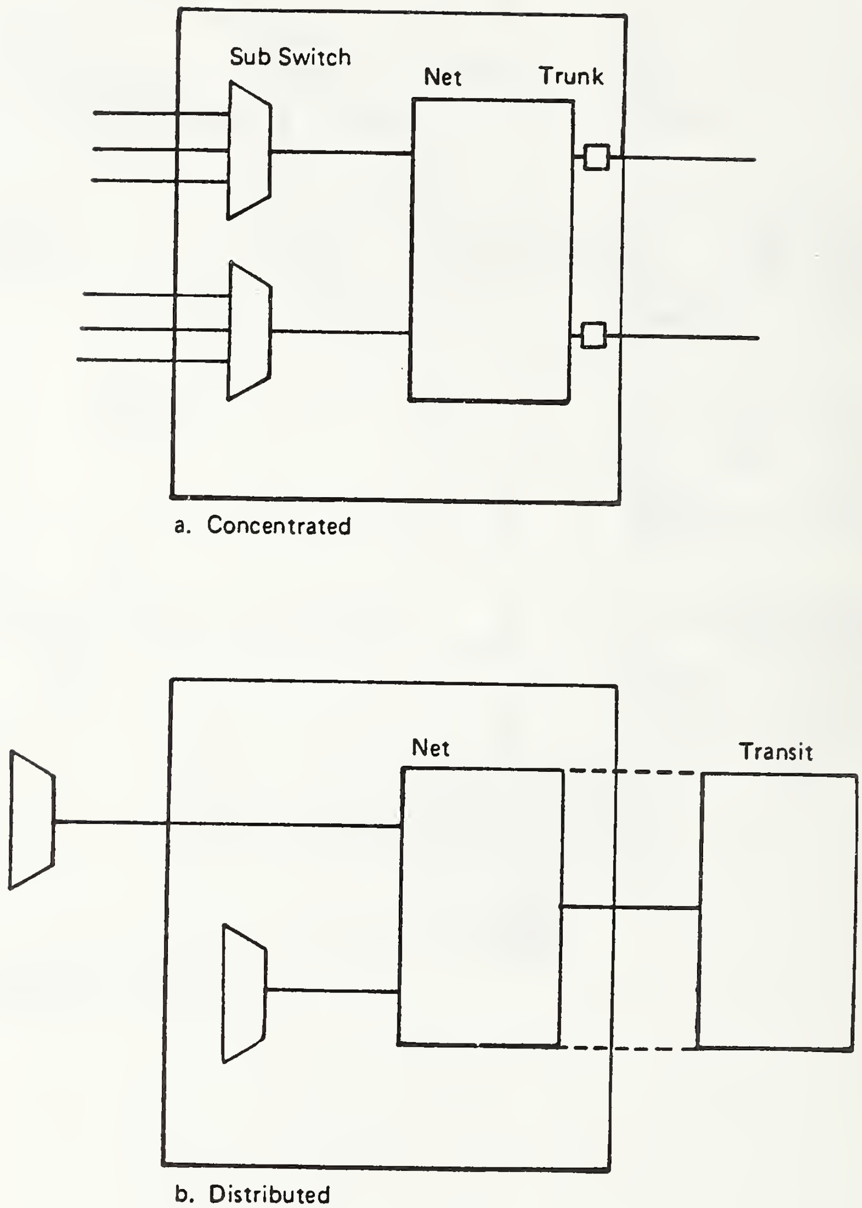


Figure 3-8 POTENTIAL MIGRATION OF SWITCHING FUNCTIONS

functional or geographical locations, taking their associated intelligence along with them. Thus, one switch (lower diagram) can serve as a master for remote switching units and provide the functions of a conventional local switch and an associated transit switch at the same time. The latter is a more attractive alternative with digital switching than with analog switching, since analog switching can be either two-wire or four-wire, which might make it unsuitable for transit applications; digital switches are inherently four-wire, so there is no distinction between the treatment of transit traffic and local traffic. The remote switching unit becomes feasible because the link between it and the central office is a low-cost digital highway similar to the one used internally in the standard switch.

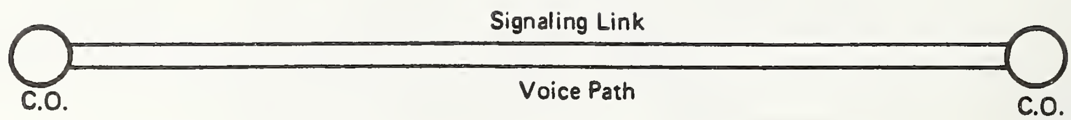
The basic advantages of digital systems, which are already being enjoyed, will continue to become more attractive in the future. These include decreases in size, weight, and (to a small extent) power consumption.

Maintenance is less troublesome in a modern digital switch, because it is facilitated by diagnostic programs that indicate the specific piece of equipment in which a fault is located. Repair consists of replacing the faulty board. The inherent nature of digital switching has also made feasible remote testing (diagnosis and fault location) from a centralized maintenance center that serves a number of exchanges through associated digital transmission paths.

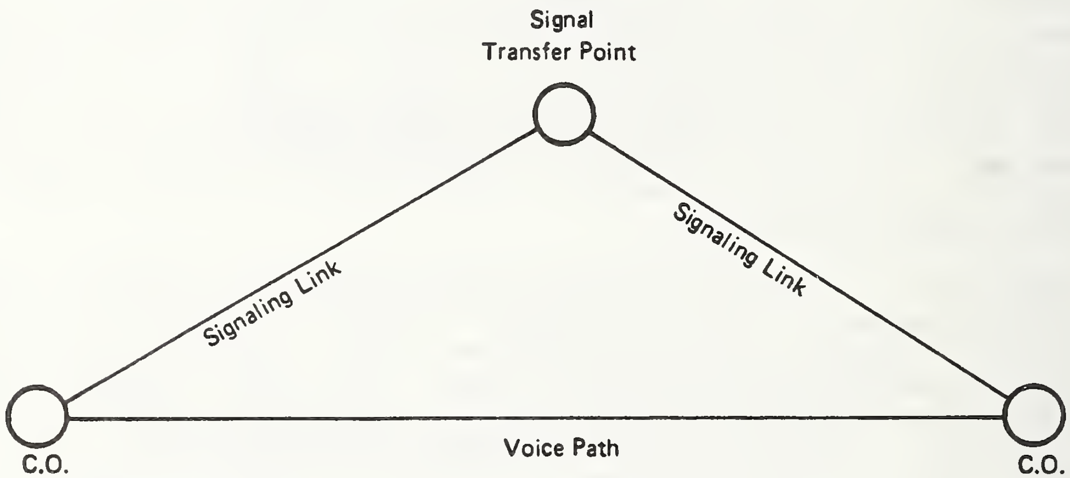
In addition to the distributed intelligence and stored program control operation already discussed, another significant driving force for changes in telephone switching topology is common channel inter-office signaling. This links processes in various switches with high-speed data links, leading to higher speed, lower cost, and more reliable set-up of connections. It also permits the transfer of packets of information for more flexible call control.

Common channel signaling can take two basic forms, as shown in figure 3-9. The simplest, called associated signaling, uses a link that operates independently of all the voice paths interconnecting the central offices (C.O.s). This may be an appropriate first step; however, to realize the full advantage of common channel signaling, non-associated signaling is more flexible. Here, the signaling links operate on a network containing signal transfer points; these are packet switched nodes (see section 3.1.7) that provide packet intercommunication between the central offices in the network.

Future national network topologies must take into account the transition from an analog network with analog switches and analog transmission links. Important issues in the transition to digital technology are shown in figure 3-10. Here we see an analog transit exchange network with dependent analog local exchanges. With the addition of nearby digital transit exchanges and digital



a. Associated Signaling



b. Non-associated Signaling

Figure 3-9 COMMON CHANNEL SIGNALING

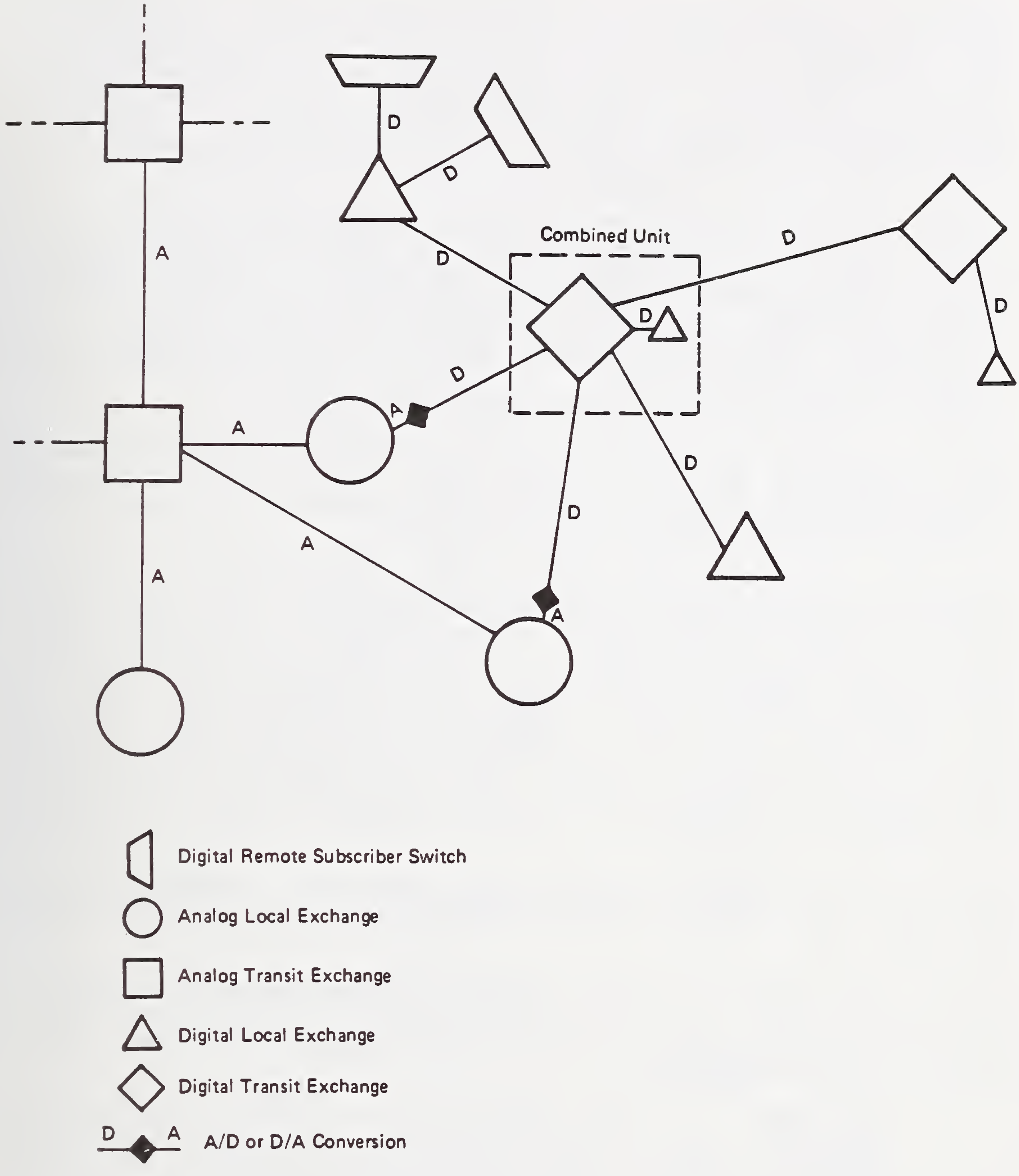


Figure 3-10 A STEP IN DIGITAL AUGMENTATION OF ORIGINALLY ANALOG NETWORK

combined end-offices and transit exchanges, analog-to-digital services are required on the trunks between them. Whether the trunk is analog or digital -- that is, which end of the trunk the A/D conversion takes place -- is a matter of economics. The diagram illustrates a stage approximately halfway through the transition to digital switches and shows the use of combined local transit switches, digital transit switches and remote subscriber units connected by digital trunk facilities.

Another likely trend in the future, made possible by the widespread distribution of intelligence and stored program control, is the advent of a dynamic non-hierarchical routing network (DNRN), illustrated in figure 3-11. There is only one class of toll switch within the DNRN. End-offices may home on these or on intermediate tandem exchanges. Dynamic routing rules are used between pairs of DNRN nodes, which appear as a large network of regional centers with complete interconnectivity.

Dynamic routing selects minimum-cost paths between originating and terminating nodes and permits the design of time-varying routing patterns to achieve minimum-cost trunking by capitalizing on non-coincident network busy periods.

The dynamic nature of this routing scheme is achieved by storing several route choices in each of the switches. The routes consist of different sequences of paths designed to satisfy given overall blocking requirements. Off-line centralized computations test these routing patterns and continuously readjust them to restructure the network. Simulation of this approach for the Bell System toll network indicates potentially very large savings. Much research must be done before the equivalent can be said for small national networks, but the idea of not restructuring routing to an inflexible hierarchy appears to be an important strategy for the future.

During this period, in the 1984-1989 timeframe, steady replacement of U.S. central office switches with digital units will continue.

By the early 1990s, the toll network will be completely digital. Digital switches will be replacing analog electronic units. Distribution of switches into subscriber plant will become widespread. [STAFF COMMENT 14]

- <u>1994-1999</u> -- A new generation of modular distributed switches will be available and there will be few suppliers left. The incorporation of ISDN - oriented switches will be widespread. [STAFF COMMENT 15]

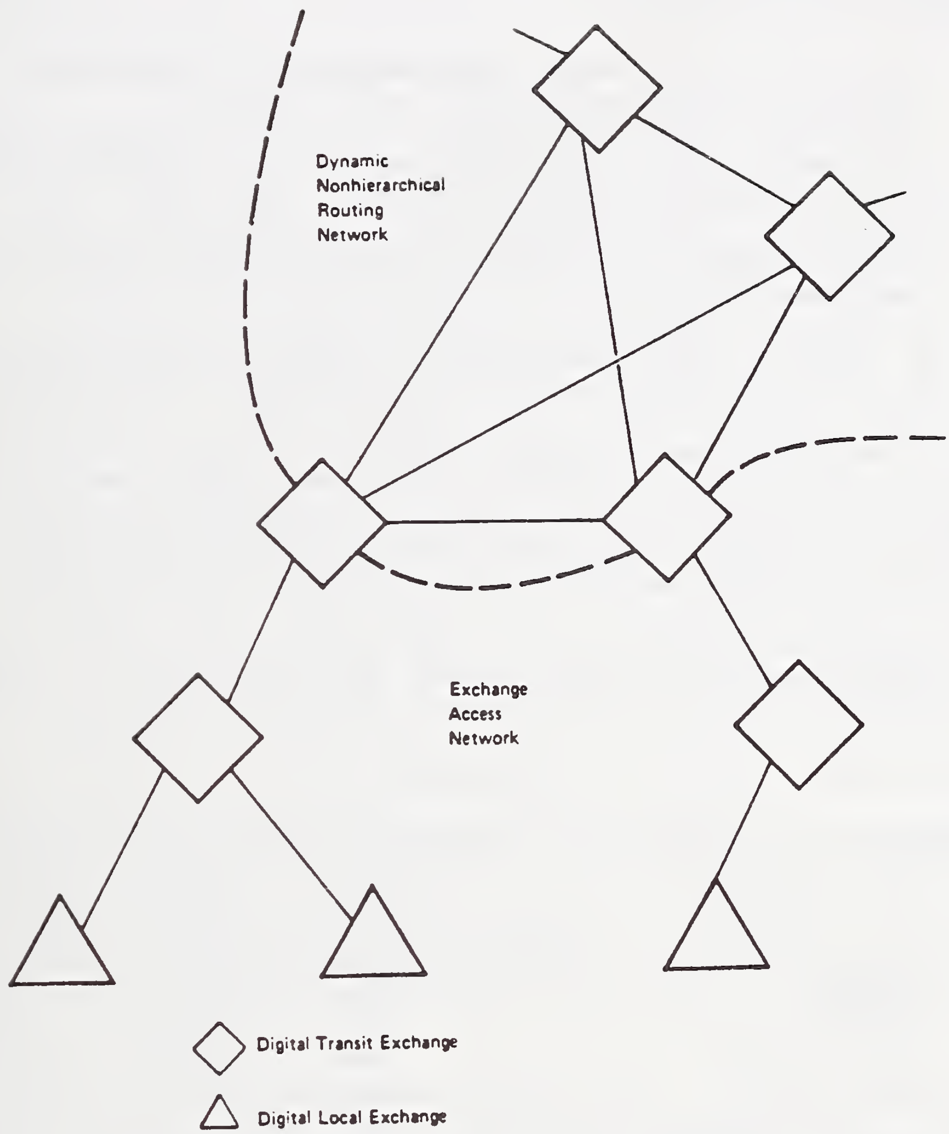


Figure 3-11 DYNAMIC NONHIERARCHICAL ROUTING NETWORK PLAN

3.1.5.3 Conclusions

Although prices differ widely, large Central Office switches in the United States presently cost in the range of $300 to $500 per line. The costs of the equipment portion of digital exchanges are expected to continue to decrease throughout the next decade, for the following reasons:

- o The costs of memory, microprocessors and other hardware items will continue their rapid decline;
- o Economies of scale will result from rapidly increasing production runs of digital switching; and
- o Productivity will improve as the manufacture of digital switches ascends the learning curve.

Projected future cost breakdowns for digital switches are estimated in table 3-5 where the cost elements are grouped into identifiable technologies. The services show a decrease from 22 percent of the 1984 installed cost to 18 percent in constant dollars because of the advance of high-voltage semiconductors. The control portion will decline even further (from 13 percent to 9 percent), as will the network (12 percent to 7 percent). The power supply and mechanical parts, however, offer little possibility for future economies and will remain constant in an amount equal to 17 percent of the 1984 installed cost. Thus, the total cost of hardware will decline from 64 percent to 51 percent of today's total.

Table 3-5

PRESENT AND FUTURE COST BREAKDOWNS FOR DIGITAL SWITCHES

Cost Element	1984	1989	1994
Interface	22%	20%	18%
Control	13%	11%	9%
Network	12%	9%	7%
Power Supply	10%	10%	10%
Mechanical	7%	7%	7%
TOTAL HARDWARE	64%	57%	51%
Software	18%	25%	35%
Installation	18%	40%	55%
TOTAL COST	100%	122%	141%

However, the two labor-intensive portions of a switch -- software and installation -- which are now estimated to be approximately equal and total 36 percent, will increase dramatically: software will rise from 18 percent to 35 percent, and installation (which will be geared directly to skilled labor costs) even more, from

18 percent to 55 percent, despite cost-cutting efforts by manufacturers. The reason that the software costs will not increase as rapidly as installation costs is that there is hope for some automation of the production of software. The total cost in 1984 dollars will increase about 41 percent by 1994.

3.1.6 PABXs

3.1.6.1 Background and Present Approaches

A private automatic branch exchange (PABX) provides local switching services on a customer's premises. PABXs have been evolving since before World War II. Historically, they started as manual switching systems with operators using cords and plugs to complete the calls (PBXs). The "first generation" of automatic PBXs (or PABXs) were based on early electro-mechanical switching technology used in telephone central offices. These switches used either step-by-step or crossbar networks. Now, "PBX" and "PABX" are used interchangeably.

The advent of analog electronic switching with stored program control produced a generation of PABXs that offered many enhanced features. The development of these "second-generation" PABXs was enhanced by the competitive restructuring of customer premises equipment, which began with the Carterfone decision in 1968.

In the mid-1970s it became evident that digital approaches, rather than analog were attractive for switching, even in a basically analog environment. The digital technology that has evolved in central office switching also found its way into PABXs; these PABXs are often referred to as "third-generation."

"Fourth-generation" switches, which are just beginning to emerge, embody the blending of data front-end processers and controllers with digitized voice. These switches may be thought of as either digital PABXs with data-handling capacity or computer front-end processors with voice-handling capability. There is considerable uncertainty as to exactly what form or forms of fourth-generation systems will be dominant.

Third-generation switches are characterized by software-driven computer control, distributed architecture, internal digital transmission interfacing with local area networks (LANs), and readily engineerable capacity but fixed bandwidth of transmission.

The emerging fourth-generation switches often include integrated LANs and invariably include distributed architecture with modular hardware as well as software. Transmission is digital in nature, capacity is readily engineerable, and bandwidth may be allocated according to need.

The characteristics of seven representative fourth-generation integrated voice/data PABXs are summarized in table 3-6. All of the data transmission speeds indicated are full-duplex, and all

Table 3-6

FOURTH-GENERATION INTEGRATED VOICE/DATA PABXs

	ROLM CBX-II	INTECOM IBX	NEAX 2400	NORTHERN TELECOM SL-100	ATT-IS SYSTEM 85	GTE OMNI	ZTEL PRIVATE NETWORK EXCHANGE
Architecture:	Modular, Distributed, TDM Bus	Modular, Distributed, TDM Bus	Modular, Distributed, TDM Bus	Modular Switch, Central Control, TDM Bus	Modular, distributed, TDM bus	Modular, distributed, Dual TDM bus	Modular, distributed, Time/Space/Time
Requires Switchroom Environment?	Yes	Yes	Yes	Yes	Yes	Yes	No
Maximum Ports	10,000	(S-10)2000, (S-80)8200	23,184	30,000	7,000	3,000	12,000
Nonblocking?	Yes	Yes	Yes	Optional	Up to 4,000 lines	"Virtually" nonblocking = 1% probability	Yes
Sets:	Digital, Analog	Digital, Analog	Digital, Analog	Digital, Analog	Digital, Analog	Analog	Digital, Analog
Wiring	1-2 twisted pairs	2 twisted pairs	2 twisted pairs	2 twisted pairs	4 twisted pairs	1 twisted pair	2 twisted pairs
Price/Line	$800-$1,000	$1,000	$600-$1,200	$600-$1,000	---	$700	$800-$1,000
Protocol Conversion	Asynch to BSC, SDLC, X-25	Asynch to BSC, X.25	No	Asynch to BSC, SDLC	---	Asynch to X.25	---
Terminal Support - Asynch/Synch	19.2 kbps/64 kbps	56 kbps/56 kbps	19.2 kbps/56 kbps	64 kbps/64 kbps	64 kbps/64 kbps	19.2 kbps/64 kbps	19.2 kbps/64 kbps
Trunk Interface	DS-I, CPI, (DMI-Maybe)*	DSI, DMI (CPI Coming)	DAI + ?	DSI, DMI	DSI, DMI	DSI	No
Note:		Lanmark LAN		Can emulate IBM 3278, 2780 and 3780	Can emulate IBM 3278, 2780, and 3780		Internal LAN, Control now, Data later

* See text for explanation of abbreviations.

switches include modem-pooling as a feature. The trunk services referred to are: DS-1 -- the services for the industry standard 1.544-Mbs (T1) carrier facilities such as AT&T's ACUNET 1.5 service; DMI -- AT&T's digital multiplex services; and CPI -- the Northern Telecom computer-to-PABX "open world" services.

3.1.6.2 Technological Evolution

- o <u>1984-1989</u> -- During this period the fourth-generation PABX should become ubiquitous and acquire increasing features for both voice and data.

- o <u>1989-1994</u> -- It is impossible to predict with assurance what the fifth generation will be like in detail, but it will doubtlessly consist of completely distributed, universal modular blocks of hardware and software working together to provide all possible combinations of voice and data needs for business organizations in buildings and campuses. The use of these systems for building management, security and even manufacturing process control will become commonplace.

- o <u>1994-1999</u> -- Front end processor, voice/data processor completely merged. New designations will have emerged for new devices.

3.1.6.3 Conclusions

In 1989 the real cost per port is expected to be approximately 70 percent of the 1984 cost (which, as shown by the previous tables, is in the order of $1000, not including installation). By 1994, the cost in real dollars should be approximately half of what it is today. Further cost reductions will not be as dramatic.

The benefits of an integrated voice/data PABX are that it provides a common, universal communication management resource, which allocates bandwidths according to need, permits easy changes in the system, and provides cost allocation among different functions and organizations. The incremental cost for handling data in addition to voice (or voice in addition to data) is small and will decrease with time.

There are many driving forces toward widespread application of these systems. They include increased competition with probably more competitors than the market will ultimately sustain. The wildfire proliferation of personal computers is placing a demand on local voice/data communication that was not anticipated even a few years ago. In addition, with increased reliance on electronic mail and store-and-forward messaging, the need for smart networks is increasing. At the same time, T1 (1.544-Mbps) capabilities are becoming widely available to support the very large bandwidths that fourth-generation PABXs will handle. Technology will drive the real cost down, making these systems more attractive. The increasing availability of database information, both public and private, will further stimulate demand.

One barrier that has existed within many types of end-user organizations has been the organizational conflicts between data processing, office management, and telecommunication functions. As they recognize these conflicts, more organizations are taking steps to integrate the three functions.

The future outlook indicates increased presence of integrated solutions with proliferation of new applications and more penetration.

3.1.7 Packet Switching

3.1.7.1 Background and Present Approaches

Packet switching has been used for data transmission since the end of the 1960s. The initial incentive for implementing this technique was to provide lower-cost transmission paths for data, in order to develop EDP resource sharing/teleprocessing; transmission services offered by the various telephone administrations and carriers at that time were almost exclusively suited for voice rather than data transmission. Packet switching thus emerged as an alternative to circuit switching for specialized applications.

Since the 1970s, packet switching networks have been developed for experimental purposes, for private data transmission services, and for public data transmission services; examples are the ARPA network, the Federal Reserve network and GTE Telenet respectively.

While circuit switching techniques allocate a fixed amount of bandwidth (typically 4 kHz or 64 kbps) to a given communication for its duration, packet switching does not allocate bandwidth to a given communication; bandwidth is dynamically shared by various communications on a contention basis. This implies that information must be sent in short packets, rather than in a continuous flow. When a particular switch reaches saturation, it will block calls (if using circuit switching) or will store packets in queue (if using packet switching).

The main functional advantages of packet switching are that it offers:

- o Multiple logical accesses through a single physical port, where each flow of data corresponding to one logical access is dynamically multiplexed on the physical link attached to the physical port;
- o Capability of speed, code, and protocol conversions, since the packet technique works in a store-and-forward way, enabling a packet switch to process a received packet before forwarding it; and
- o Better utilization of bandwidth, since it is dynamically shared and used only when transmission is actually

occurring. As a result, costs are much less duration-dependent and speed-dependent than with circuit switching.

The main functional disadvantages of packet switching are:

- o Transmission delay, which is variable and dependent on the line speed, network load and the configuration of the network; and

- o The cost of packet switching ports, which is presently several times that of circuit switching ports.

Packet switching today is used almost exclusively for data transmission, primarily because of differences in traffic characteristics among various types of applications. The applications which can most benefit from data concentration are the terminal-conversational and interactive ones while the other applications, particularly voice, have much lower data-concentration advantages, with respect to circuit switching. [STAFF COMMENT 16]

Typical applications for packet switching are:

- o EDP networks (e.g., IBM/SNA, CII-HB/DSA),

- o Private data transmission networks (e.g., Northern Telecom, SESA),

- o Public data transmission networks (e.g., GTE Telenet, Transpac), and

- o Shared-use networks (e.g., SITA).

A trend toward packet switching in such networks is evident in the United States, Canada, France, the United Kingdom, and West Germany. While packet switching was developed primarily by EDP companies, software houses, and value-added network carriers, a limited number of traditional telecommunications companies now have access to this technique. An important factor in the future of packet switching is the success of ISDNs (see section 3.1.8).

Packet techniques may offer significant benefits for voice as well as for data. The integration of digital voice with data in a common packet-switched system offers potential cost savings through sharing of switching and transmission resources, as well as enhanced services for users who require access to both voice and data communications. Packet internetworking techniques can be applied to provide intercommunication among voice users on different types of networks. Significant channel capacity savings for packet voice can be achieved by transmitting packets only when speakers are actually talking. Packet networks have advantages for digital voice conferencing in terms of channel utilization (only one of the conferees needs to use channel capacity at any given time) and in terms of control flexibility. The digitization of voice in packet systems provides an opportunity to apply security techniques. (Secure packet data communication techniques can be applied as well for data users who require this service.) Packet networks also provide a system environment for effective exploitation of variable-bit-rate voice tranmission techniques, either to reduce average end-to-end bit rate or to dynamically adapt voice bit rate to network conditions.

3.1.7.2 Technological Evolution

- 1984-1989 -- The success of packetized speech is highly speculative at the present time and predictions are too uncertain to be useful. Widespread application of packet switching for value added data services will grow.

- 1989-1994 -- Probably some application for packet switched voice will be found. Packet continues as overlay switching method.

- 1994-1999 -- Packet switching will be dominant for data and important for other services.

3.1.8 ISDN

3.1.8.1 Background and Present Approaches

The concept of an integrated services digital network (ISDN) has gained popular acceptance among telecommunications planners. There is some argument as to the precise definition of an ISDN, but the following characteristics are generally recognized:

- The ISDN is a Network -- It is generally agreed that it is a public network and that it is made up of nodes and branches extending over a geographic area. The ISDN controls the flow of information to and from users.

- The ISDN is Digital -- Its services handle all information in a digital form. Switching, processing inside the network, and transmission are all accomplished using digital means. Predefined and accepted protocols are necessary at the digital services.

- The ISDN implies Integrated Services -- It is intended to handle a wide variety of services and signals, including both voice and non-voice traffic. The ISDN is aimed at a wide variety of user needs.

Figure 3-12 shows a conceptual arrangement of an ISDN with various terminal devices.

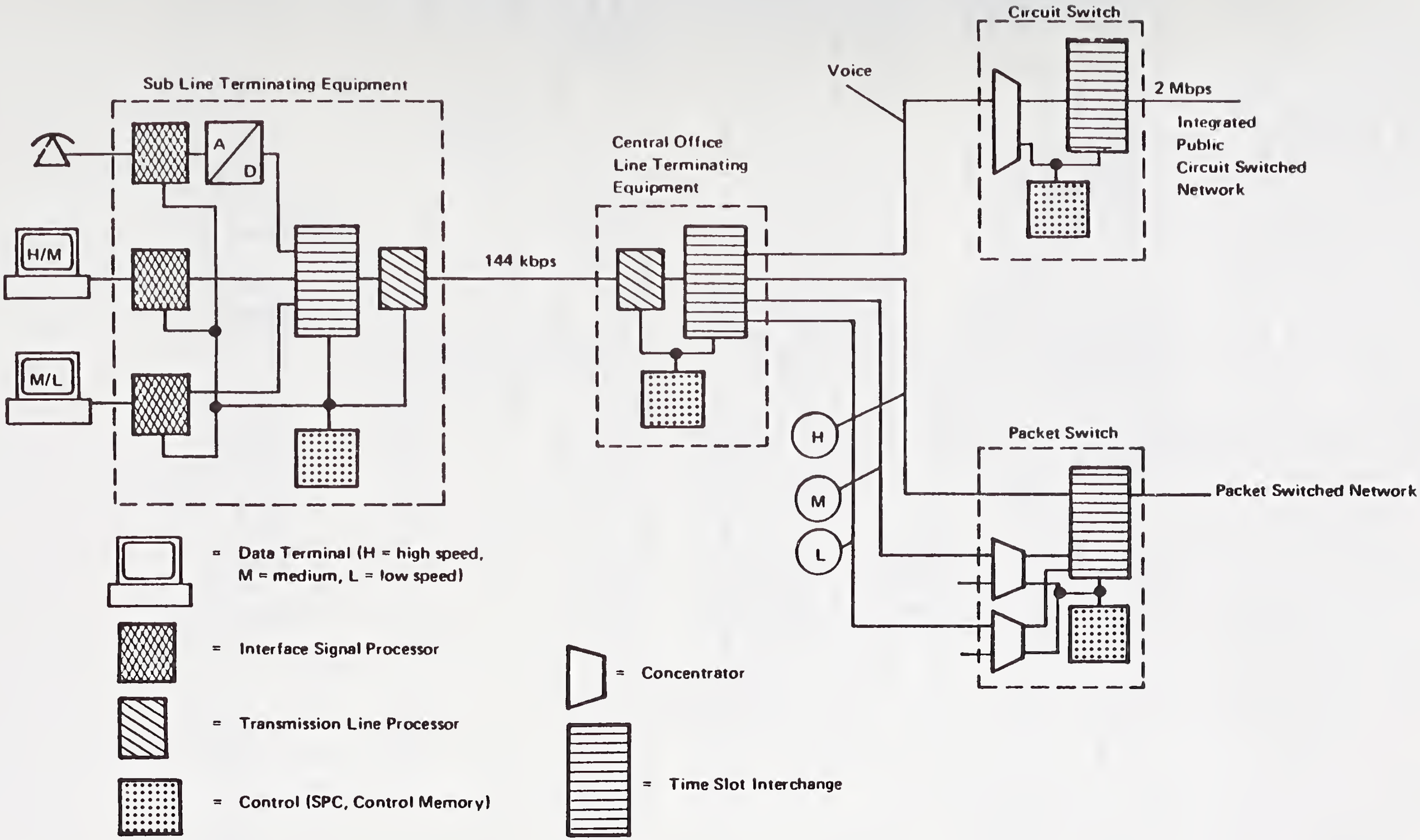


Figure 3-12 ISDN NETWORK CONCEPTS

Between 10 and 15 years ago, it became evident that digital techniques were most attractive economically for voice switching. When switching and transmission are combined in digital form, still greater economies are obtained, since digital signals can be transmitted and switched entirely in digital form. This combination of digital switching and digital transmission (still geared to analog telephony) is called an Integrated Digital Network (IDN). IDNs are now being established all over the world.

The obvious next step is to make everything digital, from beginning to end--i.e., to treat all signals, analog and digital, in a digital mode. Analog signals can be readily digitized at their origin to obtain the economies and flexibilities of an all-digital network. Furthermore, new services now emerging are inherently digital and can be efficiently combined with existing digitized services. However, whether there will be enough digital services to mix with voice to make an overall ISDN economically attractive is not yet clear.

Each customer of an ISDN obtains a telecommunications transport capacity with a very high bit rate--i.e., a digital pipe as shown in Figure 3-13. While there is no universally accepted standard, the current trend is toward a pipe capacity of 144 kbps in both directions. This capacity can provide two digitized channels at 64 kbps for voice or high-speed data; some of the remaining 16 kbps capacity must be used to control the network, but most of it can also be used for data transmission.

It is quite practical to transmit 144 kbps over ordinary copper wire pairs found in conventional telephone loop plant, as long as distances are limited to about seven or eight kilometers. Three modes of two-way transmission are under serious consideration:

- Separating the frequency bands of signals in the two directions;

- Using an electronic adaptive echo canceller to sort out the two directions of transmission; or

- Alternating the signals in each direction by means of time-burst transmission.

While the method(s) finally adopted will depend upon cost, none of the above appears to offer a significant cost advantage at present. The echo canceller technique probably has the most potential for cost saving from very-large-scale integrated circuits.

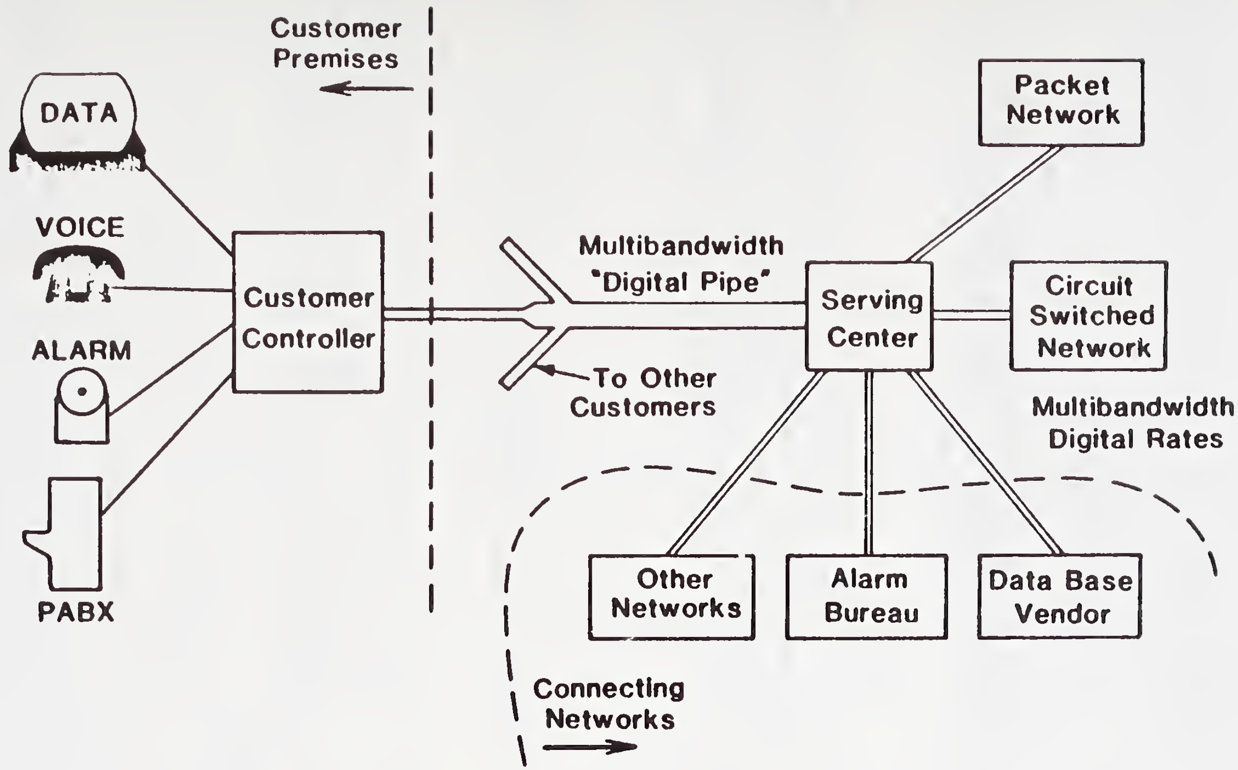


Figure 3-13 TYPICAL USE OF "DIGITAL PIPE"

At the central office end of an ISDN loop, voice signals in digital form and digital data signals are separated. The voice signal is connected to a voice switch and to the public switched voice network. (To realize the full benefits of an ISDN, this switch should be digital, although analog switching is possible.) Data streams from the ISDN loop are routed to a data network, which may be either circuit switched or packet switched.

For business users, where the services may connect with a digital PABX or voice-data switch, the large bit rate available should be attractive for handling the concentrated traffic generated at a business location. The principal use of ISDN will probably be for business applications in areas serviced by digital central office switches. ISDN is attractive for these business applications, because it will provide substantial data capability at less cost than with present modems. ISDN performance advantages include higher speeds and independence from traffic on the voice network.

The numerous potential ISDN services include personal message service, facsimile, teleprinting, computer-to-computer transmission, word processing, information retrieval, monitoring, transactions, and teleconferencing. These and many more will be available, but they will not be inexpensive; furthermore, their full potential will not be realized unless the local office is digital.

3.1.8.2 Technological Evolution

- o <u>1984-1989</u> -- First limited trials completed and definitions solidified. Some business use will start.

- o <u>1989-1994</u> -- Serious introduction of ISDN-oriented switches and loops for business applications will begin.

- o <u>1994-1999</u> -- Application of ISDN to business will be widespread. Residential use will still be minimal.

3.2 DEVICES AND MEDIA

3.2.1 Microwave Semiconductors

3.2.1.1 Background and Present Approaches

Microwave integrated circuits (MICs) serve the same purposes as conventional digital integrated circuits: they are intended to reduce the size, weight and cost of quantity-produced complex circuit components. However, conventional integrated circuit design and fabrication techniques, based on single-crystal silicon wafer material, are unsuitable for use at microwave frequencies. The resistivity of silicon material is too low for low-loss microwave transmission and the types and quality of active microwave devices that can be fabricated in integrated form from this material are very limited.

A far superior semiconductor material for microwave integrated circuits is gallium arsenide (GaAs). Its much lower intrinsic carrier concentration and high electron mobility have long made it a most attractive material compared with silicon, as shown in table 3-7. However, the techniques for making and processing compound semiconductors are far more difficult and less easily controlled than those for silicon. The development of high-quality, reproducible GaAs devices and integrated circuits has been underway since the 1950s, but many serious problems remain.

TABLE 3-7

ELECTRONIC PROPERTIES OF SILICON AND GALLIUM ARSENIDE
(at 27°C)

	Si	GaAs
Energy Gap (ev)	1.1	1.4
Intrinsic Carrier Concentration $n_i(cm^{-3})$	1.45×10^{10}	9×10^{6}
Intrinsic Electron Mobility (cm^2/sec)	1350	8600
Dielectric Constant	11.7	12

While GaAs monolithic MICs only recently have begun to be available for limited commercial applications, the use of hybrid MICs is widespread, both for military and commercial use. Most hybrid MICs consist of metallic conductors deposited to form a transmission line pattern on a high-dielectric ceramic substrate onto which active and passive components are attached to form a multifunction microwave circuit. The ceramic substrate commonly used is polished, high-purity alumina, while the metallic conductors are formed by vapor deposition of a chrome-gold thin film. The transmission lines and other conductor patterns are formed by photoetching, after which they are gold-plated to a sufficient thickness for acceptable electrical conductivity. Active and passive devices, such as field-effect and bipolar transistors, Schottky diodes, PIN and varactor diodes and capacitors and resistors are then affixed by welding, soldering, cementing or some other process.

Hybrid MICs are widely used in all telecommunications equipment operating at microwave frequencies, including terrestrial as well as satellite systems. Compared with systems that use waveguides, coaxial cables, cavities and strip transmission lines, hybrid

MICs are much smaller, lighter and generally more uniformly reproducible in performance. However, except in certain high-volume applications such as some military radar antenna arrays, appreciably lower cost is generally not achieved. Only through further improvement of monolithic MIC techniques will truly low costs be attained.

At the present time, the most important commercial monolithic MIC application appears to be for microwave receivers for 12-GHz direct broadcast satellite (DBS) subscriber stations. Here, receiver costs of only a few tens of dollars each in large volumes are required, rather than a few hundred dollars each as is now the case.

- The design and fabrication of hybrid MICs, based on thin-film-on-alumina technology, is now quite mature. The basic approach is shown in figure 3-14. Signal flow within the circuit is via so-called microstrip transmission lines. Microstrip is a transverse electromagnetic (TEM) mode transmission line, using a strip conductor over a ground plane. This configuration has propagation characteristics similar to those of a coaxial line. Radiation from the unshielded strip conductor is negligible beyond approximately one strip width away from the conductor, because the electromagnetic fields are well-confined to the high-dielectric substrate. The dielectric constant of alumina is about 9.7.

  The open construction of the microstrip line allows easy attachment of semiconductor and other devices, which are usually in unencapsulated chip form. Final packaging of the circuit is typically in a metal housing wih coaxial connectors or, in some cases, direct connection to an antenna feed or to a baseband or intermediate-frequency circuit component.

  This technology has been in practical use for more than 15 years, and only small refinements are likely to be made in the future. While less costly than previous approaches to microwave circuit fabrication, hybrid MICs still require several different, costly process steps, from initial preparation of the alumina substrate to packaging of the finished circuit. While these costs are not excessive for relatively low-volume high-price equipment such as digital microwave radios for common carrier networks, they are far too high to achieve the cost goals for DBS receivers.

- For Monolithic MICs, many types of active microwave GaAs devices have been developed over the past 25 years, most notably varactors, field-effect transistors (FETs), Gunn and IMPATT devices, and Schottky barrier diodes. The higher electron mobility of GaAs compared with silicon yields superior performance at microwave frequencies. With such promising individual devices at hand, the

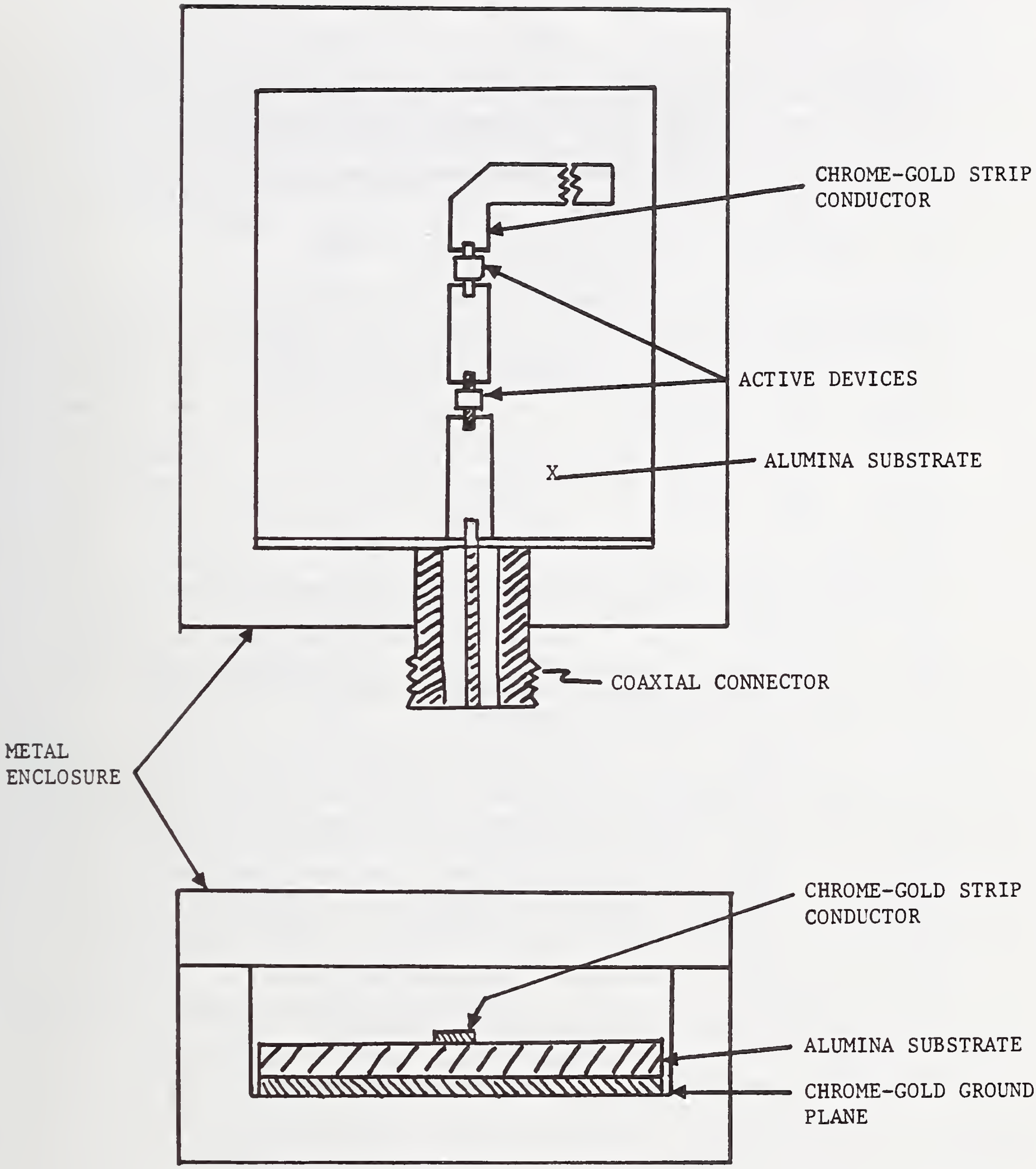


Figure 3-14 HYBRID MICROSTRIP MIC CONSTRUCTION

development of techniques for integration of multiple devices with suitable interconnections on a single GaAs chip is highly desirable.

A major requirement for circuit integration is electrical isolation of the various components. For MICs, a further requirement is for minimal distributed transmission loss through the circuit. Both requirements imply the use of a very-high-resistivity substrate material. GaAs satisfies this requirement better than any other practical semiconductor material; it is much better than silicon in this regard, having an intrinsic carrier concentration more than three orders of magnitude lower.

Excellent large-diameter GaAs crystals, liquid-encapsulated Czochralski grown from pyrolytic boron nitride crucibles can now be reliably produced, yielding high crystal purity and stable resistivity. For many years, the development of semi-insulating GaAs was plagued by tendencies of available materials to lose their semi-insulating characteristics during subsequent device processing requiring annealing at high temperatures. The problems of substrate reproducibility and stabilization are now recognized as being mostly due to excessive and variable concentrations of silicon and chromium impurities, which are redistributed during high-temperature processing. Materials preparation techniques were developed in the 1978-1980 period that have overcome these problems, making possible the availability of stable semi-insulating substrates with resistivities of the order of 100 million ohm-cm.

Active devices such as FETs are usually formed by direct ion implantation of dopants to form the active GaAs layer, although epitaxially-grown active layers are also used. Standard gold metalization is used for conductor patterns, while gold/platinum/titanium alloys are commonly used for ohmic contacts. Chemically-vapor deposited silicon dioxide is used to passivate active devices as well as for capacitor dielectrics. Sputtered tantalum oxide dielectric may also be used for capacitors. Figure 3-15 shows a typical circuit fabrication cross-section and its equivalent circuit.

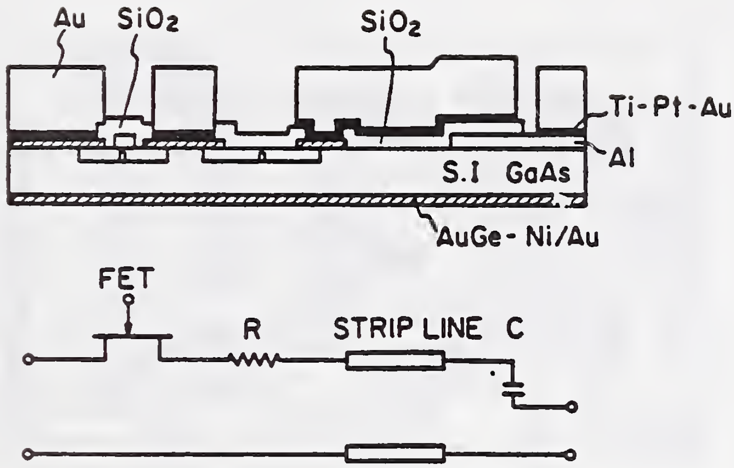


Figure 3-15

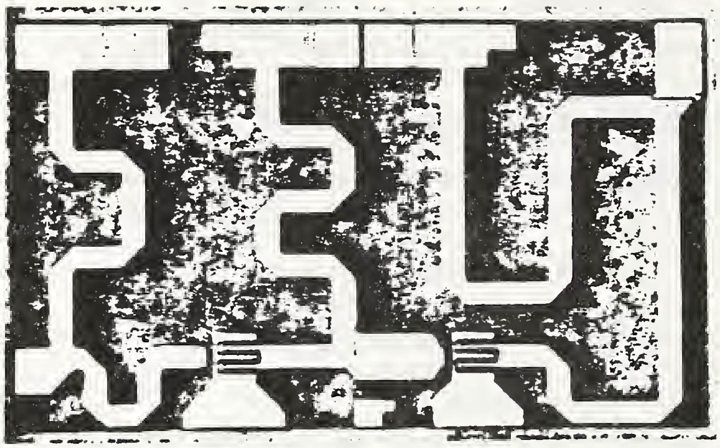
Circuit Elements: Cross-section View and Equivalent Circuit

- DBS Receivers -- The 12-GHz direct broadcast satellite (DBS) are the most important current application for GaAs monolithic MICs. Currently, they are under active development by several Japanese and U.S. companies. Single- and multiple-stage, single-chip low-noise FET amplifiers have been developed, as well as complete receivers comprising a monolithic low-noise amplifier, down-converter and IF amplifier on separate chips. First deliveries of such devices are expected before the end of 1984. An illustration of this technology is shown by the photomicrograph of a two-stage GaAs FET amplifier in figure 3-16.

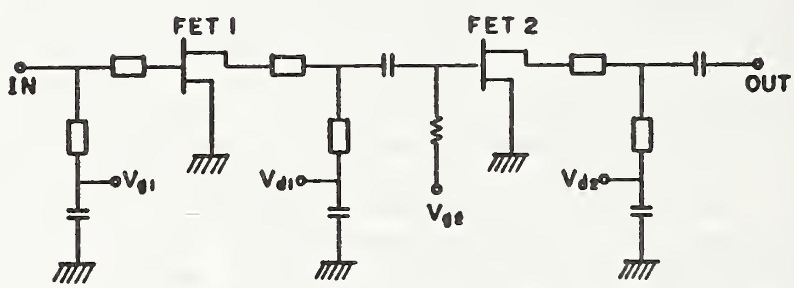
3.2.1.2 Technological Evolution

- 1984-1989 -- The key elements required to sustain low-cost, large-scale production of such monolithic MICs are:

  1. Good-quality, large-diameter, semi-insulating GaAs substrates;
  2. High-yield wafer processing;
  3. High-speed automated testing; and
  4. Low-cost circuit packaging.



Photograph of Amplifier Chip



Equivalent Circuit

Figure 3-16 TWO-STAGE GaAsFET AMPLIFIER

Continued development of each of these elements is proceeding. Many years and many millions of dollars of research and development work have already gone into the achievement of existing results, and much more will follow. Commercial telecommunications market applications alone, such as DBS receivers, cannot justify the scope of effort needed, but similar technologies are needed to support other high-volume applications, such as high-density Large Scale Integrated (LSI) circuits for future supercomputers, as well as for many critical military radar, missile and space applications. Most of the R&D funding has come from U.S. military agencies, but a very active program also exists in Japan, where interest in supercomputers is very high.

The Japanese interest in DBS, which is viewed in Japan as an extension of the consumer electronics industry rather than the telecommunications industry, is also high. The most impressive monolithic circuits for DBS receivers to date have been developed in Japan, and it appears likely that Japanese electronics manufacturers will be the first to market them commercially in the United States.

With future R&D funding tied mainly to non-telecommunications applications, we can infer that new GaAs MIC technologies available for telecommunications applications will be mostly limited to adaptations of devices developed for other purposes. Whether large-scale monolithic integration of microwave radio equipment circuits will ever occur is highly questionable, although it may some day be economically attractive to develop an adaptation of a DBS receiver front end for some microwave radio applications, as well as for other types of satellite earth station receivers.

Such eventualities may be dependent on the ultimate success of DBS in the marketplace; at present, this is very uncertain. However, there appear to be enough other potentially large volume applications for low-cost satellite receivers that the incentive to develop them will probably persist.

A likely timetable for further evolution is difficult to estimate. Significant achievements in the microwave semiconductor field tend to come via breakthroughs after long, unpredictable periods of slow progress. The last major breakthroughs occurred in the late 1970s, when the process for high-quality, stable, semi-insulating GaAs was finally made reproducible. Steady development of monolithic circuits has ensued; without any new breakthrough, continued development should follow a standard learning curve, with market volume a key factor in determining the schedule. By 1989, circuits for large-scale DBS receiver production (say, in quantities of over one million per year) may cost $10-50 each, or about one-tenth the cost of hybrid DBS MICs today. Beyond that time, costs are not expected to change significantly for similar technology. New technology will undoubtedly be sought, perhaps based on other materials, to achieve higher levels of system integration at higher frequencies, mostly for initial military applications.

With respect to the latter, there has long been a need for reliable, low-cost millimeter wave (30-300 GHz) MIC technology for applications such as terminal missile guidance, inter-satellite communications links, high-resolution radar and secure high-speed terrestrial data links. Although some work has been underway in the field for at least 15 years, progress has been limited. The most significant recent developments have concentrated on dielectric waveguides with discretely mounted active semiconductor devices. No viable approach to monolithic integration at millimeter-wave frequencies has been developed as yet, and no sign of a breakthrough is apparent.

It is far more likely that significant developments will occur at the opposite end of the microwave spectrum, in the 800-900 MHz range, where cellular mobile radio telephone systems are currently being extensively implemented. The use of GaAs MICs for receivers and (possibly) for transmitters may become economically attractive after further experience is gained. Competition is certain to drive down mobile equipment prices, and manufacturers will be seeking cost-reducing component technologies.

In summary, during the 1984 - 1989 period, the higher frequency, higher power, lower cost trend continues; also, circuit costs for DBS receivers will drop considerably.

- <u>1989-1994</u> -- Large scale demand for cellular mobile and other consumer equipment will spur continuing cost/effectiveness improvements.

- <u>1994-1999</u> -- Evolutionary rather than revolutionary advances in devices will continue.

3.2.1.3 Conclusions

Microwave integrated circuits are important to the development of mass-market microwave communications systems, such as direct broadcast satellites and possibly other types of radio communications such as cellular radiotelephone systems. Support for technology development will continue to come mostly from military sources in the United States, so commercial telecommunications developments will benefit to the extent that the basic technology will be "free." However, Japanese developers see such applications as direct development targets and have so far had the advantage of more focused technological efforts.

3.2.2 Optical Fiber Transmission

3.2.2.1 Background and Present Approaches

The transmission of information -- voice, data, or video -- by fiber optics has been made possible through the development of ultra-high-purity glass fiber lightguides, diode lasers, light emitting diodes, and photodiodes. Glass fiber cables are very strong, flexible, lightweight, immune to electromagnetic disturbances and secure. They also provide electrical isolation from transmitter to receiver, require no surge protectors and allow spans between repeaters much longer than obtained with metallic paired or coaxial cable.

Lightguides used in optical telecommunications are fabricated of high-purity fused silicon dioxide (silica) doped with precise amounts of germanium, phosphorus or boron, Two types are in use -- multimode and single mode. Both have circular cross sections with outer cladding diameters typically 125 microns. The core of multimode lightguide typically has a diameter of 50 microns. This is one of the sizes that is widely available, but there is currently considerable discussion on this subject taking place in X3T95. IBM has proposed a 140 micron cladding with a 100 micron core. Bell likes 125 micron cladding and 62.5 micron core, and has many thousands of miles of fiber of this size installed. Corning likes 125 micron cladding and 85 micron core. They argue that the larger core sizes facilitate connectorization and fiber switching when the latter is needed to bypass a failed node. To reduce mode velocity dispersion, the core refractive index is highest in the center and drops to a value slightly above that of the cladding at its periphery; this increases the information bandwidth of multimode lightguide to about 1500 MHz km in production runs.

Many systems of short and intermediate length have been installed using multimode lightguide. Most systems installed prior to 1981 operate in the wavelength band of 820 to 900 nanometers (nm), known as short-wave operation. The most recent multimode systems operate in the long-wavelength band of 1290 to 1550 nm.

The core of single-mode lightguide typically has a diameter of five to seven microns and a slightly higher index of refraction than the cladding. The index may be varied, as in multimode fiber. Most recent systems of intermediate and long length use single-mode lightguide and are operated in the long-wave band to minimize attenuation of the light signal.

The current status of lightwave component technology is outlined below.

- <u>Lightwave Guide</u> -- The materials composing optical fiber include silicon dioxide and germanium dioxide. Modes and attenuations for the most useful wavelengths are as follows:

Wavelength (nm)	Mode	Attenuation (dB/km)
820-900	Multi	3.0
1290-1350	Multi & Single	0.5
1490-1550	Single	0.2

- <u>Transmitters</u> -- Both diode lasers and light-emitting diodes are used as transmitters, with the following typical characteristics:

Wavelength (nm)	Output Power (milliwatts) Diode Laser	LED
820-850	1	0.1
1290-1350	1	0.1*
1490-1550	5	0.4*

Cleaved-coupled cavity tunable single mode diode lasers are the most recent advance in this technology, promising higher powers, linearity and low noise output. [STAFF COMMENT 17]

- Receivers -- Avalanche photodiodes (APD) or conventional photodiodes are used in the receiver front ends. Their typical characteristics are as follows:

Wavelength(nm)	Dark Current (microAmp)
820-850	0.001
1290-1350	1.0
1490-1550	0.01

Wave division multiplex technology is being used to multiplex two or more lightwave carriers on a single-fiber waveguide. The light waves differ by about 40 nm and do not interfere with each other. Each lightwave carrier may be modulated by independent information sources. Signal separation is done at the receiving end with selective filtering.

The application of wave division multiplex techniques to existing fiber cables and new systems will enable the systems to carry additional channels of information, potentially doubling or trebling the existing capacity.

3.2.2.2 Technological Evolution

- 1984-1989 -- Lightwave transmission systems are being employed in North America, the United Kingdom, Europe, Saudi Arabia and the Far East in a variety of land-based applications. These are classified into four basic categories: long haul, metropolitan trunking, rural exchange trunks, the loop plant. Transoceanic systems using optical technology are being planned for installation within five years.

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* These are available as laboratory models only.

- Long-haul routes average about 900 miles in length and offer high capacity (typically 20,000-60,000 voice circuits). The most recent Bell System long-haul system is type FT4E, which is a fiber-optic version of the DS4E transmission system. It uses single-mode lightguide, operates at 432 Mbps, and carries up to 6,048 voice circuits over a single fiber in each direction. Repeaters are 20 miles apart. These systems compete economically with microwave and have so underpriced coaxial cable in the United States that AT&T Technologies, the manufacturing arm of AT&T, has stopped making coaxial systems.

- Metropolitan trunking systems have high capacity, short spans and relatively short circuit lengths. Metropolitan trunking circuits have an average length of 7.8 miles and may have as many as 100,000 voice circuits in a trunk group. Most facilities are installed in underground conduits and are repeaterless, joining telephone exchanges in a metropolitan or city area. Included in this category are microwave entrance link routes from microwave facilities at a city perimeter to the main telephone exchange building downtown.

- Rural exchange trunks have circuit lengths ranging from 25 to 100 miles and link towns and villages. In the United States they often connect the exchanges of different telephone companies. Most of these systems have fewer than 5,000 voice circuits. The technology used in these applications competes with thin-route microwave radio systems.

- Loop plant extensions are loop circuits that are run out to clusters of rural subscribers remote from the serving exchange. They utilize lightwave subscriber carrier systems. Four-fiber optical cables connect the exchange office to an electronic concentrator 10 or more miles distant, providing service to a hundred or more subscribers. In the United States these systems (typified by AT&T's SLC-96) are economically competitive with repeatered metallic cables and TDM-PCM cable with concentrators.

A fifth major worldwide application of lightwave communications is in transoceanic systems, which are being developed for spanning the Atlantic and the Pacific. The transatlantic system TAT-8, to be owned jointly by AT&T and several European telecommunications organizations, illustrates the use of lightwave technology for very long distance, unattended transmission. The TAT-8 will have a route length of 6500 kilometers and a capacity of 36,000 voice channels. The 200 repeaters will be spaced 30-35 km apart. The system will use TDM-PCM transmission at a bit rate of 274 Mbps. Diode lasers and single-mode fiber operated at 1300-nm wavelength will be used. As presently planned, the lasers will have quadruple redundancy at each repeater, and optical switches will be used to connect one of the lasers to the transmitting fiber. When a laser degrades with age, it will be switched out of service and another will be switched into the system at the repeater in question. The cable will be armored and protected for prolonged deep-sea submersion. Its diameter will be slightly greater than one inch, and the entire length will be carried on one cable-laying ship.

- <u>1989-1994</u> -- Widespread application in medium- and short-haul systems as well as carrier subscriber systems. Transoceanic systems will proliferate.

- <u>1994-1999</u> -- Fiber transmission into homes will begin. Fiber will be the dominant transmission medium for virtually all fixed applications.

3.2.2.3 Conclusions

A major benefit to the telecommunications organization that installs a lightwave system is the capability of adding circuits to a given route at a later date by changing the electronic multiplexers or by adding wave division multiplex hardware at each end. The number of voice circuits that can be carried by lightwave cables is now limited by the multiplexers and associated light sources and detectors.

Other benefits include savings in duct space, because the cables can be installed in subducts inside the existing ductway. For metropolitan trunking applications, this approach permits the operating telephone company to postpone costly civil works construction of new ductways.

There are no problems in installing lightwave systems alongside power transmission cables or overhead wires, because optical cables are immune to interference from such systems. Similarly the security of fiber transmission is superior to radio or electrical transmission since light transmission cannot be detected outside of the medium. The use of common rights of way has obvious economic benefits as well.

3.2.3 Optical Logic

3.2.3.1 Background and Present Approaches

Several different physical effects exist in which electric fields modulate light beams, or light beams modulate other light beams, without requiring conversion from optical energy to electrical energy and back again. Repeaters for optical fiber communication systems now must go through this multiple conversion. These direct electro-optical interaction effects have been used in laboratory demonstrations of logic and switching circuits. In principle, any logic circuit that can be implemented in electrical logic can also be implemented in optical logic. The virtue of doing so is speed: the basic rise times of optical pulses demonstrated in some laboratory experiments are in the sub-picosecond range. Conceivable optical logic circuits could be built that are faster than anything achievable electronically.

Unfortunately, it appears that more power will be required per logic element in optical than in electron logic. The result will be a higher level of heat dissipation per gate, which will constrain the minimum sizes of the circuits. The operating speeds of the circuits will be a good deal less than the theoretical maximums, because of the signal propagation times through the volumes of materials needed to dissipate the heat. Electron logic is already constrained more by signal propagation times than by pulse rise times, so this requirement for higher power in optical logic appears to be a serious barrier to its widespread practical use.

A more promising application of optical logic is to the switching function in optic fiber communication systems. The concept involves bringing many fiber optic lines into a single switching matrix, where they are switched to various outgoing lines by means of conductors that are laid across the fibers and apply appropriately located electric fields. In this application, the switching operations occur only occasionally, so heat dissipation is not a serious problem, and the high data rates of optical fiber propagation are not reduced because of a need to convert signals to electric form for switching and back to optical form again.

At the present time, U.S. effort is limited to low-level R&D, mainly in universities. However, there is evidence that R&D efforts are being undertaken in Japan. Published information in the public domain is very scarce in this field.

3.2.3.2 Technological Evolution

The likely evolution of optical logic is shown in Table 3-8. [STAFF COMMENT 18]

3.2.3.3 Conclusions

It appears that optical logic will be useful in certain specialized forms in association with optical fiber technology, and probably also in optical transducer arrays used in image processing and communications applications. High-speed optical logic is unlikely to form an attractive alternative to electron logic in areas where it is presently dominant, but basic research in major laboratories in the United States, Japan, and Europe can be expected to continue.

The technology of optical logic is in an early, embryonic stage, and cost/performance trends are unpredictable.

Table 3-8 LIKELY EVOLUTION OF OPTICAL LOGIC

	1984-1989	1989-1994	1994-1999
Development	Multimode Switches are developmental. Makes use of mechanical motion of end of waveguide; or motion of prism. Switches are electronically controlled. Some switching experiments with films using opto-electronic effects. Switches consist of 1 input to 2 alternative outputs (1 x 2).	Multimode switches of several inputs/several outputs, e.g., 8 x 8 under development. More experimental/developmental bulk switching devices. Arrays of 1 x 2's are built. Switches are electronically controlled. AT&T uses 1 x 4 switches in Atlantic Ocean fiber optic cable.	Coupling single mode fibers efficiently to thin film fiber optical switches may be achieved. Integrated optical arrays made in developmental quantities. R/D on optical control of switches.
Competition	Largely at corporate research laboratories. University level research funded by NSF in the past. Some degree of military interest.	Corporate research laboratories University research. High military interest.	Corporate development. University research. High military interest. Spawns optical switching contracts and small R/D shops get into the act.
Alternatives	For optical communication systems: convert optical signals to electronic and perform conventional switching function then convert electronic signals to optical.	For optical communication systems: conversions to electronics-switch electronically -- conversion back to optical.	For optical communication systems: alternative is to convert to electronics -- switch electronically -- and convert back to optical.
Standards	Requirements for acceptable switching using conventional switching function are used for evaluating how well optical switching experiments turn out.	Conventional electronic switching standards used as a basis for comparison.	Conventional electronic switching standards used as a basis for comparison.
Penetration	Virtually none.	Miniscule in telecommunications. Some military applications possible.	Experimental switches put into operation in military labs. Still a long way to go before telephone company installs an optical toll office.

3.2.4 Coaxial Cable

3.2.4.1 Present Situation

This section on coaxial cable is included for completeness. Coaxial cable has been an important medium for:

- o Long distance telephone carrier systems,
- o Undersea cable carrier systems,
- o Wiring for local area networks (LANs), and
- o A medium for cable television (CATV).

The first two applications are no longer viable, and major manufacturers are scrapping coax production facilities.

3.2.4.2 Technological Evolution

- o 1984-1989 -- Some applications will be continued for LANs. No further R&D is being done on this basic medium.

- o 1989-1999 -- For CATV, optical fibers will also eventually supplant coaxial. Coaxial is a commodity item. Some residual use for small systems and expansion of existing systems still likely. [STAFF COMMENT 19]

4. INPUT/OUTPUT

4.1 VOICE SYNTHESIS/RESPONSE

Voice synthesis and analysis are closely related and are, in fact, two faces of the same coin. We will nevertheless consider them separately here.

4.1.1 Voice Synthesis

4.1.1.1 Background and Present Approaches

We will consider devices that can be programmed to speak different words or sentences in response to different types of inputs. Voice response systems, which have been on the market for many years, have been used mostly in connection with the telephone. In this application, a key-pad attached to a telephone terminal is used to transmit data via the telephone to a computer, which is connected to a voice response system. The voice response system then selects certain words or sentences and transmits these back to the user via the telephone. Such systems have been used for network messages, for announcement services, for transaction processing such as order entry, and for telephone answering service operations. The best-known example is the IBM 7770, which is a complete subsystem for the IBM 360 and 370 mainframe computers.

Until a few years ago, all voice response systems used recorded voice segments that could be assembled in different ways. Frequently, entire sentences were recorded in order to avoid problems associated with assembling separate voice segments into voice responses of acceptable quality. The big computer and telecommunications companies did not pay very much attention to this area; IBM, for example, has not offered a successor to its aging 7770 voice response system.

The general interest in voice response rose sharply when semiconductor manufacturers introduced voice synthesizers based on powerful large-scale integrated circuitry. The most familiar application was Texas Instruments' "Speak & Spell" device. The availability of inexpensive voice synthesizers has opened up an entire range of voice response applications in appliances, toys, aids for the handicapped and office equipment. In addition, voice synthesizers will make inroads into the traditional areas of recorded voice systems for network messages, announcement services, transaction processing, and information systems.

Recorded voice systems are programmed to respond to specific input signals or characters by selecting various segments from the analog recording and assembling them into an intelligible voice output. Synthesizers, on the other hand, use individual words or phonemes -- the basic sound elements of speech -- stored in compressed digital form. The synthesizer translates the digital pattern of phonemes or words into an analog output and intelligible speech by activating a number of resonators. [STAFF COMMENT 20] A synthesizer system usually consists of three parts: (1) a storage subsystem, usually a Read-only Memory (ROM) chip that stores the digital word or phoneme patterns, (2) the actual synthesizer subsystem, and (3) a microprocessor or microcomputer that controls the entire process. Whereas systems storing entire words or utterances are restricted to the use of these recordings, phoneme-based systems can also accept general text input and translate it into voice output.

As indicated above, there are some significant differences between synthesizers and recorded voice systems. In addition, the quality of the voice output of recorded voice systems is far superior to that presently achieved by synthesizers. Most synthesizers still have robot-like voices, without much intonation. This, however, is changing. The last year alone has seen some impressive improvement in the quality of synthesized voice output.

While the voice quality synthesizer is not as good as that of recorded voice systems, synthesizers have many advantages. To record a given number of minutes of speech, they require several orders of magnitude less storage capacity than do recorded voice systems. According to international telephone standards, the recording of voice in digital form requires 64 kbps. In contrast to this, synthesizers require only from 100 to a few thousand bps.

Furthermore, random access to and multiplexing of recorded voice segments is costly. Analog recording has to be laid out on a disk that must also contain a digital recording of address information. The comparatively small amounts of digital storage required for synthesizers makes random access and multiplexing much easier.

Recorded voice systems are always limited to the vocabulary and types of voices that have been recorded. A phoneme-based synthesizer, in contrast, has at least the potential of unlimited vocabulary and types of voice.

We believe that the long-term future potential of recorded voice systems is limited. On the other hand, we expect tremendous improvements and increasing applications of voice synthesizers. Within the next 10-15 years, synthesizers may completely replace recorded voice systems.

Two approaches to voice synthesis are presently in use:

(1) The first is based on storing a compressed digital image for each word or utterance. It is accomplished by converting speech input into digital form, which is then submitted to a type of spectral analysis for extracting and compressing a number of nonredundant parameters that represent the spoken word.

In response to a keyboard or computer input, the parameter set corresponding to the selected word is retrieved from storage and the parameter extraction process is reversed. The parameters are expanded and activate a number of resonators to create analog speech output. Several versions of this process currently use different techniques of parameter extraction and synthesis: the linear predictive coding method, developed by Texas Instruments; "waveform" digitization, used by National Semiconductor; and the partial correlation technique, developed by Nippon Telegraph and Telephone.

(2) An entirely different approach is the phoneme or formant coding method, such as DECTALK. Such systems are based on the fixed storage of a limited set of "allophones," which are variations of phonemes with different linkage and intonation characteristics. Each allophone is identified with a control word. When a given word is to be synthesized, the word is first partitioned into its phonemes. By applying a fairly complex set of rules regarding linkage and intonation, the appropriate allophones are selected. The decoded control words corresponding to the selected allophones then drive a parametric synthesizer--basically by activating resonators--to create the analog speech output. **[STAFF COMMENT 21]**

A comparison of these two approaches to speech synthesis shows that phoneme coding has a number of significant advantages over the compressed digital technique (see table 4-1). The greatest advantage of phoneme coding is the possibility of an unlimited vocabulary, since in principle all words and utterances can be constructed from the basic set of phonemes. This feature also makes text input possible, and allows the user to change the vocabulary without specialized and expensive equipment.

The greatest advantage of the first method is that, so far, the quality of the voice output is higher, because this approach does not truly synthesize speech but compiles recorded segments of actual speech. The phoneme-based approach still suffers from inadequate rules and algorithms for selecting and linking phonemes. However, impressive progress has been accomplished, and we expect this to continue in the future.

TABLE 4-1

COMPARISON OF APPROACHES

Linear Predictive Coding Partial Correlation Waveform Digitization	Phoneme Coding
o Higher-quality voice (currently)	o Potential for larger (possibly unlimited) vocabulary
o Less complicated processing hardware	o Lower storage and transfer rate requirements
	o Text input capacity
	o User can extend vocabulary without specialized equipment

Phoneme-based systems also have much greater potential for more sophisticated applications such as announcement services, transaction processing, information systems, and telephone answering services. Linear predictive coding and related methods will probably be used more in applications that require only a limited vocabulary and which are highly cost-sensitive, such as appliances, toys and office equipment.

4.1.1.2 Technological Evolution

We anticipate the following developments:

	Speech Synthesizer	Voice Response System
1984 - 1989	o Parameter extraction and compression and parametric synthesis refined	o Word-to-phrase linking preferred
	o Phoneme selection and linking improved	o Use of newly available videodiscs possible
	o Word-to-phrase linking improved	o Selected incorporation of speech synthesizers
	o Chip set and/or single chip prices to stabilize around $5	
	o Integration with voice recognition systems	
	o Entry (and re-entry) of mainframe computer manufacturers	
1989 - 1994	o Synthesis to reach quality of recorded voice segments	o Widespread incorporation of speech synthesizers
	o Human-like and personalized speech for unlimited vocabulary text-to-speech transcription	o Larger and user-expandable vocabulary, growing to virtually unlimited vocabulary
		o Choice of voice, personalized speech
1994 - 1999		o Automatic typewriter available

o Human-like two-way interaction will be possible.

4.1.2 Voice Recognition

4.1.2.1 Background and Present Approaches

Until very recently, to convey information to a machine, a user was obliged to employ a great variety of switches, buttons, and keyboards, and to read the machine's response optically.

The possibility of voice recognition opens up many new opportunities. While no one today can tell exactly where or in what form voice recognition technology will be applied five or ten years hence, it is clear that voice recognition is developing very rapidly due to the availability of large amounts of cheap processing power and storage capacity through the development of large-scale integrated circuits. Commercial voice recognition systems can now recognize several hundred discrete words. However, we are still far from the capability of recognizing continuous speech with unlimited vocabulary. The general-purpose, voice-activated typewriter is not yet in sight.

Speech recognition systems translate voice input into a corresponding character code. They can be employed to switch appliances or toys, to help handicapped persons, to enter data while the operator's hands are busy with other tasks, to control equipment in factories, to effect transactions by telephone, and to retrieve information from computerized information systems. Clearly, no one type of speech recognition system can serve equally well the entire range of possible applications.

Systems vary in complexity along at least seven dimensions:

- o discrete word versus continuous speech,
- o vocabulary size,
- o ability to recognize more than one speaker,
- o response time,
- o required quality of voice input,
- o amount of background noise, and
- o amount of training required. [STAFF COMMENT 22]

Current research on continuous speech recognition follows various approaches. One approach concentrates on broadening and perfecting the knowledge and use of many aspects of language, such as its acoustics, phonetics, and syntax; so far, however, it is not clear how such knowledge should be represented, nor how much of it is necessary to achieve reasonable recognition. Another approach is to let the recognizer organize itself automatically from the processing of speech data, rather than by using linguistic rules.

4.1.2.2 Technological Evolution

In the short and medium term at least, a more fruitful approach could very well be to develop application-specific or task-oriented continuous speech recognition systems. Here the recognition process relies on a store of phoneme templates (similar to those of formant synthesizers) and on a knowledge base store. The latter contains task- or application-specific information about phoneme syntax, vocabulary, and linkage structure. The speech analyzer extracts and normalizes parameters for the sampled time segments. These are then compared with the phoneme templates stored, to identify likely phoneme strings. Alternative strings of phonemes and words are then explored in a type of decision tree, and are evaluated by using the knowledge base store. This search-and-evaluation process is iterative until an optimal phoneme string and word sequence has been found. This is then accepted as the recognized speech and translated into a character code output.

While we will probably not see unlimited-vocabulary, unconstrained, continuous speech recognition until the 1990s, we will see some significant improvements in speech recognition capabilities. Chip sets for discrete-word, single-speaker recognition devices with vocabularies of 20 words are commercially available today for less than twenty dollars. As processing power and storage capacity increase and prices decrease, we will probably see some limited-vocabulary, continuous speech recognizers in commercial applications before 1989. Voice recognition and voice response systems will be combined for such applications as order processing and pay-by-phone. As voice recognition becomes increasingly important as a data entry method, we expect to see products from mainframe computer manufacturers.

During the beginning of the 1990s, we expect some commercial application of task-oriented, syntax-driven, continuous speech systems for several speakers and with vocabularies in the order of 1,000 words. Similar general-purpose systems could be available by the middle of the 1990s.

4.2 CHARACTER RECOGNITION

4.2.1 Background

Character recognition systems can read characters from typed, printed, or hand-printed documents, forms, and regular pages. Their output can be either a character code in some standard format (such as ASCII) or the input documents themselves, sorted according to specific criteria on the basis of characters read from the documents.

The principal components of a character recognition system are a document transport device, a scanner, a recognition unit, and a processor. The most critical components are usually the scanner and the recognition unit. The document transport device moves the input documents past the scanner. The scanner then passes the digitized image to the recognition unit, which extracts the characters. The processor controls the different components, including the document transport and various types of support subsystems, such as storage devices, printers, and output sorters.

The technology, applications, and markets for character recognition systems are fairly mature in comparison to voice recognition systems. New character recognition systems will offer more powerful and versatile recognition capabilities, and will be smaller and less expensive.

4.2.2 Document Readers/Sorters

Character recognition systems have been particularly successful in applications that require processing extremely high volumes of standard documents, the quality of which can be fairly well controlled. For this reason, batch processing of standard payments documents (such as checks) is by far the biggest application area for character recognition. Both magnetic (MICR) and optical (OCR) character recognition methods are commonly used in this application. Large systems read at a rate in the order of 10,000 characters per second and can process over 100,000 documents per hour. Other applications markets for document readers/sorters are much smaller, but some are growing faster, such as transaction processing systems, which typically operate in a start-stop mode with human operator input (e.g., processing of turnaround documents at a service counter).

4.2.3 Page Readers

Whereas document reader-and-sorter systems normally read only one or several lines of selected fonts, high-speed page readers are often much more versatile in terms of acceptable fonts and character sets. General data entry systems, for example, can read information from order forms, invoices, packing lists, social security forms, etc. Smaller page readers in OCR and other forms capture text prepared on typewriters for subsequent processing by word-processing, text-editing, and photocomposition systems. In another application, page readers capture text for subsequent communication by telex or TWX.

4.2.4 Hand-held Readers

Stationary hand-held readers are used mostly in department stores to read product labels imprinted with OCR font. Portable systems are also used to read preprinted item tickets and labels, in warehousing and distribution applications. Hand-held readers currently represent the fastest-growing segment of the market for character recognition systems.

4.2.5 Scanners

Most scanners are based on various types of linear photodetector arrays. We expect to see more use of integrated solid-state detector arrays with large-scale integrated circuits. Either charge-coupled devices or charge injection devices could be used. Interrogation logic, buffer storage, and switching are expected to be integrated into the scanner circuitry. Another interesting development is the solid-state-based flying spot laser scanner; with digital controls, this could become a very flexible and powerful device for a number of applications.

4.2.6 Recognition Units

Recognition units will benefit from the availability of more powerful and inexpensive processors. Use of such processors will allow the implementation of more complex algorithms for processing the image and recognition of characters. Of particular interest are algorithms that can be trained to recognize a wide variety of character fonts, including handwriting.

4.2.7 New Systems

Over the next ten years we will probably see a movement away from today's very large, centralized document batch processing operations and toward a more decentralized approach. The following systems are likely to appear on the market over the next ten years:

- A small document transaction processor with limited font capability and slow reading speed, to be used as a decentralized terminal in counter-type operations in banks and post offices.

- Low-cost multifont page readers with medium speed, to be connected to word processors and text-oriented telecommunications terminals as part of the trend in office automation.

- Compact and truly portable readers with slow reading speeds and exchangeable fonts, to be used as stand-alone units or as attachments to mobile data entry terminals.

- Omnifont readers that can be trained to read most typed and printed fonts and hand-print at medium to high speeds to capture general text for input into information banks.

In addition, in the 1990s recognition systems may become available which can be trained to read individualized, connected handwriting. Even though current technology is far from achieving this, there is little doubt that it can be done, if a supplier is willing to engage in a major software development program. The key question is whether there would be sufficient demand for this capability.

4.3 FACSIMILE

4.3.1 Background and Present Approaches

Although facsimile was patented by Alexander Bain of Scotland in 1843, it has only recently emerged from a long development stage and is now rapidly expanding. The primary reason for its slow early growth was the lack of several relevant technologies, such as photocells, amplifiers, transmission lines, modulation technology, and miniature circuitry. In addition, facsimile required computer arts such as software and microprocessing before its price/performance and utility could stimulate and supply a significant office market.

The technical feasibility of using the telephone to deliver a facsimile signal (telephone coupling) was demonstrated in 1935. However, except for news pictures and the transmission of fingerprints by the FBI (deemed to be in the public interest), regulatory authorities in the United States strictly forbade coupling of facsimile and other "foreign" signals into the switched telephone network.

A series of court decisions permitted the use of acoustic coupling, which enabled the Xerox/Magnavox Telecopier to circumvent the prohibition against interconnection in 1966, and other restrictions were removed by the Carterfone decision of 1968. The rules for the certification of interconnected equipment had been established by 1977 when the FCC permitted facsimile and other equipment to be connected directly to the telephone network without either acoustic coupling or telephone-company-supplied connecting arrangements. [STAFF COMMENT 23]

Leading-edge facsimile technology is now designed to meet the following goals:

- To place the burden of processing on software, while minimizing the use of hardware;
- To optimize the cost, reliability, and produceability of essential optical and printing transducers;
- To improve human factors (ergonomics);
- To keep pace with evolution of the International Standards Organization (ISO) Open Systems Interconnect reference model;
- To optimize compatibility with the developing integrated services digital network (ISDN); and
- To establish facsimile printers as the universal non-impact printers of choice to replace or enhance typewriters, office copiers, computer output printers, microfilm blowback copiers, and daisywheel printers.

To achieve these goals, development efforts are concentrating on compression codes, modems, scanners, printers, circuitry, electronic filing and optical storage, mail delivery techniques, image terminals, distributed office communications protocols, and ergonomics.

Mail delivers an original, and communicating word processors can deliver documents with the quality of the original. In contrast, most facsimile equipment cannot deliver a copy that even approximates the quality of the original.

Facsimile equipment is classified according to four "groups," numbered 1-4. Table 4-2 shows some of the more important characteristics of each group.

Group 1 and Group 2 facsimile copies, at 96 lines per inch (3.85 lines/mm), are barely of borderline quality for 10-point type and are legible only in context for 8-point type. An alternative mode at 64 lines per inch (2.5 lines/mm) is barely legible for 10-point type. It is an effort to read such "fuzzy" copy; eye and mental strain cause the reader to tire and even to develop

Table 4-2

COMPARISON OF GROUPS 1-4 FACSIMILE

Group	Speed		Terminal	Transmission	Resolution	Error Correction	Quality
	sec/page	bus					
1	360		Rotating drum scanner	Regular telephone line	96 lines/in. (3.85 lines/mm)	None	Low
2	180		Same	Same	Same	None	Low
3	24	2400 4800 7200 9600	Various	Regular telephone line	200 lines/in. (7.7 lines/mm)	High	Good CCITT
4			General purpose and non-impact printer	Data line		Low*	High CCITT Comparable to office copier

*Error correction done in data link

subconscious hostility toward the sender. Poor copy quality is the primary obstacle to general use of facsimile as a preferred document delivery method.

Groups 3 and 4 offer much higher resolution and speed, and also some form of "punch-through" error correction techniques that lower the transmission rate when repeating a block containing an error.

Various manufacturers offer equipment for groups 1-3; these devices usually operate together satisfactorily, because of standards issued by the International Consultative Committee on Telephone and Telegraph (CCITT), which have been adopted worldwide. Standards for Group 4 are expected before the end of 1984.

4.3.1.1 Compression Codes

Compression codes are sophisticated algorithms that act upon the digitized facsimile signal to reduce redundancy in the bit stream created by scanning the image. As employed in Group 3 devices, an analog facsimile scan is digitally encoded in terms of run lengths, or distances between horizontal changes in the picture. A second set of codes of ascending length describe run lengths of descending probability, so that the set of run lengths is described in a minimum of bits. This process is called "compression," because it compresses the description of a page into fewer bits of information. Since adjacent lines in facsimile are often very similar, a line can be encoded, not with new data, but by comparison with the preceding line. In 1969 Dacom developed such a run length code, plus a line comparison code every other line. These codes were incorporated into equipment supplied to compress newspaper facsimile transmissions of the *Wall Street Journal* between San Francisco and a publishing site in Riverside, California.

A year later, CBS and Savin Business Machines Company acquired Dacom and enlisted Ricoh as a partner in a venture to develop an office facsimile terminal based on data compression using the Dacom code. Although the product was developed and tested in the United States, it was made in Ricoh's Atsugi plant in Japan. In 1974 the CBS/Savin/Ricoh product, called the Rapifax 100, was introduced. Subsequently, Ricoh bought the CBS, Savin, and Dacom interests, obtaining 100 percent ownership of the Rapifax program.

Rapifax production helped to stimulate a major national effort to advance facsimile technology among Japanese manufacturers. Kokusai Denshin Denwa (KDD), the Japanese government-owned international telephone carrier, developed an improvement over the Dacom code called the Relative Address Code and offered it as an international standard. Six other codes were offered by AT&T, 3M, IBM, Xerox, the British Post Office, and the West German Bundespost. The CCITT selected a British modification of the

Japanese code; after still further modification, the latter became known as the Modified READ (Relative Address Designate) Code, which was adopted in 1980 by the quadrennial CCITT Plenary Session as an international recommendation (standard).

Higher compressions have been achieved by Compression Labs Inc., Bell Telephone Labs, and Bell Northern Research by use of a combined Modified READ and "dictionary" code system, in which each new "lump" (a letter-size mark surrounded by white), found on the page is given a short code and assigned to an accumulating "dictionary" of symbols. Both sender and receiver compile these dictionaries as transmission progresses. The next time the sender sees the same symbol, it merely sends the short code rather than the full Modified READ description and thereby avoids transmitting many bits. The dictionary codes must allow tolerances for recognizing the previously accumulated symbols in the dictionary; therefore, the reproduction is not exact, but the practical difference is small.

The Modified READ Code was selected as a standard because it is an efficient compressor and is also reasonably forgiving when bit errors occur during transmission over the telephone. To assure that "shadows" of bit errors do not spoil the rest of the page, a fresh start, coding with new run lengths, is made every one-fiftieth of an inch down the page--i.e., every two lines at 100 lines per inch (3.85 lines/mm) or every four lines at 200 lines per inch (7.7 lines/mm).

Group 3 devices employ a considerable amount of error correction within the device itself. In contrast, Group 4 devices will use data links; therefore, the technology of the data link must ensure low-error delivery of the bit stream. Group 4 devices can employ a code that need not be tolerant of errors, permitting a corresponding reduction in bit overhead related to error detection and correction. CCITT Study Group VIII has tentatively adopted the Modified READ Code, but without restarting every one-fiftieth of an inch, a variation known as "Infinite K" or "Wraparound."

The effectiveness of compression codes is demonstrated by the fact that Group 1 facsimile at 96 lines per inch (3.85 lines/mm) requires six minutes of telephone time to transmit a page. Group 3, using a compression algorithm, can transmit the same amount of text in less than a minute with twice the number of lines per inch. The exact amount of compression depends on the amount of image detail on the page; for a typical letter, transmission of the page (using a 9600-bps modem) takes only 24 seconds of telephone time.

4.3.1.2 Array Scanners

Traditional electro-mechanical facsimile scanners examined the diffuse optical reflectance of copy to be sent by looking at the light reflected from a single, small spot (called a pixel or "picture element"). The small spot sweeps across the page from left to right and line by line from top to bottom, until the spot content of the page has been completely reported. The usual practice is for the copy to be mounted on a spinning drum under stationary optical systems.

The new technology scans the original very differently. A linear array of photocells on an elongated silicon chip scans all the picture elements across a page of text in parallel. The output video signal, proportional to the reflectance values, is reported from each photocell in turn. The video signals from each photocell are thresholded to represent either black or white, a process called "digitizing." Group 3 scanners have 1,728 photocells (2,048 if they can scan 10.1 inches, as many Japanese Group 3 machines can). The current favorite among cell array designs is the charge coupled device (CCD), which has advantages in shifting the individual cell signals without distorting their levels.

The facsimile scanner is built like a camera, with the CCD array occupying the position normally held by the film. The camera focuses on an illuminated line across the width of the subject copy. The copy is fed by a stepper motor, which advances to the next line whenever the first line has been scanned, digitized and compressed. In many Group 3 terminals, the stepper motor and paper feed are the only moving parts, and the terminals are virtually silent in operation.

4.3.1.3 Optical Character Recognition Scanners

The marriage of facsimile with optical character recognition offers a number of advantages for the communication of printed material and the input of documents into future integrated office systems.

According to industry estimates, 80 percent of the facsimile page volume transmitted in the United States consists of alphanumeric text or a mixture of text and graphics. The ability of combined OCR and facsimile technologies to recognize individual letters as eight-bit character codes would not only achieve data compression ratios of more than 50:1 but would also permit the recognized text to be edited by a full-text document retrieval system and transmitted by alphanumeric electronic mail systems. Mixed-mode documents, such as letters containing a corporate logo and signature, could be captured without the loss of either information or pictorial content. OCR would also facilitate communication between the facsimile scanner units and byte code-oriented computer systems. Such a system is envisaged in the CCITT "mixed-mode" version of Group 4 facsimile.

The marriage of OCR and facsimile in Group 4 mixed-mode should allow the capture of all incoming documents for transmission and processing by an integrated office system. A primary factor delaying the integration of facsimile and OCR technologies has been image quality. While Group 3 facsimile offers a resolution of 200 lines per inch, most OCR readers require 400 scan lines per inch to recognize alphanumeric characters. [STAFF COMMENT 24]

The availability of Group 4 facsimile scanners with 400- line-per-inch resolution should eliminate any barrier to the mating of OCR and facsimile technologies. HiTech Canada Ltd., a Canadian OCR vendor, has addressed the issue of resolution quality by interfacing a standard Muirhead Group 3 facsimile unit with a PDP-11/23 microcomputer; using proprietary software to recognize typewritten fonts, it has achieved a 64:1 data compression ratio. Kurzweil Computer Products of Cambridge, Massachusetts (a subsidiary of Xerox) markets a high-end OCR system that uses artificial intelligence techniques to recognize any printed or typewritten font. Because of the costly software development effort and the computer characteristics needed to drive "omnifont" OCR, a typical configuration of the Kurzweil Data Entry Machine (KDEM) now costs $60,000-$100,000. However, amortization of programming costs and advances in microcomputer chip technology will probably reduce the price of omnifont recognition sufficiently so that it will be commonly bundled with OCR scanner units by 1990. In the meantime, Kurzweil is rumored to be developing new software that would allow its units to transmit digital facsimile through a distributed network.

Several Japanese facsimile vendors have either announced or are developing products that combine facsimile capabilities with conventional low-end OCR page readers. Toshiba, Matsushita (Panafax), and NEC are all known to have units that can recognize multiple typewritten fonts and can also transmit Group 3 protocols. Ricoh has shown a system for the Japanese market which combines store-and-forward capabilities for computer services, Group 3 facsimile, and software to recognize handwritten and printed Japanese characters. [STAFF COMMENT 25]

4.3.1.4 Array Printers

Like the recent scanners, modern printers are based on the use of arrays. For archival copy, a page-wide row of styli deposits charges on dielectric paper to form an electrostatic latent image, which first is rendered visible by toning and then fixed by heat, pressure or both. The most advanced example yet on the U.S. market, the NEC III-C, uses two interleaved stylus rows, each with 200 styli/inch; the charge depositions are properly timed to recreate the 400 dots/inch observed by the scanner (which has a CCD with 4,096 cells). The copy quality exceeds that of many office copiers.

Lower-cost Group 3 printers use 200 tiny heater elements per inch (called nibs), 1,728 of which are arrayed across a standard 8.5-inch page. A special paper with a surface emulsion of a leuco dye is used. The surface is white unless it is heated above a certain temperature (typically 235 degrees Farenheit), at which the emulsion collapses and appears dark. The nibs are heated electrically to this temperature for only about 2 milliseconds when a mark is desired. When de-energized, the nibs quickly become too cool to cause a mark. In this way the array of thermal nibs produces marks that replicate the dot pattern of the transmitted digital image.

The above is a one-step marking process, requiring no further action. The copy is not archival, as the thermal mark can fade with time, particularly when in contact with plastic or exposed to many common liquids. An archival copy, if needed, can be made from the thermal copy on a plain paper office copier. The thermal paper process is inexpensive because it is simple. The typical Group 3 terminal rendering archival toned copy costs about $10,500, while the equivalent Group 3 thermal terminal costs about $7,500.

4.3.1.5 Laser Printing Systems

High-speed laser printing systems will also play an important role in future facsimile products. These systems will offer the high-resolution output required by Group 4 protocols, the ability to mix bit-mapped graphics printing with press-quality ASCII character-fonts, and printing speeds of hundreds of pages per minute on ordinary paper. Since these units are being configured as the "print server" of many distributed office automation networks, their ability to display facsimile output is important to the integration of facsimile with the multifunctional office systems of the late 1980s.

Laser printing systems, like the electrostatic and xerographic printers that preceded them, are based upon the principle of recording a latent electrostatic image on a photosensitive drum. The drum rotates through a toning station, where the toned image is transferred to paper. In a facsimile printing system, the scanned digital representation of an image is used to control the output of a laser that scans the drum, much as a lens directs reflected light in a photocopier.

The price of the fastest laser printers ($100,000- $350,000) has limited their use to the most demanding data processing applications. However, several lower-speed units that produce 10 to 36 copies per minute have recently been introduced; these cost $10,000 to $20,000 and have all the graphic capabilities of the more expensive systems. Cannon's $9,000 LBP-10 desktop unit has been adopted by several U.S. manufacturers of computer workstations. Xerox began selling its graphics-capable Model 2700 laser page printer in July 1981, priced at $19,000. Both Hitachi and Fujitsu have demonstrated low-cost integrated systems offering CCD page scanning, photocopying, and laser printing functionality. These units will inevitably be adapted for facsimile.

4.3.2 Technological Evolution

- <u>1984-1989</u> -- The average per-page cost of delivering a facsimile copy in the United States and Canada in 1982 (including the costs of both delivery service and equipment) was 69 cents. This cost is strongly affected by the scale of operation. Greater traffic obviously reduces the cost of equipment on a per-page basis. Faster terminals have also reduced cost in two ways: (1) lower telephone charges for a shorter transmission time per page, and (2) spreading terminal costs over a greater number of pages per terminal per unit time. High traffic volumes, particularly those expected with message-switched Group 4, will permit batching of traffic for delivery on wide-bandwidth channels (e.g., satellites), which will reduce per-page costs. Over the 1966-1982 period, each 10 percent decrease in per-page delivery cost corresponded to a 20 percent increase in the overall market. Substantial further decreases in delivery cost and corresponding increases in facsimile usage can be expected through at least the mid-1990s.

Group 4 will become common during the 1984-1989 period.

- 1989-1999 -- Lower costs will lead to continued expansion of use.

4.4 TERMINALS

4.4.1 Background and Present Approaches

"Terminal is an umbrella term that covers an array of equipment on the premises of the user, whose functions include voice or alphanumeric graphic communications in either video or printed form. The most common voice terminal is the ubiquitous telephone set. Alphanumeric terminals include a variety of sub-categories such as: (a) teleprinters and receive-only printers, (b) keyboard/display units, (c) remote batch devices, and (d) communicating word processors. Similarly, graphic terminals include the following:

- Analog facsimile,
- Digital facsimile,
- Non-impact printers,
- Teleprinters,
- Intelligent copiers, and
- Graphic keyboard/displays.

- Alphanumeric Terminals -- Alphanumeric terminals with typewriter-like implementation and employing electro-mechanical technology were the most common units until the late 1960s. Following the Carterfone Decision in 1968, and led by advances in computer technology during the last decade, their development has been rapid. These typewriter-like devices employ some form of storage for intelligence; this was originally punched paper tape, later displaced by magnetic tape cassettes, floppy-disks, bubble memory, and rotating hard disks. Keyboards and video displays are now used extensively and have almost replaced teletypewriter terminals in new installations.

Before the liberalized interconnection policies that followed the Carterfone Decision, teleprinter technology in the United States was dominated by the Teletype Corporation. Terminals were included in carrier services such as telex, TWX and Dataphone, as well as in private-line message and data communication systems. The most common teleprinters during this period were the Teletype Models 33 and 35, for light and heavy-duty service respectively. These terminals were designed for the ASCII Character Set, which employs a 7-bit code to define 128 printer actions. Of these, approximately 96 actions are printed characters; the remaining 32 for functions such as line feed, carriage return, and backspace.

Electromechanical switching systems, used in private line operation, transmitted control sequences to the teleprinter-type terminals for polling operations. In effect, the switching system allocated its own internal resources to each terminal in turn, and asked if the teleprinters had a message (on tape) ready to send. If the terminal contained no tapes to send, its negative response caused the switch to interrogate the next printer in the sequence.

These printer polling controllers used relay technology and a few discrete electronic components. All-solid-state controllers, such as the Western Union 11708 Solid-state Selector, had been developed by the early 1960s, but electromechanical designs were significantly cheaper and substantially equal in reliability until the early 1970s. Today, most control circuitry is of solid-state design.

During the past decade, a number of new character-forming printing technologies have been introduced, many of which employ percussion concepts -- namely, the typeball, daisy wheel, and serial impact matrix-type printers. Among the non-percussion designs, some use ink-jet sprays to form the characters; others use lasers to burn the character into the paper or form an electrostatic charge that attracts toners, as in the xerographic process. Thermal printers employ localized heating to discolor special paper.

Of these various designs, the dot matrix is probably the most widely used. One manufacturer claims to have sold more printers of this design than all other types combined.

Dot matrix printers are now available in three standard pitches (10, 12, and 15 characters per inch). They can also print elongated characters, bold face, and super- and sub-scripts. They operate up to 20 times faster, are half as heavy, and cost half as much as "letter-quality" printers. These significant advantages suggest that the daisy wheel and other kinds of fully formed character printers will not be economically competitive in a few years.

- Keyboard and Displays -- A typewriter-like keyboard with a cathode ray tube (CRT) display is presently the dominant terminal technology. CRT terminals were first used commercially in the mid-1960s with the IBM 2260 Video-Display Terminal. Other companies, such as Baker and Bunker-Ramo, also offered CRT terminals at that time for stock-quotation services. Teleprinter replacement products were developed by other manufacturers after the TWX acquisition by Western Union. The Bell System emphasized terminals with higher baud rates, since it was enjoined from selling low-speed terminal devices. During this period, they introduced the Teletype Model 40 CRT keyboard terminal.

  Keyboard and display terminals are differentiated primarily by the level of intelligence incorporated within the terminal itself. The initial units were designed to access the processing power of the central computer with such functions as interactive time-sharing data entries and information retrieval. Many of them also had primitive editing capabilities using combinatorial logic. Later, more intelligence was added for such functions as stored forms and syntax checking of data that had been entered into the fields of such forms.

  The main thrust of this direction encouraged microprocessor developments; for example, Datapoint stimulated the development of the Intel 8080 microprocessor. Other independent manufacturers, such as Sycor and Incoterm, competed in the intelligent-terminal arena with similar concepts and technology.

  "Dumb" keyboard CRT terminals (i.e., those with little or no editing capability) range in price from $1,000 to $2,000. These are used principally for time-sharing and transaction-type processing in which the host performs all syntax and other processing functions. "Smart" terminals perform editing functions and cover a broad price range; for example, the IBM 3270 compatible versions are supplied in stand-alone, small-cluster and large-cluster versions. The average price of the stand-alone version ranges from $2,000 to $3,000; of the small-cluster version, $20,000 to $40,000; and of the large-cluster version, $50,000 to $120,000.

  "Intelligent" terminals are considered to be those with one or more programming languages available to permit the generation of programs within the terminal configuration itself. The language can be either general-purpose, such as basic COBOL, or special-purpose, such as data entry language. These range in price from about \$2,000 to \$15,000 and include most personal computers with communication ability.

- <u>Telephone Equipment</u> -- The telephone set represents a technology and concept that evolved in the late 1890s and, although improved continuously, differs in no important concept from the earliest versions. Its most significant feature is the carbon-button microphone or transmitter. This device has the distinction of offering a real power gain of about 30 decibels (dB) -- i.e., a power gain of about 1000 times -- when transducing from acoustical to electrical power; almost all other forms of microphone technology introduce a loss of about 20 dB or more when converting acoustical to electrical power. These other microphones must be connected to an amplifier that supplies 50-60 dB of gain to equal the output of the carbon-button microphone. Since the latter costs three dollars or less, there is little reason to switch to something else.

  This unusual characteristic of the carbon-button microphone has influenced the design of subscriber outside plant of all telephone companies worldwide. The outside plant design depends upon the fact that the carbon-button microphone will deliver about 30 dB of gain. The energy that is amplified must come from a power source of some sort -- in this case, a d-c voltage supplied by the local central office.

  The gain of the microphone varies with the amount of current that flows through it; i.e., the gain is reduced as the current is reduced. In practice, this means that the output of the carbon-button microphone tends to drop in proportion to the length of the subscriber's line. This is avoided by employing conductors of larger gauge (hence lower resistance), and by using booster batteries at the central office for the longer lines. Many modern carbon-button microphones become virtually inoperable when the current drops below about 20 milliamperes; thus, subscriber outside plant must be designed to provide at least this amount of current to all subscribers.

  The current for the carbon-button microphone is usually fed over the copper or other metallic line which connects the station apparatus with the central office equipment. This has caused no real problems in the past, other than the fact that the output of the microphone is reduced with distant subscribers. Accordingly, the length of subscriber lines is limited, depending upon the gauge of the conductor. It has become increasingly difficult with more modern techniques to supply the current from the central office, and a local power source is sometimes needed to provide current for the microphone. This will become an absolute necessity when optical fiber replaces metallic conductors in the subscriber loop, or when some kind of carrier-derived pair-gain system is used.

Thus, some future telephone sets will include battery systems with built-in chargers that can be energized by "plugging into the wall." A distinct advantage that derives from this approach is that the current supplied to the microphone will no longer vary with the length of the line that connects it to the central office equipment, and the output of the carbon-button microphone will be stabilized. At the same time, other microphone technologies will become more competitive, because the cost of electronic circuitry to supply 50 or 60 dB of gain will drop.

4.4.2 *Technological Evolution*

- 1984-1989 -- The telephone industry can expect the development of electronic circuitry which can extract a single digital voice channel from a large number of channels on the customer's premises. Initially, the purpose will be to extend digital transmission of voice all the way to the subscriber, and to provide the capability for the Integrated Services Digital Network (see section 3.1.8).

  In general, during this period personal computer-based terminals enter general use.

- 1989-1994 -- Voice, character, and image functions will converge.

- 1994-1999 -- Extremely user-friendly conversational interaction with voice-data systems will become commonplace.

4.5 TELECONFERENCING

4.5.1 *Background and Present Approaches*

There are two major types of teleconferences: telelectures and telemeetings. Telelectures can be characterized as teleconferences where the primary flow of information is from a single source outbound to multiple destinations. For example, the Chairman of the board conducting multiple stockholder meetings in many cities, or the marketing Vice President of a large corporation addresses his field sales staff. Telelecture meetings are usually scheduled and coordinated well in advance. The information flow outbound to the multiple sites is generally rich with graphics and prepared slides. At telelectures, physical materials, such as slides with remote slide projectors, can be delivered to the sites well in advance of the actual event. The recent low cost of satellite video-transmission systems facilitates full-motion video transmission to the outbound sites. The flow of information from the outbound sites to the central site is generally restricted to audio only. The bulk of teleconferencing now actually taking place consists of telelectures.

Telemeetings, on the other hand, are generally arranged on an ad hoc basis. They usually consist of one-to-one interactions between individuals or small groups, and are generally point-to-point with only two locations involved. For example, members of the design engineering department of a manufacturing organization located in a city may wish to discuss a manufacturing problem with their manufacturing engineering counterparts located at a factory in a distant city. Another important telemeeting application is for corporate executives to communicate with divisional management staff to save on travel time.

In both types of teleconferences, the information flow both inbound and outbound may consist of any combination of the following:

- o Voice,
- o Facsimile or hard copy,
- o Slow-scan video,
- o Slow-motion conference quality video,
- o Full-motion broadcast quality video,
- o Remote control slide projectors,
- o Computer graphics, and
- o Electronic blackboards.

Because telelectures are generally scheduled in advance and carefully orchestrated, electronic blackboards have little application to this form of teleconference use. Some limited applications could exist during question and answer sessions in telelectures but the limited availability of full-motion video zooming in on a conventional blackboard would limit even this usage.

Most telemeetings today are conducted using two-way audio only (e.g., speakerphones). Some organizations have, in fact, equipped conference rooms with speakerphones and some one-minute facsimile machines to facilitate written communications. An electronic blackboard which permits information drawn on location A, using a conventional writing implement or a special stylus, can simultaneously appear at location B and facilitate the ad hoc written and spoken dialogue that takes place during the telemeeting.

Electronic blackboard products, and indeed telemeetings in general, are not in widespread use. However, there are several experimental products that have been introduced.

AT&T Bell Laboratories has demonstrated an experimental product called Gemini, which consists of a blackboard-like transmitting device at the originating location and conventional television monitors at the receiving locations. Conventional digitizer technology locates the X and Y coordinates of the stylus that is writing on the blackboard. These X and Y coordinates, coded in digital form are sent using conventional data communications links over voice circuits to the distant location. At the distant location the transmission is decoded which results in vector stroke entries being mapped in a printing memory image bit plane. Video display generator technology, such as used in video games and personal computers, changes the spatial representation in the memory bit plane into a serial U.S. broadcast quality television signal.

Nippon Electric Corporation (NEC) has developed a simple system called Telesketch. The input device at the originating station resembles a familiar child's toy consisting of a soft blackpitch pad with a waxpaper overlay. In the NEC telesketch system, the pad consists of flexible plastic with facing linear matrix electrodes. One plastic sheet has the electrodes running in the X direction, the other the electrodes running in the Y direction. The electrodes terminate at the edge of the sheets where they butt with a material of considerable resistivity. A sheet of paper can be layed over the telesketch pad and when written upon with a conventional writing implement, the pressure deforms the plastic sheet and causes the electrodes to contact each other. By means of only four wires running into the telesketch pad, external circuitry can resolve the X and Y locations by measuring the resistance from one end of the bonding electrode to the other. Resolution and accuracy are sufficient to transmit both occidental and oriental handwriting. At the remote end the image can be displayed on a television monitor in a manner similar to the Gemini system.

Other forms of image transmission technology are competitive with electronic blackboards in that they allow the ad hoc spontaneous interaction and communication of written material. These competitive systems include:

- o All television technologies from slow scan to full motion,
- o High-speed facsimile,
- o Computer graphics -- since data typed on the keyboard, and graphics data entered with pointing devices, can be transmitted.

These competitive technologies are already highly developed and in use for Computer Aided Design and business graphics applications. While they are perfectly suitable for telemeetings, they have not yet been exploited for such applications.

4.5.2 Technological Evolution

- o <u>1984-1989</u> -- During the next five years we expect telemeeting technology and services to undergo periods of experimentation and further development. We expect the personal computer and the managerial/technical executive workstation to drive these applications. We do not expect stand-alone electronic blackboards, separate from personal computers, to find significant usage. A possible exception may be in educational institutions employing central teaching staff. While this use represents a perfect technology fit, labor, institutional and structional barriers may slow development of this application.

Low cost personal computers with graphics input capability already exist; for example, the Apple MacIntosh and Apple Lisa, and Xerox-Star workstation. The mouse is currently and will continue to be the predominant input form during this timeframe. XY digitizing cards, using low-cost technology similar to the NEC Telesketch and other conventional techniques such as ultrasonic sound-ranging, and field-disturbance senses, will be employed. Transmission of images will be through conventional data transmission technologies with upper limits in the 1200 bps range. Generated images are likely to consist of alphageometric coding techniques such as the North American Presentation Level Protocol Syntax (NAPLPS), with some color possible. The system resolution will be comparable to that provided by NTSC television limiting written text to the order of 40 characters per line and 24 lines.

- 1989-1994 -- During this time period, improvement will most likely be observed in the following:

  - Data transmission range,
  - Image compression techniques making more efficient use of data communication channels,
  - Increased resolution, and
  - Increased use of color.

  In addition, expansion in forms of input devices will be used with software specifically oriented for personal computers functioning as electronic blackboards beginning to proliferate with some commercial use.

  We expect pointing devices, such as light pens, to see wider use during this timeframe. XY digitizing pads will reach larger volume production and decrease significantly in cost. We expect the availability of low-cost data transmission systems in the 4800 bps range to be available and, in installations where higher cost can be justified, speeds of 9600 bps will be used. Low-cost signal processing systems and technology will permit highly compressed images to be efficiently coded for rapid response in transmission of sketch material. Resolutions of black and white systems, and monochrome systems should double beyond the U.S. broadcast TV standard and high resolution color displays capable of displaying 80 characters per line and 24 lines should become available.

- 1994-1999 -- During this five-year timeframe the trends of the preceding five years will continue in addition to the use of electronic blackboards provided in the personal computer workstation. Other functions will be integrated and share the data compression and data transmission systems. These should include television camera input for documents and faces in addition to high-level software retrieval, manipulation, and editing of entered images and sketches and using the electronic blackboard input device. Performance improvements should permit the transmission of TV quality images over dial-up circuits in the subminute-per-frame time range.

4.5.3 Conclusions

The availability and widespread proliferation of personal computers providing electronic blackboard and other teleconferencing functions will allow practical and economical ad hoc telemeetings to flourish. We expect more widespread use of telemeetings as an alternative to travel with attendant increases in executive and managerial productivity.

At the present time no commercial hardware exists for performing the electronic blackboard function, therefore, no prices have been established. However, personal computers with pointing devices, graphics display and storage functionality are available in the $2,000 range. To provide basic electronic blackboard functions with these devices will require nothing more than software to accommodate these needs. Since a widespread mass business market has already been established, future developments will go into improving the performance rather than significant reductions in cost. During the next 15 years we expect the primary performance improvements to be:

- Increased resolution,
- Widespread use of color,
- Hard-copy high resolution in color graphics output, and
- Rapid speed transmission through use of high-speed data communications and compression algorithms.

STAFF COMMENTS

The staff comments in this section are keyed to the body of the text of Part I. For example in section 1.2.3, [STAFF COMMENT 1] appears in the body of the text. Below, the comment is labeled 1.2.3 and **STAFF COMMENT 1.**

1.2.3

STAFF COMMENT 1

While manufacturers will continue to supply products not based on standards, this period should experience a major growth in the area of products conforming to standards. An indication of this is the continued workshops originally held in preparation for the NCC '84 demonstration.

STAFF COMMENT 2

Sometime during this period intercommunication between computers of different manufacturers should be fairly routine.

STAFF COMMENT 3

We find this unclear. We believe that even in the 1990s 6th and 7th level standards will still be under development for some present services.

1.2.5

STAFF COMMENT 4

Currently, manufacturers are factoring the standards into their product planning cycles. It is more likely that as products evolve to the communication standards, little, if any, additional costs would be incurred. The expected trend is for the gradual replacement of internal standards with international standards.

STAFF COMMENT 5

Figure 1-2 indeed supports the contention that universal OSI equipment will be a better bargain than band-aid solutions. However, the cost differential between OSI and conventional equipment is discouraging. It will take a lot of convincing to stimulate initial investments in universal OSI equipment.

STAFF COMMENT 6

Advising a buyer to obtain OSI standard equipment doesn't solve his problem as suggested in this paragraph. Consider X.25 which has too many options. In this case, a user is better advised to not only consider OSI, but to consider a specific set of options from an OSI protocol suite, for example, NBS FIPS 100. The point is, specifing OSI is not sufficient.

3.1.1.3

STAFF COMMENT 7

We feel that the changes in component technologies will occur before the 1989-1999 time period.

STAFF COMMENT 8

A different opinion on the conflict between broadband and baseband transmission techniques for cable-based LANS is that the conflict will not be resolved but that both will continue to exist.

3.1.1.4

STAFF COMMENT 9

Table 3-1 lists the price of a data switch as $175 to $275 per port plus $250 for installation and for a cable-based network, $500 per port plus $100 for installation. Both of these estimates seem to be low.

STAFF COMMENT 10

This section skips around the primary benefit of LANs, namely device integration. LANs enable people to use their workstations for multiple purposes, thus enhancing LANs' cost-effectiveness.

3.1.1.4

STAFF COMMENT 11

It should be remembered least cost is not the only factor; the services given by the LAN are far more extensive than the other techniques.

3.1.4.3

STAFF COMMENT 12

I realize that I probably hold a minority viewpoint, but I believe that the concept of cellular mobile radiotelephone has been oversold and its market potential overestimated.

I believe that there are only a relatively limited number of persons in the civilian environment that require continuous access to the switched telephone network. There are many more that require continuous capability for communication, but these are largely specialized services such as law enforcement, fire or other emergency services. Their requirements are best served by the dedicated communications networks that they have established, as these do not have the access delays associated with dialing on the switched telephone network. Similarly, military command and control requires a continuous communications capability, but I do not personally visualize cellular radio as playing a major role in this.

The market that I anticipate for cellular radio is comprised largely of the following:

a) Some members of the medical profession. Out of hours calls are presently directed through, and filtered by, doctors' referral services. In many instances the current "beepers" will prove to be more cost effective than portable cellular radiotelephones.

b) Certain handicapped persons. Handicapped persons that are able to drive a specially equipped car, but not to walk, might find the cellular system to be a cost effective system to ensure that assistance could always be summoned in the event of a breakdown.

c) Prestige users. This is the same group of business executives and bureaucrats that use the chauffeured limousines or buy the big Mercedes and Rolls.

d) Speculators in options or commodities. Here, the ability to learn about and react to market changes in a responsive manner can make cellular radio a cost effective tool.

e) Certain limited classes of sales work and of maintenance work. A large fraction of the persons in these sorts of activities can more effectively keep in touch with their offices using a borrowed customer phone or a pay phone.

f) Others. There are undoubtedly others that I cannot think of at the moment, but I do not believe that their numbers will begin to be large enough to fill the expectations of the purveyors of cellular radio. Personally, I would not give $10 per month to have one in my car.

3.1.4.5

STAFF COMMENT 13

We think that cellular radio may prove useful for data applications as well as for voice.

3.1.5.3

STAFF COMMENT 14

We believe that toll networks will be all digital and a new generation of modular distributed switches will occur in the 1984-1999 time period.

STAFF COMMENT 15

We believe that ISDN will be in general use before the 1994-1999 time period.

3.1.7.1

STAFF COMMENT 16

Packet switching delay times need to be considered when discussing packet switching of speech and video data. If there is a fixed delay time between packets of information, reassembling the data can be done without problems. If there is a mixed delay time between packets of information, buffers, which are large enough to accommodate for the maximum delay, are required to avoid discontinuity of speech and video data.

3.2.2.2

STAFF COMMENT 17

The LED powers listed here are not necessarily useful, because LED's will actually "launch" only a comparatively small portion of their radiated power into a fiber, and this is a function of the size of the emitter, the core diameter of the fiber, and numerical aperture (cone of acceptance) of the fibers. The emitter suface may be large compared to the core area, so a lower powered but smaller LED may actually launch more power than a more powerful but larger LED.

3.2.3.3

STAFF COMMENT 18

We think optical logic technology and applications will develop somewhat more rapidly in the 1989 to 1999 time period.

3.2.4.1

STAFF COMMENT 19

While we agree that coax cable technology is mature, we believe LANS and CATV will be using much more of it.

4.1.1.1

STAFF COMMENT 20

In the discussion of the synthesis process, it is not entirely accurate to say that "a number of resonators" are activated. A more accurate discussion would indicate that an electrical model of the vocal tract is activated. The vocal tract is modeled by its transfer function in terms of resonances of the vocal tract and the source excitation is modeled by noise or a series of impulses. This constitutes the basis of a formant synthesizer.

Formant synthesis becomes the basis of phoneme-based systems through the incorporation of rules for the formation of the phonemes from synthesis of the formants. Formants or phoneme-based systems accept general text input and translate it into voice output with the additional use of rule processors to translate input text to a sequence of phonemes, modified by additional rules to account for variations in pitch, loudness, and duration and exceptions to the general phonetic rule set.

4.1.1.2

STAFF COMMENT 21

A recent and potentially very significant product for speech synthesis using formant coding is DECTALK mentioned in the text. This could be considered an early speech output product offered by a main frame manufacturer, as forecast in this report. It offers the personalized speech cited in the forecast by means of user selection and/or adjustment of important speech parameters.

4.1.2

STAFF COMMENT 22

Comments on several of these dimensions are:

"Required Quality of Voice Input" per se is meaningless. Presumably this refers to intra-speaker variability for the input speech or individual utterances. This is the characteristic that Doddington [IEEE Spectrum, September 1981, page 26] refers to when considering if systems perform as well for "goats" as "sheep".

"Response Time" is an unusual 'dimension'. Present indications are that systems must respond with little or no perceived delay, or essentially in real time. It is not clear that significant delays will be acceptable in any interactive application, whereas the highest performance present research systems require substantial processing time. Systems with other than real time performance will thus be unacceptable, and there will probably not be a continuum of acceptable response times if other than real time.

"Amount of Training Required" is an important dimension, but there is no general agreement that a system with an extended adaptive training or enrollment process would be undesirable. To the contrary, such a system may ultimately perform at a higher level than a system built on a limited training sample set. Key factors that might be critical include the required training for initial minimally acceptable performance and the total training required for acceptable performance over an extended period.

"Amount of background noise" per se is meaningless. The key factor in determining performance in the presence of noise is related to the input signal-to-noise characteristics. The use or non-use of noise cancelling or press-to-talk microphones is a key factor, as is the need for close-talking microphones. The input signal-to-noise characteristics indicate the severity of the challenges put upon the recognizer in the presence of noise, whereas the "amount of background noise" may not accurately represent these challenges if the microphones perform optimally from noise cancelling considerations but place undesirable constraints on the users. Collectively, the amount of background noise (including its temporal variability) and the use of special microphones define this "dimension", and it is reflected in the input signal-to-noise characteristics.

4.3.1

STAFF COMMENT 23

As additional background, the wide use of facsimile equipment to handle Western Union telegrams at least 30 years ago should be recognized. I had such a unit in my plant then and used it extensively to communicate with a large number of suppliers.

4.3.3.3

STAFF COMMENT 24

Section 4.4.3.3 addresses OCR equipment technology. We have a special interest in this area since our agency will shortly implement a pilot project to allow companies to file certain documents in digitized format. Since it is not possible to provide a signature page contemporaneously with digitized transmission, an alternative approach was needed. We resolved this problem by using assigned personnel identification numbers, PINS, which will be transmitted along with digitized text as signature symbols of authorized persons. Of course, this is only an interim solution. The text refers to this type of problem which states, in part, the "....marriage of Group 4 facsimile technology..." Hopefully, the realization of this technology will resolve problems of this type in future systems applications. In an unrelated project we have conducted OCR experiments with only limited success. We encountered numerous problems with a variety of diverse multifont text and graphic format images of the source documents.

STAFF COMMENT 25

As data entry for processing and telecommunications, OCR and bar code recognition technologies are beginning to play major roles. These two technologies should be considered when planning for the future. For example:

Banks are hoping to do more with OCR by reading the convenience line (numeric dollar value) of checks which is written by both machine and hand. The biggest problem other than the individual lettering styles is the spectral response of the wide variety of commonly-used writing materials (inks).

OCR in the retail area got into trouble and gained a poor reputation there due to store management failing to keep equipment up and using labels with poor print quality.

Bar codes are not mentioned. Although they are coming on strong, they are running into print quality problems.

PART II: THE AT&T DIVESTITURE: THREE PERSPECTIVES

Arthur D. Little, Inc.
Preston, Thorgrimson, Ellis, and Holman
Rural Electrification Administration

PREFACE

For many years, the structure of our national communications system was in a state of equilibrium. The AT&T divestiture has changed that.

Since the early 1930's, the pace and direction of telecommunications technology has been nearly as dependent on the regulatory and judicial environment as on engineering advances. That has not changed. Because regulatory and judicial actions are more difficult to predict than are technological changes, large users of telecommunications are in a quandry vis a vis their long-range planning. This part discusses the divestiture from three perspectives.

Chapter 1, prepared by A. D. Little, provides an overview of the subject, emphasizing the technology.

Chapter 2, prepared by Nicholas P. Miller of the law firm Preston, Thorgrimmson, Ellis, and Holman, emphasizes the regulatory aspects. This chapter is an update of a talk Mr. Miller presented several months ago in a telephone conference with ICST and about 20 State and local ADP/telecommunications officials.

Chapter 3, prepared by John N. Rose of the Rural Electrification Administration, USDA, discusses the divestiture from the perspective of rural telephony. Given the growing trend toward distributed data processing -- and the concomitant dependence on telecommunications -- this discussion is of particular interest to sub-Federal governments as well as Federal agencies with sites in rural areas.

1. DIVESTITURE: OVERVIEW

ARTHUR D. LITTLE, INC.

1.1 CARRIER OFFERINGS AND THE IMPACT OF AT&T DIVESTITURE

On January 1, 1984 the Bell System ceased to exist. This radical change was the result of many forces acting over the past two decades. The most evident of these was a political move to encourage competition, but underlying it was the technology explosion that made the introduction of competition possible, and perhaps inevitable.

The change was solidified by the January 8, 1982 settlement of the antitrust suit known as the United States v. AT&T, et al. This settlement is called the Modified Final Judgment (MFJ) because it replaced the 1956 Final Judgment of an earlier AT&T antitrust suit. The MFJ defined the divestiture of the local Bell companies from the parent, AT&T, which retained its long distance and telecommunication equipment manufacturing businesses. The detailed Plan of Reorganization (POR), filed by AT&T on December 16, 1982 and subject to amendments by the Court, provided the architecture of a new structure for the U.S. telephone industry. The 22 Bell Operating Companies (BOCs) have now been grouped into seven regional companies.

The MFJ and POR further divide the franchised areas of the seven regional companies into about 160 Local Access and Transport Areas (LATAs). These are geographically defined areas of service responsibility, within which the regional operating companies are authorized to route and transport communications traffic. The BOCs are not permitted to handle any inter-LATA traffic.

The primary businesses of the regional companies are the provision of exchange and exchange access communications within the LATA boundaries. Traffic that crosses the LATA boundaries, even into contiguous communities, must be handled by inter-LATA carriers on an equal opportunity basis. A subsidiary of AT&T, known as AT&T Communications (AT&T-C) is just one of those competing carriers, albeit the dominant one.

This section addresses the impact of these changes. It should be borne in mind that:

- o Dramatic changes are continuing, making it almost impossible to predict conditions 15 weeks in the future, much less 15 years; and

- o The primary driving forces are not technical; much more important are regulatory, judicial, legislative and marketplace forces.

1.1.1 *Other Common Carriers (OCCs), Value Added Networks (VANs) and Domestic Satellite Carriers (DOMSATs)*

A wide and rapidly changing selection of service offerings is available to users. A representative sample includes:

- o Private Line Facilities (MCI) MCI provides point-to-point communication channels for voice, data, facsimile and various wide-band applications.

- o Private Line Facilities (GTE Sprint Communications Corp.) These are point-to-point voice bandwith channels for voice, data, facsimile, or other applications.

- o Private Line Facilities (Western Union Telegraph Co.) Low-speed data channels are offered on a full-time rental basis.

- o Satellite Channels (American Satellite Corp.) These are point-to-point satellite communication channels for voice, data, facsimile and various wide-band applications furnished by domestic satellite in combination with conventional land line access facilities.

- Satellite Channels (RCA American Communications, Inc.) These channels are similar to those provided by American Satellite Corp.

- Communications Network Service (Satellite Business Systems) This is a two-point network service operating between SBS network access centers located on customer premises.

- Packet Switch Data Service (GTE Telenet and Tymnet) These are packet switched data communications services offering station-to-station transmission between 50 bits per second (bps) and 56 kbps. Differences in speed or protocol are compensated by the network. Data is transmitted in 1,024-bit blocks called packets with automatic error detection and correction. This service interconnects with Datapac in concentrating on graphic and textual material.

- Voice Message Telephone Service These are switched national message services. "Sprint" is offered by GTE Sprint Communications Co., "Execunet" is provided by MCI, and "Private Line Switched Service" is provided by RCA American Communications.

Competition here is entirely on the basis of price. As AT&T lowers its prices, the market should settle at a point that will enable AT&T to argue that it is no longer dominant. If this thrust succeeds in removing regulations, a chaotic situation similar to that in the airline industry may result.

1.1.2 AT&T

1.1.2.1 Background and Present Approaches

AT&T provides two forms of communication services: regulated via its AT&T Communications (ATT-C) subsidiary and unregulated through its AT&T Information Systems (ATT-IS) subsidiary.

AT&T Communications is the largest common carrier in the United States with an estimated 60%-70% share of the long-distance market. It provides both interstate and intrastate inter-LATA communication services under the regulation of the FCC and the state Public Utility Commissions, respectively. Because of the restrictions imposed by the FCC Computer Inquiry-II order, these services are limited to basis end-to-end communication transport and do not include computer processing enhancements. AT&T channels are provided through use of its wholly owned inter-LATA communications network. This includes basic transmission, switching and control facilities. ATT-C supplies a vast array of services to the consumer. These generally can be placed in one of two categories (switched and non-switched) as follows:

- o Switched services can be "addressed" by the sender and delivered to the proper destination via the telephone network. Most telephone services are switched.

- o Non-switched services represent dedicated point-to-point communication paths. Leased lines are typical non-switched services.

These two categories can be further subdivided by their basic approach to information transmission: analog or digital as well as narrow and or wideband. In addition, switched services may be divided into two categories as follows:

- o Circuit switched in which a unique end-to-end transmission path is dedicated to a subscriber for the entire length of his conversation.

- o Packet switched in which data transmissions are subdivided into bursts of information (packets) and travel over differing transmission paths to and from a subscribers premises.

AT&T also provides enhanced network services through its unregulated subsidiary ATT-IS. To date this entity provides only one service which will be described in the next section. ATT-IS does not own or operate any network transmission or basic central facilities. It does, however, own and operate equipment (computers, databases, etc.) necessary to provide enhanced services.

ATT-C provides a large number of services to the business and residential communications subscriber. These services are listed in table 1.1. However, because of ATT-C's move into the more competitive environment it has chosen to rename many of its offerings. Thus, each offering is shown with both its old and new name together with an abbreviated description.

The services shown in table 1-1 are covered by tariffs filed with and approved by the FCC and the local Public Utility Commissions.

ATT-IS basically provides a single network service referred to as NET 1000. Previously, this service has been referred to as the Advanced Communications Service (ACS) and NET 1. Net 1000 is an enhanced communications packet switched service for computer processing as well as data transmission, storage and protocol conversion. It is based on the use of ATT-C Private Line ACCUNET Packet Service and is available in 15-20 centers around the United States.

1.1.2.2 Technological Evolution

Over the next fifteen years there will be a major change in the character of the ATT-C communications network. These changes can be placed in four broad categories: network design, communications medium, transmission techniques/devices, and switching. Each of these will be examined briefly.

- Network Design

  Over the next fifteen years the major thrust of ATT-C will be to develop a software-controlled all digital network. However, in the short term the emphasis will be on providing digital connectivity between the major business centers in the United States. This overall digitalization plan is reflected in the application of newer and more technologically advanced transmission and switching devices.

  ATT-C's second thrust will be to provide customers with conveniently located points-of-presence or POPs which have the capability of not only connecting subscribers to the AT&T long distance network but also of bundling and unbundling U.S. industry basic T-1 1.544 mbps digital pulse streams into subrate channels which can be more easily used by subscribers.

- Communications Media

  For the terrestrial portion of its network, ATT-C presently relies on microwave radio, coaxial cable, and copper cable as its basic transmission media. However, there has recently been an increasing trend towards the installation of fiber optic cable particularly on the Eastern seaboard and in the Atlantic Ocean. Between 1980 and 1983 almost 200 high capacity fiber optic based systems have been installed by AT&T. This trend will continue at an accelerated pace throughout the 1980's and 1990's.

- Transmission Techniques and Devices

  Much of the long haul AT&T network is based on the use of analog transmission systems. Although in the past much of this network has been adapted for the transmission of data, through use of techniques such as Data Under Voice (DUV), this is by no means the most efficient way to provide a low cost, digitally connected network. Therefore, in the next five to ten years there will be increasing emphasis on installing digital microwave radio systems and high digital capacity fiber guide systems. In addition, there will also be an emphasis on increasing the capacity of those digital systems already in place. This will be accomplished through increasing use of Bit Compression Multiple (BCM) techniques. Devices based on the use of this approach derive 44 voice band channels from a T-1 1.544 mbps signal which normally provides only 24 voice channels.

  Satellite systems are used by ATT-C in its long haul network, although satellite transmission accounts for only about 3 percent of all domestic long-distance voice transmission.

Table 1-1 AT&T -C Services

OLD NAME	NEW NAME	DESCRIPTION
I. Public Switched Network Services		
DDD	AT&T Long Distance	Basic long distance voice service
Dial-It 900 Service	AT&T Dial-It 900 Service	Prearranged recorded announcement available on a direct dial basis
WATS	AT&T WATS Service	Special bulk calling arrangement for directly dialed one station to many station toll calls
800 or expanded 800 Service	AT&T 800 o Single Number Service o Customized Call Routing Service o Variable Call Routing Service	A toll free service for inward calling to a single number
Video Teleconferencing	No change	Two-way video teleconferencing services
Audio and Audiographic	Alliance Teleconferencing Services	
	o Alliance 1000 Service	Up to 59 party audio conferencing
	o Alliance 2000 Service	Up to 59 party analog graphics teleconferencing
Operator Handled Services	No change	Provision of person-to-person, collect, calling card, and third party calling as well as dialing assistance
II. Private Line Services		
HCSDS	SKYNET 1.5 Service	Provides satellite 1.544 Mbps channels between earth stations
STS	SKYNET Television Service	Provides satellite television signal transmission between earth stations
SAS	SKYNET Audio Service	Provides satellite dual 7.5 khz or 15 khz audio signals between two or more earth stations

Table 1-1 AT&T -C Services (continued)

OLD NAME	NEW NAME	DESCRIPTION
HCTDS	ACCUNET T1.5 Service	Provides terrestrial 1.5 & 4 mbps digital channels between two locations
HSSDS	ACCUNET Reserved T1.5 Service	A terrestrial based digital network switching system which provides for the simultaneous two way transmission of either 1.544 or 3.0 mbps signals
BPSS/PTN	ACCUNET Packet Service	Provides a customer dedicated packet switching system
DDS	DATAPHONE Digital Service (A member of the ACCUNET family)	Provides terrestrially based 2.4, 4.8, 9.6 and 56 kbps dedicated digital two-way circuits
CSDC	ACCUNET Switched 56 Service	Not yet tariffed. Will provide a terrestrial based switched 56 kbps digital circuit
Private Line Series	"Analog Private Line"	Provides point-to-point dedicated analog circuits for
o 2000	o Telegraph Service	o low speed signalling and teletypewriter channels
o 3000	o Voice Service	o voice channels
o 4000	o Data Service	o data transmission to 9.6 kbps
o 8000	o Wideband Service	o data transmission between 19.2 and 230.4 kbps

It is doubtful whether satellite transmission will overtake a large share of the transmission market because it is generally less economical than improved microwave or fiber optic transmission. In the long term, fiber optic transmission should supersede satellite transmission for switched and private-line transmission services, but it is not likely before the mid 1990's.

In contrast to the long haul network, the medium haul intercity and short haul metropolitan networks currently make heavy use of digital transmission systems, such as T1. For parts of the networks which remained with ATT-C after divestiture, there will be an emphasis on increasing digital carrying capacity by using BCM and in some instances replacing copper cables with fiber optic cables.

- <u>Switching</u>

  AT&T's long distance network is almost entirely computer controlled and 80 percent of it utilizes digital switches. Over the next five to ten years the remainder of the network will be converted to digital switching and software control. In addition, POPs will make increasing use of digital cross connect devices which permit convenient, customer responsive bundling, unbundling, administration, and switching of the standard T-1 1.544 mbps signals.

  To support Value Added Networks, there will also be a trend towards the installation of additional packet switching capability. The need for increased capability in this area will be heavily dependent on the success of such service offerings as Local Area Data Transport (LADT) by the Regional Bell Operating Co's, Net 1000, by ATT-IS and Tymnet/Telenet services.

1.1.2.3 Impact of Expected Development

As evidenced by recent market actions and filings before the FCC, ATT-C is attempting to:

- Obtain an increasing measure of deregulation of the inter-LATA telecommunications market;

- Become more competitive in terms of basic network service offerings, optional calling plans, and operator services; and

- Become more price competitive with the other interchange carriers.

From a technological perspective these goals have been supported, in part, since:

- o Making use of new digital and optical systems lowers the cost of providing service and, therefore, lowers the price that can be charged the customer.

- o Making increasing use of modernized software controlled devices such as DACs and digital switches permits the easy provision of new sub-rate digital services, billing services and other basic service enhancements.

The provision of an increased digital capability by AT&T could result in reduced costs for the ACCUNET family of services and, thereby, substantially increase the demand for both these digital services and the subsidiary services which depend on them. These include:

- o Video teleconferencing, such as Picturephone Meeting Service, which utilized ACCUNET Reserved 1-5 Service;

- o Videotex, which in turn depends on ACCUNET Packet Service;

- o VAN, which utilize ACCUNET Packet Service; and

- o Private User bypass networks.

1.1.2.4 Cost/Performance Trends

Because of the AT&T divestiture of its local operating companies and the attendant attempt to eliminate local and toll service cross-subsidization, there is a massive rate restructuring now taking place in the telecommunications industry. The major effects to-date of this restructuring have been the following:

- o A reduction of 6.1 percent in the rates associated with ATT-C Long Distance, WATS, and 800 Service, effective May 1984.

- o The imposition of a $6 (maximum) access line charge on large business customers effective May 1984.

- o Filed tariffs (tentatively effective July 1985) to restructure the rates for all private line services (SKYNET, ACCUNET, Analog Private Line, etc.).

- o The imposition of a $2 (maximum) access line charge on residential customers effective in 1985.

- o Long Distance price reductions by ATT-C competitors particularly MCI (6 percent) and GTE Sprint.

Given the confusion in the rate making arena today, it is very difficult to predict specific outcomes. However, the trends for the following services are becoming evident:

- **Long Distance and WATS** -- Over the next ten years competition will result in significant reductions in the price of these services. The May 25, 1984 6.1 percent price reduction is just a beginning. Late in 1984, ATT-C indicates that if rate restructuring proceeded according to plan it would like to reduce Long Distance Service rates by an average of 10.5 percent and WATS Service by 6.9 percent. Some observers believe that rates could ultimately fall by as much as 50 percent.

- **Private Line Services** -- Over the past few years the monthly tariffs for Analog Private Line Service have increased at an accelerated pace. These increases resulted from a realization on the part of ATT-C and the FCC that the tariffs for these services did not adequately reflect the cost to provide them with a fair market return on investment. This trend is expected to continue on a mileage selective basis. Thus, in July 1984 the monthly cost for a 50 mile analog private line is expected to increase 59 percent and the cost for a 1500 mile line is expected to decrease by 9 percent. (see table 1-2) Similar rate changes are planned for ACCUNET T1.5 Service (see table 1-3).

  Over the next ten years it is anticipated that the costs for Analog Private Line Services will continue to increase, since this is based on an old technology and tariff structure. The cost of digitally based services such as ACCUNET, however, after a catch up period should either level off or actually decrease. This would be a direct result of the cost savings obtained from network digitalization.

Table 1-2 Analog Private Line Service

	OLD RATES	NEW RATES
Miles	Monthly Cost	Monthly Cost
25	203.52	348.00
50	244.02	388.00
100	325.02	468.00
500	701.01	848.00
1,000	1,171.08	1,223.00
1,500	1,572.10	1,423.00
2,000	1,751.02	1,623.00

Table 1-3 ACCUNET T1.5 Service

	OLD RATES	NEW RATES
Miles	Monthly Cost	Montly Cost
25	2,621.00	4,690.00
50	3,786.00	5,690.00
100	5,286.00	7,190.00
500	17,286.00	18,390.00
1,000	32,286.00	30,890.00
1,500	47,286.00	43,390.00
2,000	62,286.00	55,890.00

1.1.2.5 Conclusions

Many actions are being taken by ATT-C in both the regulatory, technological, marketing and pricing arena:

- o Because of competition from OCCs and in spite of ATT-C's aggressive pricing, ATT-C will lose market share in the inter-LATA marketplace. It is not unconceivable that its share will drop to 40 percent - 50 percent.

- o Beginning in the late 1980's, the regulatory restrictions on ATT-C will be loosened and probably entirely eliminated by the late 1990's.

- o The Computer Inquiry-II restrictions which artificially separate the communication activities of ATT-C and ATT-IS will be eliminated by the mid-1990's.

- o Because of competition, the price charged for normal Long Distance service will be lowered to the extent that WATS will no longer be attractive. Thus, the traditional reseller market segment will no longer exist.

- o The ATT-C network will become increasingly digital during the late 1980s and early 1990s until the distinction between analog and digital based services will be eliminated.

- o Because of the capabilities of a digital network the distinction between switched, non-switched and private line services will be eliminated. These latter services will be provided with a "virtual circuit" established as long as needed under software control.

- o The provision of digital services at a sub T-1 rate will become common place and the concept of the Integrated Services Digital Network (ISDN) will become a reality, at least at the ATT-C POP.

1.1.3 Resellers

Before addressing Resellers and Bypass, we should point out that the development of both of these markets is almost solely dependent on future regulatory developments.

A continuing market for the resale of telecommunications services depends on regulators at both state and Federal level maintaining the present arbitrage opportunities contained in the existing Wide Area Telephone Service (WATS) and Private Line Tariffs. A significant increase in monthly lease costs coupled with a significant decrease in usage rates would signal the beginning of the end for Resellers.

1.1.3.1 Background and Present Approaches

The FCC's Other Common Carrier decision opened up the U.S. long distance market to competition in the late 1960s. The first new entrants into this market were carriers such as MCI which perceived an opportunity in the leasing of call carrying capacity from established carriers (such as AT&T and the local telephone companies) and then re-selling this capacity at lower rates. The opportunity existed in the ability to attract large numbers of users to their systems, while realizing a profit through volume sales. The opportunity certainly existed; a number of these companies flourished. Many, such as MCI, went on to build their own networks and to leave the resale business. However, many Resellers remain, and many new ones have entered the market. The function they provide is discounted long distance or interexchange telephone service. To be sure, the idea of paying less than what AT&T charges for service has captured the imagination of the U.S. public. On the residential side, this appears to be primarily due to the increased mobility of the U.S. population and the subsequent increase in the need to use long distance telephone service. For business users, the use of the telephone can help control expenses formerly incurred for travel to meetings and the like.

The technology involved in the resale business has not changed much over time. There remains a heavy reliance on WATS and private line services. In order to serve a given market a Reseller needs to install a central office type switch through which subscribers can access the high capacity lines that have been leased (most common are WATS type line). In many cases access to the switch is available over a dedicated private line circuit. With the existing tariffs, rates charged for such service remain well below those of AT&T message telephone tariffs. However, a second level of competition is developing between the OCC's and Resellers. Now, the Resellers are holding their own. However, they are at a disadvantage. Their ability to expand their network is dependent upon the availability of facilities from the established providers of communications service. Often such facilities are not readily available. Thus, Resellers have been limited in their ability to expand geographic coverage and increase market share.

1.1.3.2 Technological Evolution

- 1984-1989 -- By the late 1980s, regulation of the U.S. Long Distance Telecommunications will be lessened. Today, the FCC does not regulate OCC's or Resellers. The FCC is also currently examining the future treatment it should accord AT&T. The most logical near-term scenario involves the lessening of regulation of AT&T as equal access becomes available (no later than 1987). As a response to competition posed by the Resellers, AT&T and other providers of WATS type services (e.g., MCI) would restructure their rates to limit the present arbitrate potential. Most Resellers, faced with increased operating expenses due to increased charges for access to the local network and limited arbitrage opportunities in the tariffs, will be squeezed out of the market by 1990.

1.1.3.3 Conclusions

As stated above, Resellers will be squeezed out of the U.S. long distance market. However, some limited opportunities may remain. First, expect some acquisition activity such as United Telephone's purchase of U.S. Telephone. Second, any surviving Resellers will probably turn their attention to more limited markets. An example of this could be Lexitel which only serves a limited number of states in the mid-West. Another possibility would be the re-sale of Telecommunications service on an intrastate basis in selected states (e.g., California, New York).

When discussing the re-sale market it is significant to talk about cost/value trends, since Resellers have prospered based on subscribers perception of the value of the service provided. During the seventies, and until today, the cost/value trend for Resellers was on an upswing. Due to recent regulatory developments, such as the FCC's access charge decision of May 25, 1984, the trend has reached stasis. For the remainder of the 1980s, it will be on the downturn.

Although their history will have been short, it is safe to say that Resellers will have played an important role in developing the competitiveness of the market. It is, however, rather ironic that they will most likely be one of competition's first victims.

1.1.4 Bypass

1.1.4.1 Background and Present Approaches

Bypass is the circumvention of the local telephone company plant or services by users who employ alternative means of telecommunications.

The Bypass phenomenon can be traced to the FCC's opening up of the long distance market to competition in the late 1960s. At the time, however, it was limited to Bypas of the long distance company. Now, more and more attention is being paid to Bypass of the local network.

The use of Bypass may be stimulated by a number of factors. Foremost among them are:

- o Price differentials making Bypass more economical than the local telephone company's network offerings;
- o Unsatisfactory local network service;
- o Technological superiority of the Bypass system;
- o Preference for owning communications facilities to increase security or privacy; and
- o Anticipation of inferior service or higher local service costs.

The major Bypass technologies in use in the U.S. today can be grouped into four broad categories:

(1) Radio Based Systems -- Private microwave or digital termination systems;

(2) Cable Based Systems -- CATV or fiber optics;

(3) Intra Office Systems -- Electronic PABXs or Local Area Networks (LANs); and

(4) Multiple Technology Systems -- Teleports using a combination of the above technologies.

1.1.4.2 Technological Evolution

- o <u>1984-1989</u> -- The Bypass market is currently estimated at approximately $100 million per year and growing rapidly. The late 1980's should see a proliferation of the satellite earth station farm--teleport concept, enhanced communications and ventures in which real estate developers provide telecommunication for tenants.

- o <u>1989-1994</u> -- It is during this time frame that the acid test for Bypass will occur. It will be here that we will see the effects, if any, of regulatory action in the area of Bypass. The two scenarios that have been developing are:

  (1) Regulators, both State and Federal, impose fees (similar to access charges) on Bypassers making it a less attractive economic alternative and thus, preventing losses to local telephone companies. Hence, the industry will never really fulfill its potential, and

(2) Regulators allow both ATT-C and the local telephone companies to compete in the Bypass area themselves. In this case, the Bypass market could increase to over $10 billion dollars annually and be a significant portion of the U.S. telecommunications industry. The definition of Bypass in this case becomes meaningless.

- 1994-1999 -- Depends solely on regulatory developments in the 1989-1994 time frame.

1.1.4.3 Conclusions

Regulators can stop the Bypass industry in its tracks. If this were to happen, advances in local distribution and service technology would become available primarily through the local telephone company. On the other hand, if regulators decide to allow open entry into the Bypass market, technological innovation at the local level may be markedly enhanced, e.g., proliferation of two-way interactive CATV systems.

Absent regulatory intervention, technological advancements, coupled with the trend for increased rates for service on the public switched network, will likely make for very impressive cost/performance ratios for Bypass. However, any type of surcharge imposed by regulators will more than likely offset any gains from technology and reduce cost/performance.

The Bypass phenomena has occurred primarily as a result of technology. If we could be certain that it would remain a child of technology, it would have an extremely bright future and serve as a primary source of technological innovation. Unfortunately, this future is now clouded by the potential impact that regulators and their policies will have on it.

2. IMPLICATIONS OF THE AT&T DIVESTITURE FOR COMMUNICATIONS OFFICERS

Nicholas P. Miller*

2.1 INTRODUCTION

It has been nearly nine months since the massive reorganization of the American Telephone & Telegraph Company took effect on January 1, 1984. Since the divestiture went into effect, the U.S. telephone industry has undergone sweeping changes affecting telephone users at every level. This article will briefly review the divestiture, discuss some of the recent and probable future changes in the American telephone industry and assess their impact upon the procurement of telephone services, and finally, provide some guidance to communications officers in understanding the AT&T divestiture and working within its framework.

WHAT WAS THE DIVESTITURE?

The divestiture is not difficult to understand provided one does not dwell on the details of the actual split up of the phone system. Quite simply, in mid-December 1981, the Department of Justice and AT&T reached a settlement of the antitrust suit against AT&T which, effective January 1, 1984, split those services perceived as being competitive in today's telecommunications market from those services perceived as remaining monopolistic and therefore not subject to effective competition.

Background Of The Divestiture

In 1974, the Department of Justice initiated suit against AT&T, alleging that AT&T was using its market dominance to inhibit competition in the telephone industry. The Department sought divestiture of AT&T as a means to ensure that AT&T would no longer be able to use revenues from its regulated, local monopoly services to subsidize its competitive services.

Several years ago the FCC reached the conclusion that terminal equipment could be subject to effective competition. The FCC drew the same conclusion with regard to the long-distance services. It was generally conceded, however, that the local telephone exchange had all the characteristics of a natural monopoly.

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The general purpose of divestiture was to split the two competitive areas, terminal equipment and long-distance service, from the one area that was viewed as non-competitive. Such a split would, among other things, eliminate the competitive problems associated with AT&T's providing exchange access through its Bell operating companies (BOCs), to its competitors. Thus, the Bell terminal equipment services were transferred to a new AT&T organization (AT&T Information Systems) and the long distance operations to AT&T Communications. Ownership of the local telephone networks was transferred to seven new regional BOC's which are independent of AT&T.

2.2 THE EFFECTS OF DIVESTITURE AND COMPETITION

The AT&T divestiture, although conceptually simple, effectively spawned radical changes in the telecommunications industry and the way competitive and non-competitive services are offered. The most important changes involve the way long distance service is provided. AT&T's competitors have been unable to compete on an equal basis since AT&T, through its historic ownership of the local telephone network, designed its local networks to access only one toll network. Because AT&T's competitors (Other Common Carriers or OCCs) have had more difficult and complicated exchange access, called "unequal access," they currently pay a reduced access charge -- 45 percent of the amount paid by AT&T -- for their use of the local exchange to originate and terminate long-distance calls.

The industry, however, is moving towards a system of "equal access." Under the new system, the OCC will pay the same access charge as that paid by AT&T but in return will have the capacity to offer their subscribers a service equivalent to that provided by AT&T. In essence, this means that OCC subscribers will be able to complete long-distance calls using rotary telephones and will no longer have to dial the extra-digit codes which they currently must use in placing long-distance calls. OCC will also be provided with automatic number identification and answer supervision capabilities which will allow them to identify the caller without use of the current identification codes and give them the ability to commence charging only when a call is answered at the distant location. Thus, under equal access, the OCCs will have the capacity to provide long-distance service on a basis comparable to that of AT&T's service.

The transition to equal access for the BOCs began in July 1984 and should be completed by September 1986 under the consent decree. (Some 1400 independent telephone companies are not affected by the consent decree. However, the FCC has proposed regulations which would also require most of them to eventually provide equal access also.) Under the new system, telephone users will pre-subscribe to one of the available long-distance services. The impending pre-selection process has resulted in a massive advertising and publicity campaign by the long-distance companies, each hoping to increase its share of the lucrative $45 billion-a-year long-distance market. AT&T, whose long-distance rates were reduced 6.1 percent effective May 25, 1984, has lost customers since the divestiture. In addition to a shift of subscribers to OCCs, the BOCs handle a significant amount of local toll traffic, which is permitted under the consent decree (within defined areas called LATAs).

Exchange Access Charges

This transition in the treatment of long-distance service has had an impact on local service as well. Local telephone service uses many of the same facilities as long-distance services. Long-distance revenues contribute to the cost of these "joint and common facilities" and have held local rates at relatively low levels. With the breakup of AT&T, however, AT&T and the OCCs have sought to reduce these payments for jointly used facilities, thus forcing the local telephone subscriber to pay more of the cost of these facilities. In an effort to more accurately allocate the costs for use of local exchange facilities, the FCC has devised a system of access charges, including end-user access charges, which are intended to cover the non-traffic sensitive costs associated with the common use of the "local loop" between telephone central office and the subscriber.

Under this new access charge system, which began May 25, 1984, multi-line business users pay an initial monthly fee of $6 per line to the local telephone companies for the privilege of accessing the interstate long-distance network. Similar end-user charges for residential and single-line business customers will supposedly go into effect on June 1, 1985. The FCC had originally slated all end-user charges to begin simultaneously, but in the face of congressional pressure, elected to delay residential and single-line user charges in order to further study the consequences of their implementation. The proposed monthly rate for residential and single-line business end-user charges will initially be $2 per line, with this rate not to exceed $4 until at least 1990. All of these end user charges are for access to the interstate toll network only. State regulatory commissions are likely to apply a similar charge, if they haven't already, for access to the intrastate toll network.

With regard to access charges on Centrex-CO lines, the FCC has ruled that such lines are equivalent to business lines and thus should be assessed end-user charges in the same manner that business line charges are imposed. Critics had argued that applying per-line access charges to Centrex-CO lines would bring about the demise of Centrex-CO service since one such line is required for each telephone extension, while PBX systems require significantly fewer network access lines. The FCC rejected this argument, choosing instead to implement access charges for Centrex-CO lines on a gradual basis. Thus, for all Centrex-CO lines in place on July 27, 1983, the monthly per-line charge is initially set at $2. Centrex-CO lines not in place or on order on that date, however, are assessed the full $6 monthly per-line charge. All Centrex-CO lines will eventually be charged the full business end-user fee.

In addition to end-user fees, large users will soon be faced with implementation of the controversial tariffs on "special access," the dedicated local facilities used for connecting the long-distance private line and other facilities to the large users' premises. The proposed special access tariffs were initially filed in October, 1983 by the National Exchange Carrier Association (NECA) and by some of the BOCs, which filed separate but similar tariffs. Examination of the proposed tariffs revealed that major rate increases were in store. The FCC took a dim view of these tariffs, finding the rate structures unreasonable, discriminatory and contrary to FCC policy, and ordered them modified.

Revised special access tariffs were filed on March 15 and 19, 1984, and again they met a storm of protest from a number of interexchange carriers and large users. As a result of its review and the adverse comment received, the FCC has suspended the effectiveness of the special access portions of the tariffs until November 13, 1984, pending completion of a more thorough investigation. In the meantime, the interim intercarrier agreements negotiated earlier this year, which largely reflect the settlement provisions and costs in effect prior to the AT&T divestiture on January 1, 1984, will remain in effect. However, the FCC announced that it would allow the special $25 monthly surcharge on private lines commencing in August 1984. Users may avoid this surcharge if they certify that their private lines cannot be interconnected to the local telephone exchange facilities.

The eventual implementation of all access charges, could have important consequences for large users. With their imposition, long-distance rates will include a reduced part of the costs of local facilities and thus should be driven downward. Conversely, local telephone rates will be forced substantially upward since they will have to cover a larger share of the local facility costs. As a result, while the new charges overall may deter some large users of long-distance service from seeking alternatives, some access charges (particularly special access) may well induce other large users to bypass the local network. Falling prices and technological improvements in coaxial and fiber-optic cable, microwave radio, satellites, and other bypass systems have already led some large users to develop their own private bypass facilities.

The potential savings from developing private networks and bypassing the local telephone company can be substantial. These potential savings have already been recognized by such corporate entities as Westinghouse, Sears Roebuck & Co., and Bank of America, and by government agencies such as South Carolina, New York State, and New York City.

However, if enough bypass operations occur, they will seriously affect local exchange revenues, thus driving up local telephone costs and rates even more. Consequently, the BOCs and independent telephone companies have begun efforts to minimize potential revenue losses and in many cases are even willing to provide by-pass facilities themselves.

2.3 COMPETITIVE OPERATIONS BY AT&T AND THE BOCs

The BOCs may enter competitive markets closely related to local service such as customer premises equipment and enhanced services on a limited and supervised basis, but the FCC requires that they form separate subsidiaries for the provision of such services. The BOCs ability to enter competitive markets unrelated to local service, however, has been sharply restricted. In a July 26, 1984 decision, U.S. District Court Judge Harold Greene, who presided over the divestiture of AT&T, ruled that the BOCs must concentrate on the provision of local service and may not branch out into such activities long-distance service and new business ventures. Greene's ruling was specifically aimed at a request by BellSouth for permission to bid on a contract for construction of a telecommunications network for the National Aeronautics and Space Administration.

While Judge Greene had previously indicated that he would not approve new business ventures if they were potentially anti-competitive, the new order established four conditions for the approval of new ventures. To gain such approval, the BOCs must: (1) place new ventures in separate subsidiaries; (2) establish methods to insulate local phone customers from any financial consequences arising from new ventures; (3) limit the size of the new venture to no more than 10 percent of total company revenues; and (4) agree to the monitoring of these new ventures by the Department of Justice. Thus, the new order makes it difficult for BOCs to significantly expand their business beyond providing local telephone service.

While the consent decree removed all legal restrictions on the ability of the post-divestiture AT&T to embark on new business ventures in diverse, unregulated markets, under the FCC's Computer II restrictions, AT&T must provide "enhanced" communications services, such as data processing and customer premises equipment, through separate subsidiaries with separate accounting systems. AT&T has taken full advantage of this new freedom, entering both the business and personal computer markets within the past year.

AT&T has filed a request with the FCC to remove certain Computer II restrictions on it. While the Commission has yet to act on this request, it has partially relaxed the restrictions. In a June 27, 1984 decision, the Commission ruled that AT&T Information Systems may provide domestic interstate transmission service through the resale of the lines of any carrier, including those of AT&T Communications.

2.4 POLICY IMPLICATIONS AND PRACTICAL ADVICE FOR COMMUNICATIONS OFFICERS

The divestiture of AT&T and the related developments in the telephone industry carry significant implications for governmental communications officers. The ultimate goal of communication officers, and probably their most difficult task as well, is to keep pace with the changing developments within the industry in order to obtain the most efficient, cost-effective services available. As rates for both local and long-distance telephone services are driven more towards actual costs, communications officers must pay increasing attention to the development of alternatives to traditional telephone services.

With regard to particular developments within the industry, the impending implementation of equal access and the other structural changes related to the divestiture significantly alters the procurement of long-distance services. As the equal access date for a city approaches, each of the long-distance competitors, including AT&T, will be soliciting large users, claiming that they can offer the most effective services at the best rate. Communications officers should recognize that this initial attack will produce an abundance of creative schemes to attract large uses, and they must carefully examine each company's ability to provide effective, efficient service over the long-term. An important point to recognize is that the rate structures of the various carriers are simply not comparable on an absolute basis. Rather, the costs of long-distance service will vary both according to geographic location and the usage patterns of individual customers.

Communications officers should also recognize that the long-term effect of the move to "equal access" may have some ironic consequences. While the transition is intended to enable all long-distance carriers to compete on an equal basis, it may reinforce and expand the market power of AT&T. The ability of OCCs to provide service during the past few years at significantly lower rates than those of AT&T, has resulted in a gradual erosion in AT&T's share of the long-distance market. Evidence indicates, however, that these companies have been able to offer cheaper service not so much because of lower costs, but rather largely because of the lower access rate paid to the local BOC's due to unequal access. Once equal access is implemented, the gap in rates between AT&T and its competition will likely narrow, and while the OCCs will most likely continue to expand their respective shares of the market, their operating margins will be reduced. The "resale carriers" are likely to experience greater difficulties than facility based carriers since their operating margins are dependent upon the arbitrage between long-distance rates and the rates for WATS and private line services. This will likely result in consolidations among competitors like the recent acquisition by United Telephone of U.S. Telephone.

In addition to changes in the long-distance market, recent developments in local service will have a significant impact on large users as well. As noted above, the implementation of access charges, particularly special access charges, will significantly affect service costs for large users. While the precise resolution of the controversial special access tariffs cannot be predicted, some general observations can be made. First, special access costs will increase overall, although the increase will vary geographically and among users. Some users, depending on their location, type of facilities used, and their level of participation before the FCC, will experience much smaller increases than other users. Non-recurring charges, which in the past have not been entirely cost-based, are likely to increase the most. Second, it is possible that the FCC will cushion the largest increases for certain classes of users by ordering a transition period. Third, while the FCC may require some simplification of the currently proposed rate structures and regulations, the new rates are certain to be more complex than the current pricing structure.

The bottom line is that communications managers for large users should pay extraordinary attention to these tariffs and participate in the FCC proceedings in which they are being tested and the related issues resolved. As indicated above, while interexchange costs are generally going down, the reverse will be true for that "last mile" from the interexchange carrier's local terminal to the user's premises. Large users of voice and data communications services that make heavy use of dedicated local access facilities should review the relevant tariffs to ascertain their impact. If rate increases are in store for them, the FCC should be advised. Unless the FCC receives objections about a specific rate element, it is unlikely to require any changes in the rate element.

As mentioned above, bypass will become increasingly attractive. While the potential savings from bypassing the local exchange may be substantial, they could be temporary depending on regulatory developments. Thus communications officers should carefully explore bypass alternatives, but they should commit substantial capital investment to them only when they are convinced that regulatory changes will not reverse their economies in the near future.

In addition to rapid technological advances in the development of bypass networks, most telecommunications managers are aware of the increasing interdependence of communications and computing/data processing technologies. Terminal equipment development is increasingly moving toward combining voice and data communications in a single terminal. There will be very strong price competition among hardware vendors, comparable to that found in today's home computer market. Communications officers must constantly reconsider their changing needs and must recognize that rapid technological developments may quickly render existing equipment obsolete. Before making substantial investments in services equipment, large users should make special efforts to ascertain the likely future effects of making such purchases, and must recognize that what may be an excellent purchase today may result in substantial financial losses down the road. The potential for economic losses is very often foreseeable, and telecommunications managers can thus avoid such losses by constantly monitoring the changing developments in the industry and the regulatory environment.

The changing developments in the telecommunications industry may give rise to potential conflicts of interest for state officers. As public servants and employers of elected officials, they will support low overall telephone rates for all citizens in their jurisdictions. But as telecommunications managers for large users, the same individuals will be interested in new service offerings and new price structures allowing substantial cost reductions for large users. The conflict emerges because, as the large user's costs are cut, residential and small business users will face rate increases necessarily imposed to make up for the lost revenue. These tensions will not disappear during the next few years, and in fact will continue to face every political jurisdiction in the country. Communications officers, therefore, must seek new ways to balance the overall responsibility of the government to protect the welfare of its citizens against the government's interest as a user in obtaining efficient, cost-effective telephone service.

2.5 CONCLUSION

Keeping abreast of developments within the telephone industry during the next several years will be extremely difficult, and communications officers will face a nearly impossible task in doing so unless they enlist outside assistance.

They should consult with each other frequently and read trade publications in order to keep abreast of developments within the industry. Communications officers who are isolated may be unable to keep on top of industry developments. By maintaining close contact with each other and exchanging views on common problems, communications officers will increase their ability to identify trends which either offer opportunities to save money or which present the potential for being locked into inefficient systems or usage patterns.

As new technological and policy developments become increasingly difficult to monitor, telecommunication managers will find it necessary to solicit the advice of specialized consultants. Telecommunication consultants are in a position to closely monitor industry developments on a continuing basis, and they generally have extensive resources to provide accurate and effective analysis and to foresee future industry trends. Communications officers should recognize the increasing importance of seeking the assistance of specialists prior to making substantial investments in telecommunications services.

Finally, in order to keep track of and understand policy issues, the rapid policy changes and regulatory developments, advice from the legal community will become increasingly important. These policy and regulatory developments carry far-reaching implications for the procurement of telecommunications services. While these future trends and consequences may not be immediately apparent to the telecommunications manager or even the technical consultant, the communications attorneys are in a position to carefully analyze and predict likely policy and regulatory changes and assess their probable impact upon particular large users.

3. A RURAL PERSPECTIVE OF THE RESTRUCTURED TELECOMMUNICATIONS INDUSTRY

John N. Rose
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3.1 INTRODUCTION

Judge Harold Greene, the author of the most significant antitrust case in decades, the AT&T divestiture, said that it was caused by three major forces: antitrust laws, changes in technology, and competition forces. He went on to say that because of the growing strength of these forces, the breakup of AT&T was inevitable.

I agree that the breakup of AT&T was inevitable; however, I believe there was only one driving force, technology. Technology provided the means for companies to compete with AT&T. Technology provided low cost incrementally priced alternatives for industry and for new common carriers. Technology provided a wide range of new services not available at first from traditional common carriers. In fact, technology spawned the competition, AT&T reactions, and thus the Justice Department's reasons for filing suit based on the antitrust laws.

New technology, along with a vast pent up customer demand for new and cheaper communication services, is driving much of the communications industry toward deregulation. The AT&T divestiture is a result of this movement, not a cause. Therefore, REA views the divestiture in the context of being a part and parcel of the whole movement toward deregulation.

The word deregulation is so general that it obscures a host of problems. The basic one is deciding what part of the communications industry should remain regulated and what part should be deregulated. With deregulation comes changes in both who pays and how much they pay. As with all changes, there are winners and losers. The losers in telecommunications deregulation will pay much higher prices. And if those prices are too high, decisions must be made as to what should be done to preserve universal service, a goal that has been enunciated by the Federal Communications Commission (FCC) and is embodied in REA's basic enabling legislation.

In order to integrate the new competitive toll market with the still regulated local exchange market, and concurrently accomplish some of the requirements of the divestiture's Modified Final Judgment, the FCC decided upon a system of access charges. This is a nine billion dollar (based on 1981) decision industry-wide. The nine billion dollars are costs that are being shifted from one group to another. It will affect every telephone company and every telephone customer in the United States to a greater or lesser extent.

In making the decision to shift these costs, known as access charges, the FCC believed that toll customers, especially big users like large business firms, were paying too much of these costs through their toll rates. The FCC feared that in order to lower costs, these big businesses would build their <u>own</u> telephone systems and bypass the present network. This would leave everyone who was left, small businesses and residential customers, to pay that nine billion dollars. To make sure those big businesses did not bypass, the FCC decided to take some of the costs they were paying and shift them to the local telephone customer.

By the drastic shifting of these costs to the local customers, REA believes that universal telephone service is endangered. [Charts 3-1 and 3-2 demonstrate the effects of this cost shifting to rural telephone systems and rural telephone customers.] I feel that pricing rural residential telephone service so high that people are forced to drop off the line and substitute CB radio or other modes of communication creates the <u>ultimate</u> form of bypass.

Chart 3-1 shows how much higher local rates will be under the access charge plan. As you can see, over two thirds of the rural telephone systems financed by REA will have to <u>at least double</u> local rates. Some will quadruple, <u>or more</u>. If state regulatory bodies adopt an access charge plan for intrastate long distance calls similar to the one adopted by the FCC, local rates of 25 dollars or more will be common. In the Western states where customers are even more spread out than in rural areas of the South and East, the local monthly rate could be 35 dollars or more. You have to remember that access charges must be paid by all customers, including those who may never make long distance calls. Again, these increases are caused by a shift in who pays the costs of the local exchange - that nine billion dollars. [Chart 3-2 shows that shift in a different way.] If this whole system was in place in 1981, instead of the average rural telephone system getting two thirds of the money it needs to operate from the toll carrier and one third from the local customer, it would get only one quarter of its revenues from the toll carriers and three quarters from the local customer. The important fact to remember is that <u>none</u> of what is happening changes the costs that need to be paid -- all that is happening <u>is a change in who pays</u>.

3.2 FOUR BASIC ISSUES

From the rural point of view, divestiture is only one of the major changes taking place in the industry, sorting out the changes and the potential effects is difficult at best. Both the quality and quantity of new and present services for rural areas depends on adequate revenues for rural systems and reasonable rates for rural subscribers. In order to achieve both adequate revenues and reasonable rates REA has framed the changes into four basic issues accompanied by recommended solutions:

Chart 3-1

INCREASES IN AVERAGE SUBSCRIBER RATES PER MONTH

BASED ON 1981

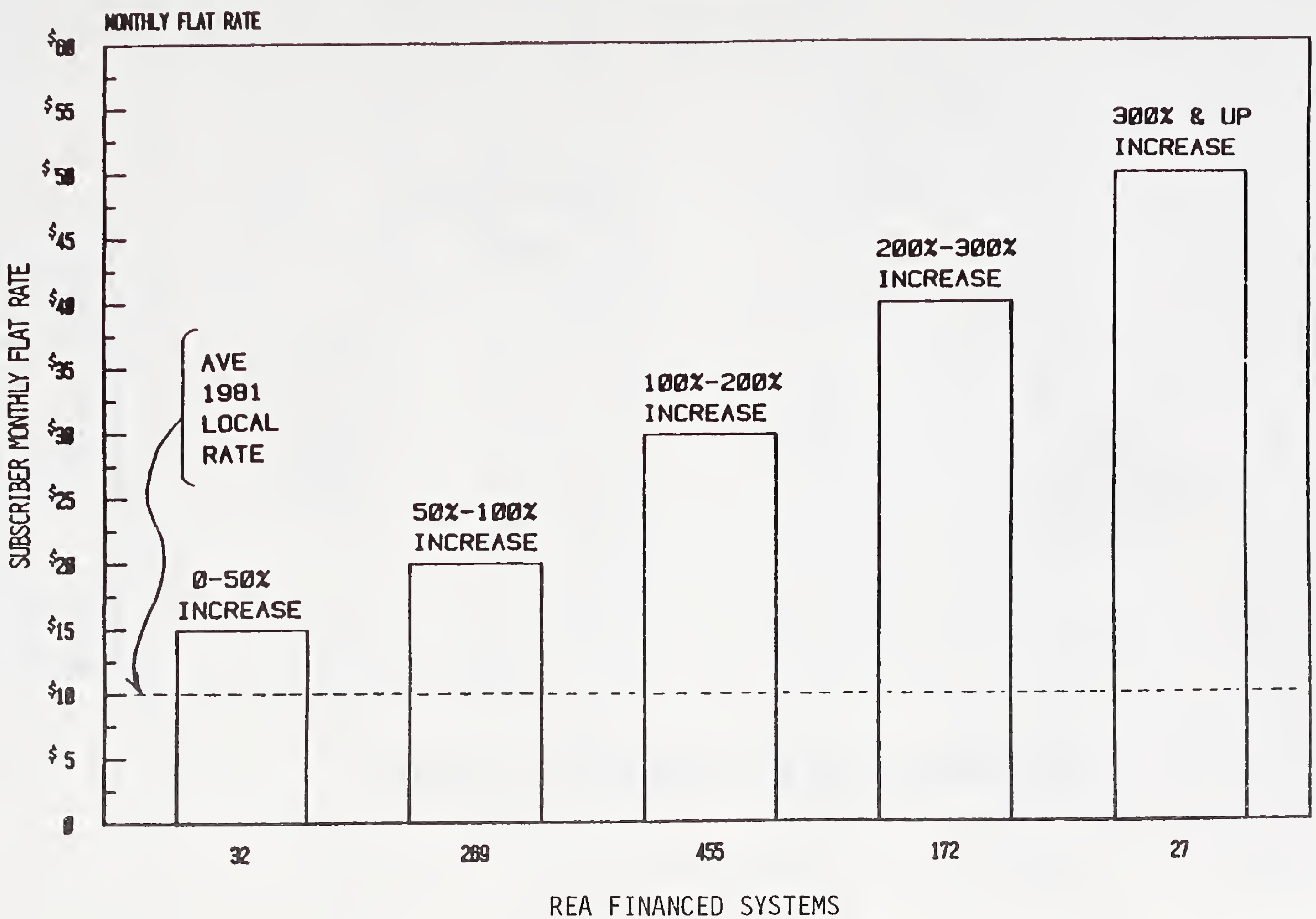
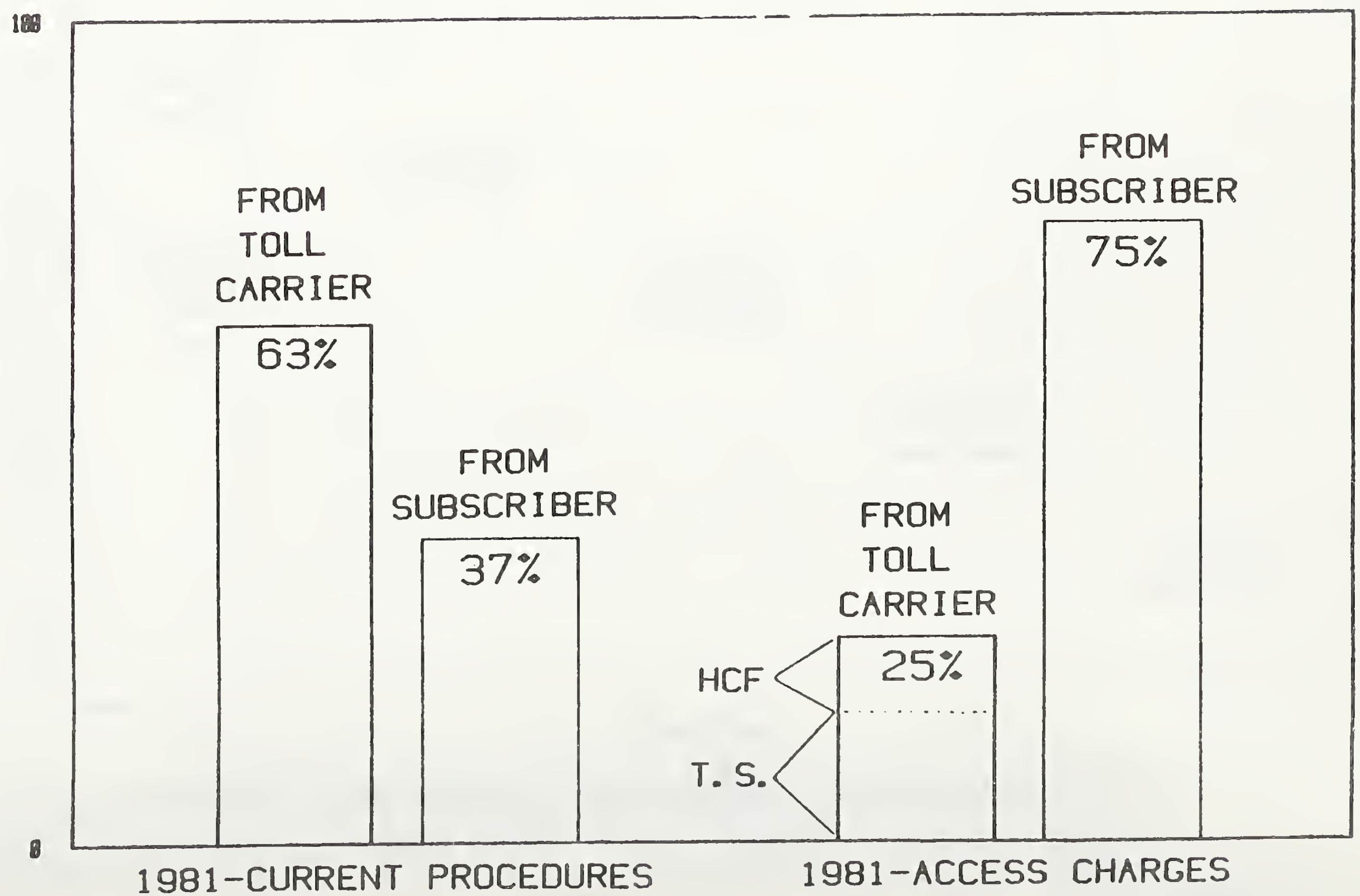


Chart 3-2

SOURCE OF REVENUES FOR REA BORROWERS



Summary of Four Basic Issues

I. Issue - Universal Service

The achievement of the goal of universal service in rural areas, both local and long distance, is threatened by the numerous regulatory changes currently impacting the telecommunications industry.

Solution

Continuing to strive to provide universal service in rural America is an important policy goal which we hope that the REA and FCC share. Determining appropriate relief for high cost rural areas must take into account all the increased costs in order to ensure that rates, both local and toll, remain at a universal service level.

II. Issue - Paying for Use of the Local Exchange

The local exchange carriers must be properly compensated for the use of their investments, while at the same time, the amount of local costs loaded onto toll rates must be reduced.

Solution

A level of interstate allocation approaching the level of subscriber line usage (SLU) should be applied on either a flat rate or usage basis to compensate the local exchange carrier. At this level of compensation, access charges to the end user may not be necessary as the increase in revenue requirements can be included in local rates.

III. Issue - High Cost Fund

In order to properly recognize the truly high cost nature of providing adequate telephone service to rural Americans, an appropriate high cost fund (HCF) mechanism must be installed.

Solution

Local exchange telephone companies and cooperatives that have 100,000 or less loops per study area or under 25 loops per square mile should be eligible for relief amounting to 90 percent of all costs exceeding 110 percent of the national average. To properly direct compensation to the systems that most need it, an overall interstate rate of return of on net telephone plant should be used in calculating the High Cost Fund.

IV. Issue - Reasonable Long Distance Rates for Rural Areas

Competition in the long-distance segment of the industry appears to be leading towards a deaveraging of toll rates. Such an occurrence would dramatically rise rates on rural toll routes and would deter achievement of the goal of universal service.

Solution

Non-competitive toll routes should be regulated and priced to allow all long distance carriers to use them and afford rural residents the benefits of competition. If necessary, a small surcharge on all toll routes should be used to support non-competitive routes. Intra-LATA trunking costs to the LATA point of presence (POP) should be averaged and pooled to the greatest possible extent.

REA believes that if these four basic points are implemented, universal service to rural America can be preserved and enhanced at minimal cost.

Discussion of Four Basic Issues

I. Achieving Universal Service

The proper resolution of the four points raised by REA are crucial to achieving universal service to consumers served by the more than 1,000 small rural independent telephone companies and cooperatives financed by REA. These telephone systems, covering more than half of the geographic area of the United States, have been dedicated and innovative in coping with the problems of serving high-cost rural areas. The four and a half million consumers served by REA-financed systems are important to the economic well-being of the nation and must continue to receive affordable priced telephone service, both local and toll.

The Rural Electrification Act of 1936, and its telephone amendment in 1949 which established a rural telephone program, were enacted by Congress to improve the quality of life for rural Americans. Through the telephone companies and cooperatives it finances, REA attempts to assure, on a universal service basis, that rural customers receive the same grades and quality of services as are enjoyed by urban residents.

Rural families have the same, if not greater, need for the grades and quality of telephone service provided those living in the cities, suburbs and small towns. It is because of this need that Congress has mandated REA to assure universal availability of adequate telephone services in rural areas. The REA believes that:

1. Rural residents need access to facilities that enable them to enjoy adequate telecommunications service with rates that cause no undue hardships or inequities.

2. Improved telephone service in rural areas benefits both rural and urban residents.

3. Rural residents as well as urban residents need reasonable and affordable local and toll rates.

There are many industry changes that will ultimately influence rates, and thus affect universal service. Several of these are significant regulatory changes. They will either increase rates or force a greater interstate allocation to maintain universal service. Some of the regulatory changes are detailed below:

Changes	Potential Results
1. Direct Assignment of WATS Access Lines	Higher Local Rates
2. Phase-Out of Terminal Equipment from Separations	Higher Local Rates
3. Possible Changes in Central Office Equipment Separations	Higher Local Rates
4. Depreciation Rate Increases	Increased Expenses Higher Local Rates
5. Possible Deaveraging of Toll Rates	Higher Toll Rates in Rural Areas
6. Cost-Based Pricing of Installation for New Customers	Incentives Against Adding New Customers
7. Customer Access Charges	Higher Local Rates
8. Usage-Sensitive Pricing	No Cost-Lowering Benefits In Rural Areas
9. Bypass	Potential Loss of Large Business Customers Resulting In Higher Local Rates
10. Competition	Benefits Flow Mostly To Urban Areas

11.	Rate-of-Return	Reduction in Toll Settlements and Higher Local Service Rates
12.	New Uniform Systems of Accounts	Imposition of Additional Costs on Independent Telephone Companies

The 12 regulatory and other factors which are identified above, all have the potential to contribute to higher rates and result in a threat to universal service. Studies will be very helpful to the FCC in determining the proper level and eligibility for the High Cost Fund (HCF); however, any study will be limited if it is retrospective in nature. Studies should take a prospective view to be a greater assistance to the Commission in promoting universal service. The full impact of many of these regulatory changes has yet to be felt.

3.3 The Proper Interstate Allocation

The difficult question is to balance competing interests. On one hand, the decision and proposed rules following the Second Supplemental Notice in CC Docket 78-72, adopted in 1980, required all services (i.e., MTS, WATS and Private Line) and interexchange carriers (i.e., AT&T and the OCCs) to be burdened at the Subscriber Plant Factor (SPF) level for access to the local loop. This was an incentive for interexchange carriers to bypass local exchange facilities. On the other hand, the Commission's decision following the Fourth Supplemental Notice in CC Docket 78-72, released in early 1983, to phase out the carrier's carrier charge for NTS telephone plant, except for contributions to the HCF, posed a threat to universal service -- especially in rural areas. This threat was further aggravated by other regulatory changes which resulted in lower revenues and higher expenses to exchange carriers. The dilemma now facing the FCC is how to establish a system of pricing that will balance bypass with universal service, and preserve a national network which benefits all customers. The FCC must provide an answer that accomplishes the following: 1) pricing for the use of the local exchange plant by toll services so that minimal bypass occurs; 2) pricing local service so customers will stay on the network; and 3) recovering the embedded costs.

A palatable compromise would be to move from a SPF to a subscriber-line usage (SLU) allocation to the interexchange carrier. In this manner, a much smaller HCF would be necessary for high-cost areas such as Alaska and many western states. Even if a usage-based allocator such as SLU is found not to be appropriate, a non-usage-based allocator approximating the level of SLU could be substituted; e.g. 1) a flat amount per toll trunk; 2) a flat amount per line-side connection used for interexchange services; or 3) a gross allocator assigned to toll carriers. Reducing the allocation to a SLU level would reduce the incentives to bypass, promote universal service and minimize the HCF. An additional benefit would be that state regulatory bodies would have the flexibility to structure local rates and access charges according to community needs.

3.4 The Appropriate High Cost Mechanism

Given the access charge and separations uncertainty present at this time, the most objective formula for ensuring universal service should contain a HCF that provides 90 percent of all costs exceeding 110 percent of the national average. This level of assistance is necessary to offset not only above-average non-traffic sensitive (NTS) costs, but high traffic sensitive costs, and other high costs resulting from the new telecommunications environment, including the inevitability of deaveraged toll rates.

Qualification for the HCF should be limited to those systems with less than 100,000 loops per study area or a density less than 25 loops per square mile per study area. Within the above parameters, arbitrary size distinctions have not been shown to accurately correlate with the cost. The eligibility limit on the number of loops per study area is basically a simplified method of distinguishing companies that have urban areas with which to average with those which do not. Absent the necessity for making that distinction, uniformly comparing NTS costs with the national average within the suggested range more closely approximates need.

The high-cost formula should not be targeted on the basis of high growth. The high-growth rate of a study area may be irrelevent to costs for many reasons. Other considerations, such as extreme environmental conditions, where the life of the outside plant is shortened, also should not be a targeting factor. These factors are reflected in costs.

In many circumstances, large independent exchange carriers have an advantage over small carriers in recovering above-average costs. For example, many Bell Operating Companies, which serve both urban areas and high-cost rural communities, are able to average costs to offset the expense of serving rural areas. On the other hand, some large independents serve high-cost areas without the benefit of having lower-cost urban exchanges in the same study area. Less densely-populated areas of the country are no more economically attractive to large companies than smaller companies. Every carrier, however, is mandated by the Communications Act to serve the public interest, whether those markets served are lucrative or high-cost. Should this be the case, a waiver process should be made available to those companies with a limit of 100,000 loops per study area and density limit of over 25 loops per square mile, so they may qualify for HCF assistance.

The eligibility and compensation requirements for the HCF should include all. This would include outside plant, line terminations, the mainframe, repeaters, loop extenders, carrier equipment, and land and buildings associated with this equipment. The intent of the HCF is to keep end user charges within reasonable bounds. The costs of NTS plant are the basis for those charges.

The sliding scale for compensation previously proposed is inadequate to preserve universal service, and creates only a marginally greater incentive for cost efficiency by local carriers than using a flat rate of 90 percent. It does not reflect an appropriate balance between bypass considerations and universal service. The sliding scale does not provide adequate funds for high cost carriers to prevent large rate increases. The imposition of high subscriber rates would greatly threaten the survival of universal service.

Providing less than 90 percent compensation is a redundant incentive since sufficient incentives for efficiency already exist. Incomplete compensation, especially at the sliding scale level, is a signal that telephone service to rural Americans is not an important goal. Clearly, if the Commission finds it necessary to impose an incentive factor, any rate less than 90 percent of all non-traffic sensitive costs over 100 percent would be a threat to universal service.

We recognize that there is concern by the FCC with the overall size of the HCF. A large fund is seen as a mechanism that will encourage bypass. Yet, out of the 9 billion dollar shift of costs from interexchange carriers to local customers, only a small amount will be spent on maintaining universal service. Thus far, both the Joint Board and the FCC appear to have made the bypass issue their paramount concern. However, at present there are no studies showing at what price bypass may occur and to what extent non-economic reasons are involved. It seems more than reasonable that the Commission could impose a small charge in exchange for the guarantee of universal service, thus increasing the value of service for all customers.

The FCC's suggested use of the actual cost-of-debt and the interstate return-on-equity will shift HCF compensation away from the small rural systems that need it most.

Because this aspect of cost determination misdirects the fund from systems originally targeted for assistance, these systems will experience substantial hardships. Small independent companies and cooperatives have always relied on the industry interstate or intrastate rate-of-return because of the partnership in the provision of toll service. Because of circumstances beyond the control of independents, that partnership has been severed. REA-financed systems will have to deal with yet another reduction in revenues. An overall interstate rate-of-return on net telephone plant should be used in receiving compensation from the HCF. This compensation would work toward preserving universal service.

3.5 Deaveraging of Toll Rates

The inquiry into the appropriate long-run regulation of AT&T's basic interstate telecommunication service <u>is a significant rural issue</u>. Maintaining high-quality interstate long-distance services at reasonable rates for rural areas must be a vital part of the public discussion on regulatory policies involving AT&T. At this time and for the foreseeable future, AT&T will carry almost all of the interstate toll traffic generated by rural customers because of the lack of interest in the rural market by other interexchange carriers. Maintaining a national network, partly competitive and partly regulated, is a goal with major benefits to the nation as a whole. Section 202(a) of the Communications Act of 1934 sets national policy and states that unreasonable discrimination in charges, regulation, and services to any class of persons, localities or on any other basis should be prohibited. Therefore, any deregulation of AT&T should include specific assurances that quality long-distance service to rural areas will continue to be available at reasonable rates. Such a policy benefits the nation as a whole.

Selective relaxation of regulation to allow competition is a positive step as long as rural high-cost areas continue to receive equivalently priced quality toll service. We have always been convinced that the concept of universal service includes both local and toll service. Adequate and affordable local and toll service in rural areas benefit both rural and urban residents. In order to maintain universal local and toll service, the Commission need only look to its own Act. Nondiscrimination in charges promoted by the Communications Act of 1934 includes reasonable equality in rates for equivalent value of service.

Rural areas have high long-distance costs for several reasons. First, the costs of providing long-distance service to and from rural areas are significantly higher than providing that service between urban areas. Second, urban local calling areas are immensely larger than rural local areas. Thus, rural people make many more relatively expensive short-haul toll calls.

The national policy of competition for inter-LATA long-distance service can benefit the nation as a whole if the following policies are pursued:

1. Non-competitive routes should be regulated and priced so that all long-distance carriers can use them and extend their networks to all areas of the country.

2. A small surcharge on all routes should be used to support non-competitive routes.

3. On regulated routes, AT&T would be a carriers' carrier.

4. Intra-LATA trunking costs to the point of presence in the LATA should be averaged and pooled as much as possible.

5. An adequate transition and continuing review of the entire issue is crucial.

As you can see, the deregulation of the telecommunications industry is inextricably intertwined with the AT&T divestiture and has the potential to dramatically impact the achievement of universal telephone service in rural America. In order to prevent the isolation of rural families, the recommendations stated in this paper concerning our four basic issues must be understood and addressed by those in a policy making capacity in the telecommunications industry.

PART III: SECURITY IN A DISTRIBUTED ENVIRONMENT

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PREFACE

Wherever the technology may lead us, we will still have to protect the integrity and reliability of our data. The problem, therefore, is not only that of predicting where the technology is going but also how it will affect the security of our ADP systems. This Part considers some of the security issues associated with the technology trends.

Chapter 1 contains an overview and forecast of the computer security technology itself.

Chapter 2 discusses computer security in the context of a distributed data processing environment and presents a two part methodology for use in computer security and risk analysis. The first part of the methodology consists of a framework for constructing a "profile of abuse." The second part involves the use of descriptive modeling techniques. These techniques are adapted from earlier work at ICST.

About two years ago, ICST began the development of a new approach to cost-benefit studies. The concept is a simple one: if we were to have reasonably accurate descriptive models of the various elements that comprise the Federal data processing environment, then we would be able to trace the probable effects of planned changes on specific points in that environment. In other words, we would have a much better idea of where to look for costs and benefits of proposed or actual change (e.g., an ADP standard). To date, we have constructed models of two elements: data processing operations [1] and applications software development [2].

As we considered the potential effects of the trend toward distributed data resources on computer security, it seemed that the descriptive models would provide a useful analytic tool in that context. We therefore adapted some of the cost-benefit work to the security problem. The results of the adaptation are shown in section 2.4. We would appreciate your comments on the usefulness of this approach.

1. SECURITY: OVERVIEW AND FORECAST

1.1 SECURE TRANSMISSION AND STORAGE

1.1.1 Background and Present Approaches

With the widespread availability of personal computers and remote terminals in extensive use on public common carrier telecommunications systems, the possibility of eavesdropping, interception and unauthorized access to data transmission and computer systems has greatly increased. For both military and business communications, privacy and secrecy of data are now severely threatened. In addition, U.S. industry is on the verge of establishing widespread home consumer information and transaction services following the European Videotex model. Such services might include home banking, shopping and personal information storage; and would, therefore, also require private and secure data communications. Current networks of bank automatic teller machines and data communications also are vunerable to electronic theft, further increasing the need for cost effective security means for the transmission and storage of information.

Systems providing for secure data transmission and information storage are not widely used in 1984. This is despite the fact that a widely accepted Data Encryption Standard (DES) has been issued by the ICST/National Bureau of Standards. During the early part of this decade, a number of manufacturers did, in fact, offer data link encryption and ciphering equipment at reasonable prices ($4,000 - $12,000) for commercial sale. Sales results were quite disappointing and many of these products were, in fact, withdrawn. At the present time, the predominant usage of data security systems is in specialized military systems, federal government non military systems and small numbers of commercial and banking systems employing the ICST DES.

Several firms, such as Western Digital Corporation, offer integrated circuits which perform the ICST DES. The DES requires that encryption be performed with hardware as opposed to software. The present ICST DES employs a single well defined private key encryption technique requiring a variable, user selected, 56 bit key. Data is blocked, and encrypted by combining the use of multiple feedback shift-registers with the 56 bit key. The data must be decrypted using the identical 56 bit key as was used at the encrypting end. At slow data speeds (1200 bps and less) single chip microcomputer based implementations of the DES suffices. For higher speeds, custom LSI chips are available ranging from $10 for 640 bit per second data rates (bps) to 10 million bps devices at $120 each. With support electronics and a package, slow speed, low-cost devices could be fabricated for under $500. The data encryption standard is quite suitable for coding of the information for storage on magnetic media; however, it is not widely used due to speed/throughput limitations of reasonable cost hardware. There are, however, a number of software based ciphering techniques available for encrypting data to be stored on magnetic storage. These ciphering techniques pre-date the ICST DES, and are more widely used.

1.1.2. Technological Evolution

- 1984-1989 -- During this time period improved technology custom large scale integrated circuits (LSI) will implement DES at lower cost while permitting higher speeds and increased functionality. We expect that the growth of consumer home information transaction services, with home banking as the key component, will create large mass-market demands for low cost 1200-2400 bps DES chips which will spill over into additional industrial applications. During this time period, additional hardware for providing data compression will begin to be employed to make more efficient use of the slow-speed switched telephone network. A by-product of employing data compression hardware will be the provision for encryption at little or no incremental cost. Also during this period, public key ciphers will begin to be validated and employed. Such public key ciphers differ from the ICST single private key DES in that the encrypting and decrypting keys are different. In a two key, public key system, knowledge of matched plain text, cipher text and one of the two public keys, is not sufficient to deduce the other non-public key. This public key cipher technology is now known but has not been subject to sufficient analysis and scrutiny to have widely accepted levels of comfort. Already, software based public key ciphers are being marketed by small firms for use on personal computers. We expect, by the end of the next five-year time period, that the level of comfort of these public key systems will grow and their use will begin to proliferate, in particular in applications in conjunction with the faster, secret key DES system.

  Work in the ANSI X9.E9 committee to develop well-defined Key Management Standards should be released during this timeframe.

- 1989-1994 -- During this time period, low cost implementations of ICST DES will be available and widely utilized. The difficulty of maintaining security and distribution of private key will provide impetus for shifting to public key ciphers. Such public key ciphers will also provide the electronic equivalent of a signature which can be authorized, validated and authenticated by electronic means. While the DES can be used in this mode also, key management poses a logistics problem. Public key hardware implementation will be developed during this time period and supported by custom chips. We expect a public key cipher standard, similar to the ICST DES, to be adopted toward the 1994 timeframe. Also during this timeframe, low bit rate digital voice coding hardware will become cost effective and when utilized with encryption systems, the combination will provide voice security over common carrier communications circuits.

Together, these trends will further reduce operational and logistical barriers to employing encryption systems.

- 1994-1999 -- During this time period, the ICST DES will become all but extinct. Public key ciphers will be widely used for both the encrypting and coding of information. Disk storage and other bulk magnetic and optical media will be controlled by dedicated high-speed processors with public key cipher an integral part of the design. The advance of very large storage bulk media, such as optical devices, will permit interesting applications of the public key cipher. For example, it will be cost-effective to publish an entire software company's repertoire on a single optical disk but code sections of it with different public key ciphers. In that way, purchasers will be able to obtain access to pieces of software in a controlled manner by simply placing a telephone or computer call and receiving the public key deciphering code for that portion of the software which they wish to buy. Hardware will be available in high-speed gallium arsenide based integrated circuits and optical computing techniques to do the high-speed ciphering of digital data in the 100 megabit range suitable for digital television video transmission. Such ciphering costs will be miniscule given the already substantial processing power to do the digital coding and compression.

1.1.3 Conclusions

Wide-spread consumer financial information transactions will cause the development of low-cost encryption hardware and support components such as integrated circuits to proliferate. This natural evolution will extend to industrial applications also, permitting cost reductions and performance improvements in existing hardware. The net result will be by the end of the 1999 planning horizon, data encryption for both transmission and storage will be widely used.

Technology will facilitate both significant cost reduction and performance improvements. Performance improvements will permit the high-speed real-time ciphering in the hundreds of megabit range suitable for digitized video transmission and other images. Costs will decline from the present $10 for 640 bps, $120 for mbps to almost no incremental cost as ciphering is subsumed by other processing power available for compression.

With the proliferation of public key data encryption systems, privacy issues, management barriers and misgivings about the development of consumer and business data communications and distributed computing services will disappear. Encryption systems will be widely utilized and public confidence in their integrity will be high, thereby fostering an additional greater usage. Failure of a public key data encryption standard to emerge will slow down the development of such distributed computing applications as local area networks, metropolitan area networks, and long-haul inter-city data communication systems.

1.2 ACCESS CONTROL USING BIOMETRICS

1.2.1 Background and Present Approaches

Three basic techniques are known for authenticating an individual's right to obtain access to a closed area:

- o Some secret the individual knows such as a personal identification number (PIN).

- o Some physical item the user has such as a magnet-striped card.

- o Something the user is, that is a physical attribute of their being.

Passwords, PINs and access devices ranging from keys to card media are widely used today. However, they are easily subject to compromise, by theft, interception, eavesdropping, or unauthorized disclosure of information. A key can be acquired by unauthorized individuals and information or passwords can be compromised by interception, or calculated by exhaustive search. Passwords and physical devices can be lost or forgotten at inappropriate times. The ideal situation would be to authenticate access to an area or system by means of physical attributes of an individual.

Biometric access control devices are not widely used today. Research has been performed by the military and at least one company has received a contract to supply biometric access control devices to military personnel desiring access to ultra-secure areas such as missile silos. Interest among private utility operators of nuclear power plants for such devices is also high. It can be expected that should the cost, convenience, and utility of devices improve, that they would be of general widespread interest to other commercial entities. A variety of biometric features that can be recognized and authenticated are possible and indeed all have been investigated:

- o Hand geometry -- the length of individual fingers on a hand is measured.

- o Speaker recognition -- spoken voice utterances are compared to previously entered normalized templates of particular utterances.

- o Signature analysis -- the static or dynamic features of the user signing his name using a special stylus on a digitizing tablet is analyzed and compared to normalized templates previously entered.

- Fingerprint recognition -- an image of a finger, palm or handprint is compared to normalized previously stored templates.

- Face recognition -- an image of the user is compared to previously stored input.

- Retinal vein patterns -- imaging device of veins or microphotograph of the interior of the eye compares retinal vein patterns to previously stored normalized templates.

It is known that work is currently underway with the goal of development of low-cost point-of-sale signature dynamics analysis for the identification of people associated with credit cards. Such a system would employ the dynamics of a stylus on an XY digitizing pad to perform verification. Experimental installations of speaker identification systems have been developed, although not currently commercially offered. There are, however, computer facilities now protected by such a speaker identification system.

1.2.2 *Technological Evolution*

- 1984-1989 -- During this time period the advent of low-cost digital signal processing microcomputing and integrated circuit devices, additional research into the algorithms of pattern recognition and development of systems of feature classification will permit the development of functional low-cost biometric access control devices. These devices will have utility in access at locations and also for physical access to areas in conjunction with or supplanting conventional mechanical door locks. Areas for fruitful commercial exploitation include: handwriting dynamic analyzers, finger prints and speech analyzers. Speech input devices have the utility of being capable of being operated over conventional voice grade telephone circuits. The systems employed during this period will exhibit only marginal performance as measured in terms of their probability of correct detection and probability of false alarm. They will therefore need to be used to augment conventional password protected and physical media protected systems. A typical system would involve a magnetic stripe credit card inserted in a slot. The user will then enter a secret identification number through a keyboard and provide spoken or handwritten signature information for biometric input. Only if all three levels of access meet the preselected balance will the user be granted access. During this timeframe speaker recognition systems will become practical but still too expensive for wide-scale proliferation.

- 1989-1994 -- During this time period, low-cost memory, solid-state imaging devices and higher speed digital signal processing hardware will permit imaging systems to become feasible for use in biometrics. In addition the performance of the speech recognition systems will be considerably improved as discriminate functions are better understood. Speech systems will migrate down from expensive military uses to wider scale commercial exploitation while image systems will still be confined to the highest security areas such as sensitive commercial industries, the military, and secure facilities such as nuclear power plants. These systems will all share the common characteristics of employing remote data gathering devices with the authentication performed centrally.

o <u>1994-1999</u> -- During this timeframe, low-cost high-capacity optical storage devices will become available. This in combination with the continued evolution and development of biometric devices will permit the template information to be carried by the user. The whole graphic or optical storage technique employed can be secure enough against counterfeiting to permit template information to be read locally rather than at a central source. This will facilitate more complex image analysis, voice, or possibly fingerprint verification. Without the need for access to a real time central computer on a high-speed data communications link between the data access points; small, standalone systems will be possible.

1.2.3 Conclusions

By providing clear accountability that cannot be compromised both business and industry will use more distributed data processing and remote terminal access systems hardware. These systems will deter theft and system compromise, and prevent catastrophic access to highly secure areas by unauthorized persons. Peace of mind gained by such systems will also encourage consumers and users to make wide-spread use of electronic funds transfer and consumer home information and transaction services.

Cost and performance will improve significantly during this timeframe. Performance will be measured in terms of correct rejection going from rates of 70 percent to better than 99.9 percent with false acceptance going from the order of 3 percent to far less than 1 percent. Cost will go from thousands of dollars down to tens of dollars, making proliferation even at the retail store level probable.

If secure access control systems employing biometrics fail to materialize, this will significantly deter a variety of consumer point-of-sale, home information, business, and financial transactions services based on distributed data development. The appearance of these systems will not in itself assure the success of these other systems, but will be a major catalyst toward their development.

2 COMPUTER SECURITY IN A DISTRIBUTED DATA PROCESSING ENVIRONMENT

2.1 INTRODUCTION

The primary objective of this chapter is to assess the implications for Federal computer security policies and practices resulting from anticipated technology changes and (2) provide a framework to help managers understand, compare, and evaluate CSRM actions. Additional objectives are to: review the nature and magnitude of the computer security and risk management (CSRM) problem in the Federal Government and describe an essential set of CSRM policies that constitutes good security practice.

The remainder of this chapter is presented in three sections. Section 2.2 discusses computer security issues and policies, and presents a framework that will be used throughout the chapter. Section 2.3 discusses the implications of distributed processing for CSRM policy and practice. Section 2.4 notes some important trends in data processing technology, provides descriptive models fo prototypical centralized and distributed systems, and -- using a case example -- demonstates how descriptive models can be used in CSRM analyses. Section 2.5 uses another case example framework presented in section 2.2 and the descriptive modeling techniques shown in section 2.4. Section 2.6 contains some conclusions and a summary.

Additional objectives are to: review the nature and magnitude of the computer security and risk management (CSRM) problem in the Federal Government; and describe an essential set of CSRM policies that constitutes good security practice.

2.2 FEDERAL COMPUTER SECURITY ISSUES AND POLICIES

Computer security entails policies and related activities to protect and safeguard computer resources and the assets they control. The general goal of Federal computer security policies is to achieve and maintain the required level of confidentiality, accuracy, integrity, and availability of data processing as set by the controlling organizations. That goal encompasses broad Federal functions and responsibilities in national security, government program effectiveness, computer misuse prevention and detection, and the safeguarding of individual rights and privacy [3].

All major government activities are critically dependent upon computerized systems to achieve their objectives. Thus, ensuring that computer systems are correctly collecting, processing, storing and retrieving essential data is of vital importance. Additionally, the value of the computer resources themselves warrant special safeguards against misuse. As of 1980, the Federal Government's investment in computer systems (excluding computers in weapons systems) exceeded $5.5 billion [4] and projected ADP-related acquisitions of information technology systems, facilities and services for the 1983-86 time frame are about $25 billion [5].

The concern about -- and evidence of -- Federal data processing system vulnerabilities to misuse and accidents have been documented in a variety of reports over the years [6]. There is a consensus that computer misuse does exist, that "hard" estimates of the magnitude of actual instances are not available, and that too many Federal computer systems have inadequate safeguards against misuse and accidents [7].

Any given computer security problem can be divided into three components: (1) The cause: who or what and how, (2) The effect, and (3) The response: the actions designed to prevent or control the problem.

The cause of computer security problems can be either people or disasters (such as fire or earthquake). Those caused by people are, by far, the more ubiquitous [8] and will therefore provide the focus for the remainder of this discussion.

The primary effects of the problem are a mixed bag which include:

- Loss of data integrity through errors and omissions
- Fraud and embezzlement
- Privacy invasions
- Loss of data integrity through alteration of records
- Theft of computerized information
- Unauthorized use of computerized information
- Denial of service

The first of the listed effects, loss of data integrity through errors and omissions, appears to constitute the single largest security problem -- roughly 50 percent to 80 percent of computer losses [9]. That, combined with the next item, fraud and abuse, appears to account for 70 percent to 90 percent of the losses. Although there are no hard data, conservative estimates place the annual loss to the Federal Government at about $175 million due to errors and omissions and $13 million due to fraud and embezzlement [10].

Concern about the entire range of effects have led to a collection of responses that collectively make up Federal computer security policy. There is no lack of comprehensive reviews of Federal computer security policy [11] and only a brief overview will be provided here. Controlling Federal Statutes and Executive Orders are listed in table 2.1; security-related publications from ICST are listed in table 2.2; OMB circulars on the

TABLE 2.1 TABLE OF FEDERAL STATUTES AND EXECUTIVE ORDERS PERTINENT TO PRIVACY AND SECURITY ASPECTS OF COMPUTER-RELATED CRIME [3]

CITATION	RECORDS AFFECTED	TITLE OF THE STATUTE
5 U.S.C. 552	G	Fredom of Information Act
5 U.S.C. 552a	G	The Privacy Act of 1974
12 U.S.C. 3401 et seq.	P	Right to Financial Privacy Act
13 U.S.C. 9214	G	Census Act
15 U.S.C. 1666a	P	Fair Credit Billing Act
15 U.S.C. 1681	P	Fair Credit Reporting Act
15 U.S.C. 1693	P	Electronic Funds Transfer Act
18 U.S.C. 641	G	Embezzlement and Theft Prohibition
18 U.S.C. 793, 794	G	Espionage Acts
18 U.S.C. 1343	G-P	Wire Fraud Prohibition
18 U.S.C. 1905	G	Trade Secrets Act
20 U.S.C. 1232g	P	Family Educational Rights and Privacy Act
26 U.S.C. 6103, 7213, 7216, 7217	G-P	Internal Revenue Code on Confidentiality
26 U.S.C. 7609	P	Special Procedures for Third Party Summons
42 U.S.C. 408(h)	G	Confidentiality of Social Security Numbers
42 U.S.C. 5103(b) (2)(e)	G	Confidentiality of Child Abuse Information
44 U.S.C. 3101-3315	G	Records Management by Federal Agencies
44 U.S.C. 3508	G	Interagency Information Exchange
E.O. 10865	G	Safeguarding Classified Information within Industry
E.O. 12065 *	G	Rules Governing Classified Information

KEY: G = Government Records Covered
P = Private Sector Records Covered

Source: U.S. Department of Justice. Bureau of Justice Statistics. Computer Crime: Legislative Resource Manual. Washington, U.S. Govt. Print. Off., 1980.

* Superceded by E.O. 12356, 1982

TABLE 2.2 INSTITUTE FOR COMPUTER SCIENCES AND TECHNOLOGY COMPUTER SECURITY PUBLICATIONS

Contingency Planning

FIPS PUB 87
SPEC PUB 500-85

Database Security

FIPS PUB 88
SPEC PUB 451

Encryption

FIPS PUB 46
FIPS PUB 74
FIPS PUB 81
SPEC PUB 500-20
SPEC PUB 500-27
SPEC PUB 500-54
SPEC PUB 500-61
NBSIR 76-1189
NBSIR 77-1291

Evaluation of Computer Security

SPEC PUB 500-19
SPEC PUB 500-57

General Computer Security

FIPS PUB 39
FIPS PUB 73
SPEC PUB 500-24
SPEC PUB 500-25
SPEC PUB 500-33
NBSIR 76-1189

Network Security

SPEC PUB 500-21
SPEC PUB 500-33
SPEC PUB 500-24

Physical Security

FIPS PUB 31

Privacy

FIPS PUB 41
SPEC PUB 500-10
SPEC PUB 500-50
NBSIR 76-985
TECH NOTE 906
Monograph 157
SPEC PUB 469

Risk Management

FIPS PUB 31
FIPS PUB 65

Software and Operating Systems

SPEC PUB 500-2
SPEC PUB 500-24
SPEC PUB 500-25
SPEC PUB 500-67
NBSIR 76-1041
TECH NOTE 919

User Authentication

FIPS PUB 48
FIPS PUB 83
SPEC PUB 500-9

subject are shown in table 2.3; and pertinent Federal Property Management Regulations are in table 2.4. Figure 2.1 portrays the general relationships among the Federal computer security policies, and table 2.5 lists the major areas within which policy can be classified.

The tables of policy documents are representative of the efforts of the Federal Government to do something about computer security problems. Responsibility for those efforts is shared by the central management agencies, i.e., ICST, GSA, NSA, OMB, and OPM. In addition to the centrally prepared and distributed documents, individual agencies interpret the policies to prepare specific computer security controls and activities [13]. Thus, there seem to be sufficient policy directives vis a vis Federal computer security goals and objectives despite some concern expressed over the putative policy shortcomings [14]. However, there are widespread problems with inconsistent implementations and interpretation of that policy. For example, one authority [15] has stated:

"- Federal agencies' top-level management lacks an awareness of the nature and extent of computer and telecommunications abuses;

- there is a lack of specific guidance directed at promoting effective security programs;

- computer and information systems security often has little upper-level management support;

- variations in policy and guidelines cause problems in implementation;

- available tools and techniques associated with computer security are not always used;

- the information security function generally is misplaced within Federal agencies; and

- there is a lack of comprehensive management coordination and oversight of Federal agencies' automated information security programs, and there is a tendency to use a 'patchquilt' and 'band aid' approach to provide security for Federal information resources."

The result of those problems is evident in the list of <u>effects</u> noted above. For typical Federal computer facilities, good computer security policy and management practices can hold those effects to tolerable levels. ICST has recommended a set of activities (table 2.6) that comprises "good" computer security

TABLE 2.3 OMB CIRCULARS PERTAINING TO COMPUTER SECURITY

Circular A-71,	Transmittal Memorandum No. 1, Security of Federal Automated Information Systems, July 1978
Circular A-108,	Responsibilities for the Maintenance of Records About Individuals by Federal Agencies, August 1978
Circular A-109,	Internal Controls Systems

TABLE 2.4 GSA FEDERAL PROPERTY MANAGEMENT REGULATIONS RELATED TO COMPUTER SECURITY

FPMR 101-35.304-308,	Security Program Elements, August 1980
FPMR 101-34.17,	Privacy and Data Security for ADP and Telecommunications Systems, August 1980
FPMR 101-36.17,	Management and Control of Computer Rooms and Related Support Areas, October 1980

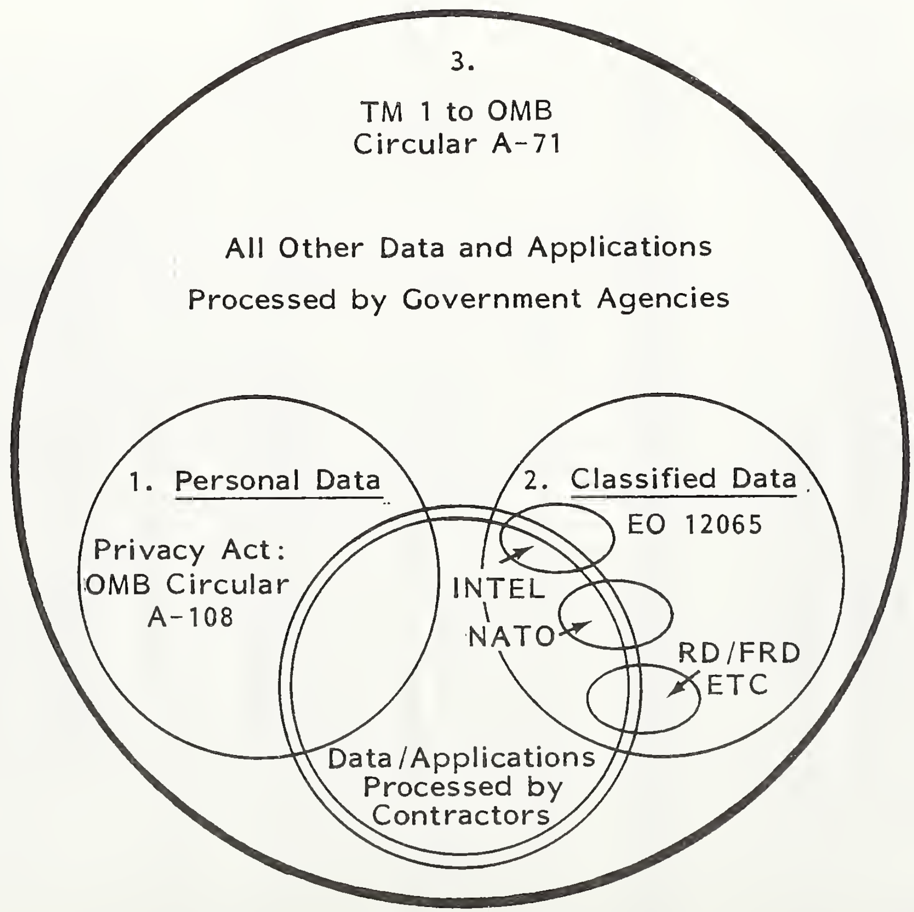


Figure 2.1 Federal Automated Information and Computer Security Policy Sets [12]

TABLE 2.5 COMPUTER SECURITY POLICY AREAS

1.	Identification	-	of system users, operators, data files, database transactions, system devices, system output products, input sources, and telecommunication lines
2.	Accountability	-	of system users, operators, programmers, and maintenance personnel
3.	Authorization	-	rules for the access levels of system users, devices, and programs to system data and software
4.	Access Controls	-	for physical access, and for operational access to system components and resources
5.	Operations Controls	-	for ensuring that system devices, programs, operating interfaces and databases can control the data and resources they share
6.	Consistent Performance	-	in carrying out system functions and operations correctly and consistently according to program logic and performance criteria
7.	Recovery-Restart	-	capabilities to recover in a timely and planned manner from any disruption of datafile access or processing capability
8.	Auditability	-	of all critical system functions and resources to ensure that all the above 1-7 policies are properly implemented and performing as planned

TABLE 2.6 RECOMMENDED ACTIVITIES FOR A "GOOD" COMPUTER SECURITY PROGRAM

I Policy and Administrative Activities

- Develop a comprehensive organizational policy covering management and individual responsibilities for computer security, including internal and external review policies.
- Establish a focal point for computer security information and assistance.
- Establish policies for employee selection and continued evaluation.
- Establish awareness of security and personnel policies through bulletins, job descriptions, employee agreements.
- Develop and complete authorization agreements for all personnel who are associated with computer utilization (users, computer managers, computer operators, maintenance personnel, systems personnel, and computer security officers).
- Establish continuing education programs emphasizing computer security, accuracy, and reliability.
- Identify organizational vital information and data processing functions.
- Prepare risk analyses, and update annually or when there is a major change in computer systems.
- Implement activities from Groups II, III, and IV as needed for a balanced program of management and technical procedures.

III Physical Security Activities

- Analyze site requirements and select appropriate site.
- Establish a fire protection system.
- Select electrical power supply system(s).
- Establish access controls for buildings, computer facilities, and terminals.
- Establish procedures for protection of data storage media.
- Establish a security labeling system for data storage media.

II Backup and Recovery Activities

- Identify critical data processing functions.
- Identify critical data processing hardware and software.
- Identify critical data resources.
- Identify alternate data processing and data communications capabilities.
- Identify back-up personnel.
- Specify and document overall back-up strategy.
- Specify and document detailed contingency plans.
- Test and evaluate contingency plans periodically.

IV Automated Technology / Access Controls Activities

- Implement computer reliability and maintenance programs.
- Establish personal identification and authentication systems.
- Establish resource labeling and authorization systems.
- Establish controls for data accuracy and integrity.
- Generate resource use audit trails; analyze when required.
- Establish controls to protect secrecy of data.
- Suppress electronic emanations and interference.

practice. Depending upon the facility and organizational setting, computer system characteristics, and the nature of the applications, the appropriate set of "responses" (passwords, journalling, etc.) will vary -- there are literally hundreds of candidate actions that can be implemented singly or in combination [16].

2.2.1 The Anatomy of Computer Security Abuse

The technology trends are leading toward an environment of decentralized small, but powerful, systems that can communicate with a central mainframe, as well as with one another, over a variety of networks. Assessing how these trends will affect the already problematic status of computer security requires a model with explicit technology-related parameters, such as the one shown in figure 2.2. That figure, which shows the anatomy of the cause component of the security problem, embeds the technology parameters in a process model which details how computer misuse occurs from the time that it is perpetrated to the time that it has its effect.

Computer misuse occurs when a perpetrator is motivated to access a computer process and/or resource and take actions, which may or may not be authorized, that affect an organizational through a selected strategy and result in an effect on the organization. These events form the "dimensions" of the causal chain. The dimensions are, in turn, defined by specific "elements" (e.g., an "element" of the motivation dimension might be material gain). An element from each dimension must be present for an effect to occur. An "event" happens when an element is actually introduced into an organizational environment to form part of the chain of events leading to the effect.

The dimensions of people-caused computer security problems are discussed next and significant elements in each dimension are enumerated.

2.2.1.1 Perpetrators

The sequence begins with a perpetrator who either has a deliberate motivation for committing an abuse or encounters a factor (or factors) responsible for the inadvertent creation of an error. The relative importance of the remaining dimensions and the appropriate response to the effects of the misuse depends on whether the motivation is deliberate or inadvertent.

The perpetrator must have a time and place to access or indirectly influence a computer system resource or process. Some action, either authorized or unauthorized, which may be part of a coordinated strategy of related actions, must be taken by the perpetrator (or an appropriate action omitted) in order to attack a target resource. If this sequence is broken at some point, the perpetrator cannot have the effect on the data processing system

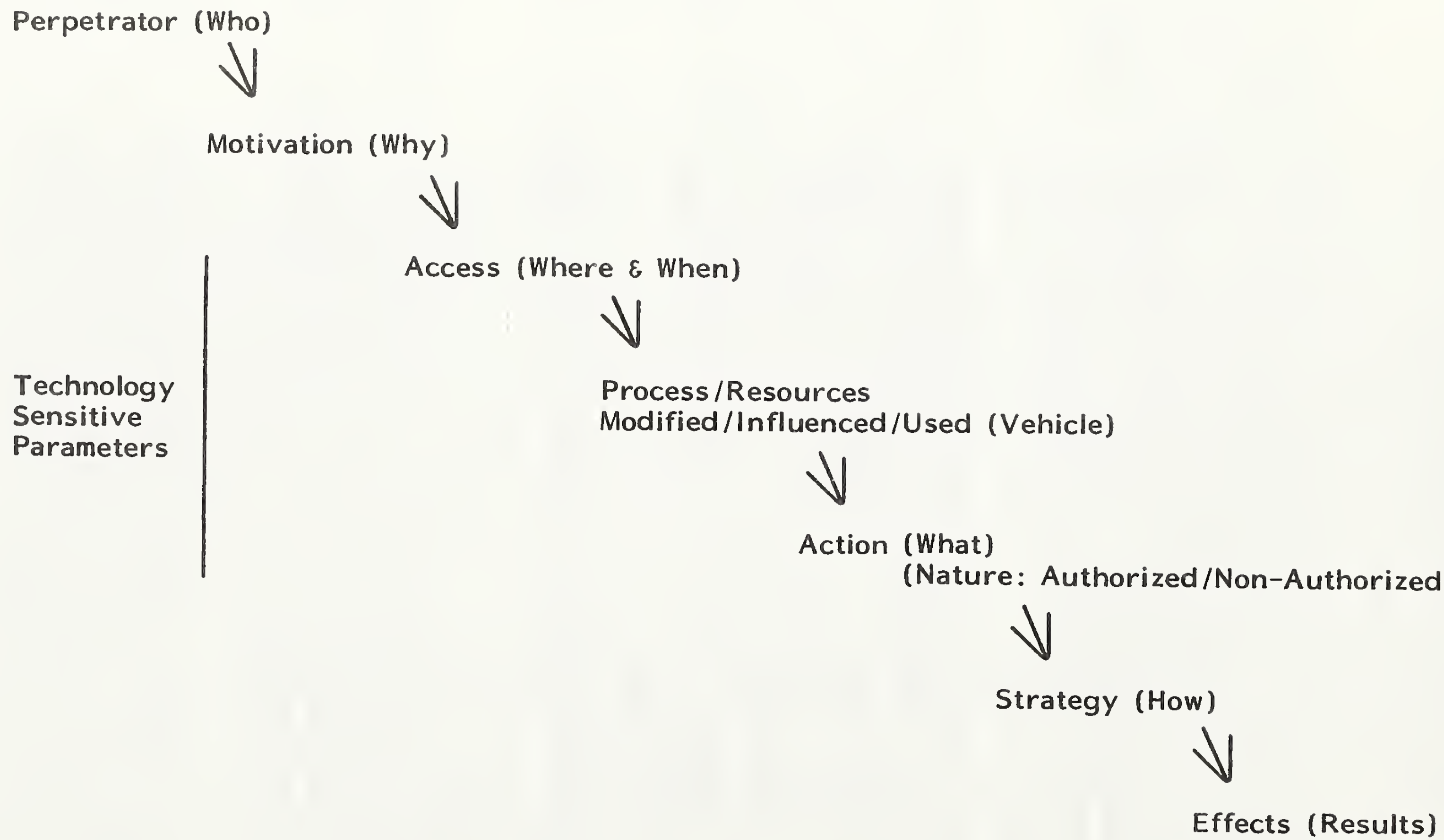


Figure 2.2 Events Comprising People-Related Computer Misuse

or its applications. <u>Each dimension must be represented if an ultimate impact is to occur.</u> Note that an effect can yield a gain for the perpetrator without implying an equivalent loss for the organization and vice versa.

A list of typical perpetrators is shown in table 2.7. In the category of fraud and abuse, the perpetrators of greatest concern are data entry/terminal operators, officer/managers, and technically knowledgeable outsiders. In one study of 150 major cases [17], those perpetrators, together, accounted for over 65 percent of the losses. A variety of other evidence [18] supports the hypothesis that most frauds are committed by data entry/terminal operators.

2.2.1.2 Motivations for Error/Abuse

Different motivations apply to inadvertent, as opposed to deliberate, acts (or omissions) that lead to errors and abuse in computer systems. In fact, "motivation" is not really the correct term in the case of errors -- here we are referring to any specific factor(s) and environmental situation(s) that predispose errors to occur more frequently than some achievable baseline level.

Table 2.8 characterizes both motivations for deliberate acts and contributing factors for accidental errors and omissions.

It is important to recognize that an effective attempt to reduce the motivation dimension of the computer security problem requires sensible implementation of organizational policies well beyond those labeled "security policy." As an illustration, consider the categories of ICST security publications listed in table 2.2: contingency planning, database security, encryption, evaluation of computer security, general computer security, physical security, privacy, risk management, software and operating systems, and user authentication. None of the categories deals with, for example, the deliberate motivations or the contributing factor of "overworked staff", and only a handful of the associated publications takes up topics such as documentation procedures. For coverage of the entire motivation dimension, the organization must maintain "good" practice not only in other areas of ADP policy (e.g., see ICST's *Management Guide for Software Documentation*, NBS Special Publication 500-87) but also in all of the areas of general personnel policy.

Of deliberate motivations, material gain appears to be, by far, the most significant in terms of causing problems for organizations [19]. Mischief/challenge and curiosity may well be more frequent, although little data exist on this point, but we believe their effects are relatively small as compared to actions motivated by material gain.

TABLE 2.7 PERPETRATOR (WHO)

1. Data Entry/Terminal Operator
2. Clerk/Teller
3. Systems Programmer
4. Application Programmer
5. Computer Operator
6. Inventory Control Staff
7. Officer/Manager
8. Other Staff
9. Outsider - Technically Knowledgeable
10. Outsider - Not Technically Knowledgeable
11. Maintenance Technician
12. Unknown

TABLE 2.8 MOTIVATION/CONTRIBUTING FACTOR

DELIBERATE	ACCIDENTAL
1. Material Gain	1. Ignorance
2. Power/Prestige	2. Incompetence/Apathy/Carelessness
3. Malfeasence/Malevolence	3. Inadequate Cross Checks for Data Verification
4. Mischief/Challenge/Curiosity	4. Inadequate Documentation Procedure
	5. Inadequate Training
	6. Inadequate Accounting/Audit Controls In DP Procedures
	7. Overworked Staff
	8. Excessive Software Complexity
	9. Residual Human Error, Inherent Despite Use of State-of-the-Art Technology and Practices.

Apart from the contributing factors that lead to accidental errors and omissions, as shown in table 2.8, there is the residual level of errors, inherent in human nature and the present state-of-the-art, that will occur even under the best of conditions. Most of these accidental factors are general in nature and apply to a number of different kinds of errors. For example, inadequate documentation could lead to both data entry errors and software development mistakes.

2.2.1.3 Access

Categories for where and when a perpetrator may obtain access to computer systems are shown in table 2.9. This is one of the security model dimensions that is particularly relevant to technology trends.

It is important to know the predominant locations used for the initiation of computer abuse for the placement of physical safeguards, as well as for the selection of safeguards related to mode of access. Knowledge of when abuses occur may either encourage or discourage the application of time-dependent safeguards. Historically, the most significant access location of vulnerabilities appears to be in the facility which houses the computer system (i.e., the CPU room) and the key-entry area(s). One might expect this to change in the future as the use of microcomputers and distributed processing become more common.

2.2.1.4 Process or Resource That is Influenced, Modified, or Used

Table 2.10 categorizes the system resources and activities that become the "vehicle" through which the abuse or error can occur. This is not a tightly-defined element, in that its characteristics are a mixture of:

- Things -- hardware, telecommunications links, media;
- Activities -- data input, system operations;
- Concepts -- design philosophy; and
- Software -- logic statements, application programs.

Yet, all of these diverse entities are important to successful computer applications, and any can be subverted in order to perpetrate an abuse, to commit an error, or to create a situation in which abuses and errors are more easily accomplished and/or more likely to be attempted. This is another of the security model dimensions particularly relevant to technology trends.

The vehicle of interest is the one primarily subverted to commit a crime or abuse, or the one that is most directly the source for an error. For instance, hardware and software are of necessity utilized when a data entry clerk submits a fraudulent transaction, which is processed on the computer in conjunction with legitimate transactions. However, the vehicle of interest here

TABLE 2.9 ACCESS TO COMPUTER SYSTEMS

WHERE	WHEN
1. On-Site Terminal	1. Regular Business Hours
- Hardware	2. After Work Hours
- Dial-Up	3. Overnight
2. Off-Site Terminal	4. Weekends
3. Computer Program Development Office Areas Development	
4. Clerical Office Area (Forms Preparation)	
5. Key-Entry Area (and related equipment)	
- Data Entry (staff work area)	
- General Use (programmers)	
6. Central Computer Site	
- Computer Console	
- Job Submission	
- Output Pickup	
- Operations	
7. Remote-Batch Terminal	
- Manned	
- Un-Manned	
8. Adjacent to Main Site or Computer Communications Links	

Table 2.10 PROCESS/RESOURCES - MODIFIED/INFLUENCED/USED (VEHICLE)

1. Data (Files, Database)
2. Network Software; Communications
3. Data Input/Output Process
4. Personnel/Procedures/Documentation
5. Operations Activity/Physical Security
6. Application Software
7. Processing/Storage Media
8. System Software (System Security)
9. System Design Philosophy

is the data input activity, where the incident occurs. Hardware and software are included in order to represent those instances where the hardware and/or software of a system are attacked directly, and not necessarily in the course of some otherwise normal system activity. However, if some direct attack on software could only be undertaken under the camouflage of some particular system operations activity, then both would be indicated as the vehicle. Overall, data input is indicated in several studies [20] as clearly being the most significant source for fraud and abuse. In terms of inadvertent errors, data input, general system philosophy, algorithm design, and application software development are all significant sources [21]. In some studies [22] data input errors are reported as the most serious problem, while in others [23], software errors are reported as more significant. However, different types of applications were represented in these studies, and we are not aware of any study sufficiently comprehensive to resolve this point. Whatever the ultimate resolution, however, it is abundantly clear that these two areas should be priority targets for preventive responses.

It should also be noted that there very likely are some causal connections between inadvertent errors and deliberate abuse. For instance, a user may accidentally discover that (due to a software error) the system does not behave in the expected manner but, rather, in a way that makes the system vulnerable. For some users, that constitutes an invitation and an opportunity to perpetrate an abuse.

2.2.1.5 Action and Type of Authorization

Table 2.11 lists what actions may be taken by a perpetrator and indicates that the action taken may or may not be of a type

TABLE 2.11 ACTIONS TAKEN BY PERPETRATORS

(WHAT)	(NATURE)
1. Add/Delete/Alter/Examine -- Transactions -- Data Files -- Application Software -- System Software	1. Within Normal Job Activity/ Authority
2. Improper Use of -- Communications System -- Processing	2. Outside Normal Job Activity
3. Theft of -- Output -- Media (Tapes, Disks, etc.)	3. Authorized, but Atypical of Normal Job Activity
4. Covert Interception of Communications -- Electromagnetic Radiation Detection -- Wiretaps	
5. Improper Hardware Wiring/ Connections	
6. Inadvertent Circuitry/ Component Failure	
7. Software Design Flaw Incorporated/Executed	

within that person's normal job authority. For example, the preparation of fraudulent transactions is never authorized. However, the act of entering specific types of transactions would be authorized for certain terminal operators but not for programmers or for terminal operators in departments other than the one in which those particular transactions are normally prepared. There is a "gray area" in the case of officer/managers who may be authorized to enter certain transactions under their cognizance, but who do not normally enter transactions as part of their daily job activity. This is another of the security model dimensions particularly relevant to technology trends.

As noted in 2.2.1.4, data input may be the most significant vehicle leading to loss. This is true whether the action is a deliberate, fraudulent transaction [24] or inadvertent error [25]. A reasonable inference to be drawn from the data presented in the literature is that most fraud and abuse occurs within the scope of normal, authorized job activity.

2.2.1.6 Strategy

To realize material gain and/or cause loss to an organization, computer-related fraud or abuse must co-opt, obtain, or destroy some resource managed or controlled by the data processing system. Common strategies are given in table 2.12. For example, one perpetrator might modify (manipulate) application software to serve as a vehicle for reaching the target resource, e.g., inventory materials. To another perpetrator, that same application software might itself be the target of a scheme to sell pirated software, and compromising the telecommunications could be the strategy.

In complex strategies, the target resource may be a system resource whose compromise yields no direct gain, but does provide a method for attempting a further attack on some other target cf value. There could be several such initial compromises, achieved in the course of general system use, and the ultimate compromise of a target resource. In the case of deliberate abuse, several principles underlie the strategy dimension:

Table 2.12 STRATEGY

1. Disrupt

2. Compromise

3. Manipulate

- To compromise a system, a perpetrator must be able to detect (and correctly interpret) data flows of interest in use at the point of access.

- To manipulate a system, a perpetrator must be able to at least compromise the system and also influence or control at least one point in a data processing system. A key point of access may be accomplished by destroying data, inserting noise, or severing linkages. It is not necessary for the perpetrator to possess the in-depth knowledge of system processing that might be required to accomplish compromise or manipulation of data or assets.

- To <u>disrupt</u> a system, a perpetrator needs only to disrupt any one layer, which may be accomplished by destroying data, inserting noise, or severing linkages. It is not necessary for the perpetrator to possess the in-depth knowledge of system processing that might be required to accomplish compromise or manipulation of data or assets.

As an illustration, to compromise a system by wiretapping, a perpetrator must be able not only to detect the electrical impulses in the phone line but also to interpret correctly those impulses as characters in order to gain information. Secure encryption prevents the perpetrator from correctly interpreting any text in order to get to the desired information.

It is more difficult to manipulate a system by interrupting telephone communications. The perpetrator not only has to insert new signals but also to have full knowledge of the system if the new signals are to have the desired effects on, say, the data presentation while not affecting the rest of the system in any detectable way.

To disrupt a system communication, the perpetrator need only cut the telephone line or inject noise into it; there is no need to manipulate or compromise anything else. More extensive disruptions require either more extensive or more critical physical destruction, or an ability to manipulate other parts of the system. An instance of the latter is the submission of a program that in fact "takes over" an operating system.

In general, detected errors or omissions are a form of disruption -- they cause additional work to be performed to straighten them out, and they slow down operations. Undetected errors and omissions are like manipulations -- as they flow through a system, they cause improper actions and opportunities for misuse.

2.2.1.7 Effects and Impacts

Earlier we enumerated and discussed some of the primary <u>effects</u> (or outcomes) of the computer security problem, i.e., errors and omissions, fraud and embezzlement, privacy intrusions, alteration of records, theft of information, unauthorized use of information, and denial of service.

An "effect" or "outcome" is the last result of an intervention to a process that can be directly and certainly attributed to that intervention [26]. For instance, in the computing process, the loss of data integrity due to deliberate omissions is an effect that can certainly be attributed to a specific intervention: the activity or activities committed by a perpetrator.

Beyond the immediate effects, however, are the broader "impacts" on the environment. Unlike "effects", they are not directly attributable to the intervention; their attribution depends on some cause-and-effect hypothesis. And, unlike "effects", the results of an impact are not easily quantified. Nonetheless, the impact can be devastating to an organization. For instance, the loss of data integrity can be described in terms of "how many" data are in error and in, say, a payroll system, "how much" money was lost to the organization. However, it is a reasonable hypothesis that, for some organizations, disclosure of those results would lead to extreme public embarrassment, loss of public confidence in the institution and -- in the case of a private sector organization -- serious loss of business. Banking officials, for example, believe that hypothesis to be true and in cases where computer fraud and embezzlement are uncovered, banks typically "cut a deal" with the discovered perpetrator. In return for public silence by the perpetrator, the bank agrees not to prosecute.

The potential loss of confidence in public organizations is, if anything, ultimately more serious than the loss of confidence in private ones. Unlike banks, democracies do not and should not have the option of "hushing things up." Thus, the impact of "computer errors" that lead to gross overpayments to welfare recipients or, conversely, to denial of payments to qualified recipients, is probably an erosion of public confidence in government in general. That kind of loss, which affects the entire fabric of society, is not quantifiable in the terms of cost-benefit analysis, but it can be no less real than the loss of a data element.

2.3 DISTRIBUTED DATA PROCESSING: IMPLICATIONS FOR COMPUTER SECURITY PRACTICES

This section discusses the implications of the trend toward distributed data processing (DDP) on computer security policy and practices. The discussion will focus on the technology sensitive dimensions of the computer security and risk management model presented in section 2.2, i.e., access, actions, and process/resources. Within these dimensions, those vulnerabilities that are unique to or increased by the distributed environment are noted and a set of responses that lessen the risks are presented.

Table 2.13 displays some major DDP computer security vulnerabilities and controls. Column one lists the technology-sensitive dimensions (access, process/resource, and actions) defined in section 2.2.1. Column two classifies the major security vulnerabilities according to those dimensions. Column

TABLE 2.13 DISTRIBUTED DATA PROCESSING: SECURITY VULNERABILITIES AND CONTROLS [27]

TECHNOLOGY-SENSITIVE DIMENSIONS	MAJOR COMPUTER SECURITY VULNERABILITIES OF DDP SYSTEMS	COMPUTER SECURITY POLICY AREA (See Table 2.5)	GOOD COMPUTER SECURITY PRACTICES TO COMBAT DDP VULNERABILITIES
ACCESS	- Many diverse and remote sites permitting unsupervised access to the system	1,2,3,4,8	- User identification, authentication rules - User instruction for access procedures - Random/continuous access permission checks - Network and remote site hardware protection rules; encryption* - Terminal identification control - Physical security controls - Surveillance logging and journalling
PROCESS/RESOURCE			
o DATA (files, database)	- Unauthorized database access or data processing - Inadequate or no data transaction audit trail - Inadequate data file integrity or consistency - Unauthorized transactions or file manipulation - Data file destruction	1,3,4,5,6,8	- Interactive user-system audit trails - Local site source data/document retention rules* - Data back-up and sharing procedures - Data file security tables, lockouts, passwords, - Table parity codes - File documentation and backup controls - File label controls for handling and packaging - Create special files for end user applications with special controls* - Restrict local software to access local files only*
o NETWORK SOFTWARE/ TELECOMMUNICATION CONTROLS	- Poor network software restart/ recovery capability - Telecommunication failure - Transmission errors, message loss or disruption - Incompatible transmission protocols - Telecommunication hardware failure	1,3,4,5,6,7,8	- Message identification and logging procedures - Divide the distributed system into audit-critical or non-critical groups with limited controls on the latter* - Error detection and correction codes* - Standardized network protocols* - Message transmission control totals* - Transmission encryption procedures* - Network software security controls*
o INPUT/OUTPUT	- Errors and omissions at remote data input points - Missing data transaction audit trail - Inability to recover lost or incorrect data - Incomplete or non-standard local software	2,5,6,7,8	- Data validation/editing procedures - Transaction control totaling, data batch and sequence logs - Automatic recording of data I/O errors and reentries - Automatic recording of program initiated I/O transactions - Standard I/O forms designs - Utilize dumb terminals - Terminal fixed identification controls - Read-only memory controls for selected I/O lines - Validation procedure for uploading or downloading data files up/down or across the network*

* Practices particularly relevant in the DDP environment.

TABLE 2.13 DISTRIBUTED DATA PROCESSING: SECURITY VULNERABILITIES AND CONTROLS [27] (continued)

TECHNOLOGY-SENSITIVE DIMENSIONS	MAJOR COMPUTER SECURITY VULNERABILITIES OF DDP SYSTEMS	COMPUTER SECURITY POLICY AREA (See Table 2.5)	GOOD COMPUTER SECURITY PRACTICES TO COMBAT DDP VULNERABILITIES
o PERSONNEL/ PROCEDURES/ DOCUMENTATION	- Pooling of staff functions at remote sites - Poor staff training and supervision at remote sites	1,2,3,6,8	- Effective separation of critical duties for data processing and non-data processing personnel - Standard documentation at remote sites* - Centralized development and maintenance of all DDP system-wide software* - Effective training program for remote site staff* - Data Dictionary and automatic documentation procedures - Remote diagnostic analysis for hardware and software*
o OPERATIONS/ PHYSICAL CONTROLS	- Operator cannot recover from a system failure - Poor hardware maintenance - Incompatible equipment	4,5,6,7,8	- Procedures for maintaining job manuals at each site* - Independent control-console log reviews, and job characteristics statistical analysis - Main memory protection capabilities - Compatibility standards*
o APPLICATION SOFTWARE	- Unauthorized application software modifications - Unauthorized application software access and distribution - Misuse of application software - Inconsistent application software languages and development across local sites	4,5,6,7,8	- Formal, standard documentation of remote site application software* - Standard program change controls - Passwords, user access controls standards - Verification and validation procedures - Isolate end-user software at the local sites*
ACTIONS	- Directly alter data in data base	1,2,3,4,8	- Protect documents with passwords and alter passwords frequently - Create sufficient backup and compare with on-line copy of data - Password protect individual fields - Define and enforce procedures for identification of violators by other users - Create audit trails of transactions to restrict use of database or portions of database to physical ports - Assign read only passwords to users who do not require modify access

* Practices particularly relevant in the DDP environment.

TABLE 2.13 DISTRIBUTED DATA PROCESSING: SECURITY VULNERABILITIES AND CONTROLS [27] (continued)

TECHNOLOGY-SENSITIVE DIMENSIONS	MAJOR COMPUTER SECURITY VULNERABILITIES OF DDP SYSTEMS	COMPUTER SECURITY POLICY AREA (See Table 2.5)	GOOD COMPUTER SECURITY PRACTICES TO COMBAT DDP VULNERABILITIES
	- Read/list outputs	1,2,4,5	- Restrict outputs to specific devices which are under a physical security system - Destroy excess physical media through shredding, burning, or other method when it is no longer needed - Automatic logoff of unattended terminals - Automatic clearing of workstation memory and media at logoff - Blank screen when no input is received from work-station within specified period of time
	- Alter data intransmission	1,3,5,8	- Encryption of transmitted data with random assign-ment of encryption codes - Encode time record sent and check for prolonged delays - Double transmission of records over separate line for verification of accuracy of data - Utilize line tap detection equipment - Mail printout of transactions sent for verification - Place locks on connectors to avoid removal - Use checksums whenever possible
	- Set up hooks for future intrusion	1,2,3,4,8	- Audit all software before it is put into production - Log modification dates of object/source code and tag files to detect tampering - Place all production code in location inaccessible to development/user staff
	- Disrupt transmission of data	2,7,8	- Transmit on multiple paths, preferrably using different technologies - Install detection devices - Provide physical security of lines - Automatic retransmission of data not passing protocol verifications
	- Interject data stream into output to create false document	1,2,3,4,8	- Require authorization of any outputs which disburse funds by two unrelated persons - Provide physical security of both lines and peripheral devices - Use "smart" peripherals which can process checksums and multiple transmissions of data - Utilize callback procedures to restrict access from unauthorized devices - Destroy all trash immediately

* Practices particularly relevant in the DDP environment.

three identifies the relevant security policy area. The final column keys good security practices to the vulnerabilities. Practices which are especially pertinent to DDP systems are asterisked.

In this chapter solutions to the security problem have been addressed primarily by focusing on the implementation of policies and procedures. Advances in computer technology are resulting in hardware and software aimed specifically at reducing the vulnerability of computer systems. Whereas the implementation of policies and procedures is an "active" approach to solving the problem by requiring that users and staff make a conscious effort at increasing security, the use of hardware/software is "passive".

2.3.1 DDP System Security Practices

Computer security practices are the controls and procedures utilized as part of the system operations and support activities. They are the operational steps to achieve computer security policy. Typically computer security practices or safeguards fall into three classes: Preventive, Detective, and Recovery. The worth of a security safeguard is a function of how much it costs to implement and maintain relative to its decreasing the potential losses associated with system vulnerabilities.

Safeguards, in general, do not have a one-for-one relationship with vulnerabilities. For example, controlling an access vulnerability typically requires several safeguards (passwords, user access controls, journalling...) to achieve adequate user accountability.

The safeguards associated with controlling the major DDP vulnerabilities are listed in column 4 of table 2.13. These safeguards represent good computer security practices for the DDP environment. In any one setting, only a subset of the practices need be implemented. The objective is to achieve a balance between the costs of implementing safeguards and the costs of residual risks.

In part IV, "Management Implications of the Trends in Information Technology", section 4.2.2 discusses related materials vis a vis micro-to-mainframe link technology.

2.4 DATA PROCESSING OPERATIONS: TECHNOLOGY TRENDS AND DESCRIPTIVE MODELS

This section discusses important trends in data processing technology and use, and introduces descriptive models of basic Federal data processing operations. The purpose of the descriptive models is to introduce Federal managers to a tool for use in analyzing their agencies' vulnerabilities.

2.4.1 Trends In Data Processing Technology And Use

Virtually all aspects of information technology are undergoing changes. Some changes will exacerbate existing security problems; other changes will have a mitigating effect.

Positive effects are expected from:

- o Fiber optical technology, which does not emit electromagnetic radiation and is not susceptible to electromagnetic pulse damage
- o Closed-computer systems with "hard wired" programming that cannot be altered through software commands
- o "Trusted-Computer Systems" with the potential for formal certification procedures

Computer vulnerability may be increased by:

- o The "automated office" with machine-readable and -stored data
- o High density and capacity storage media that can be easily concealed or lost
- o Inexpensive, powerful microcomputers that can be used to access data through networks
- o Increasingly capable software packages that enable greater numbers of people to use data processing facilities
- o A growing population of computer-literate individuals
- o Advanced communications capabilities in
  - --networking
  - --teleconferencing
  - --electronic mail

For the purpose of this discussion, we will use two data processing prototypes: Centralized Data Processing (CDP) Systems with batch and time-shared operations and Distributed Data Processing (DDP) Systems with multi-level data processing and storage (figure 2.3). The CDP system represents much of the current design. The DDP system represents the type of computer system toward which the Federal agencies are migrating. Descriptions of a variety of DDP system designs can be found in James Martin's <u>Design and Strategy of Distributed Data Processing</u> [28].

2.4.2 Federal Data Processing Descriptive Models

ICST is developing a set of descriptive models to represent the data processing environment in the Federal Government. In this subsection, we will describe the set of previously-identified

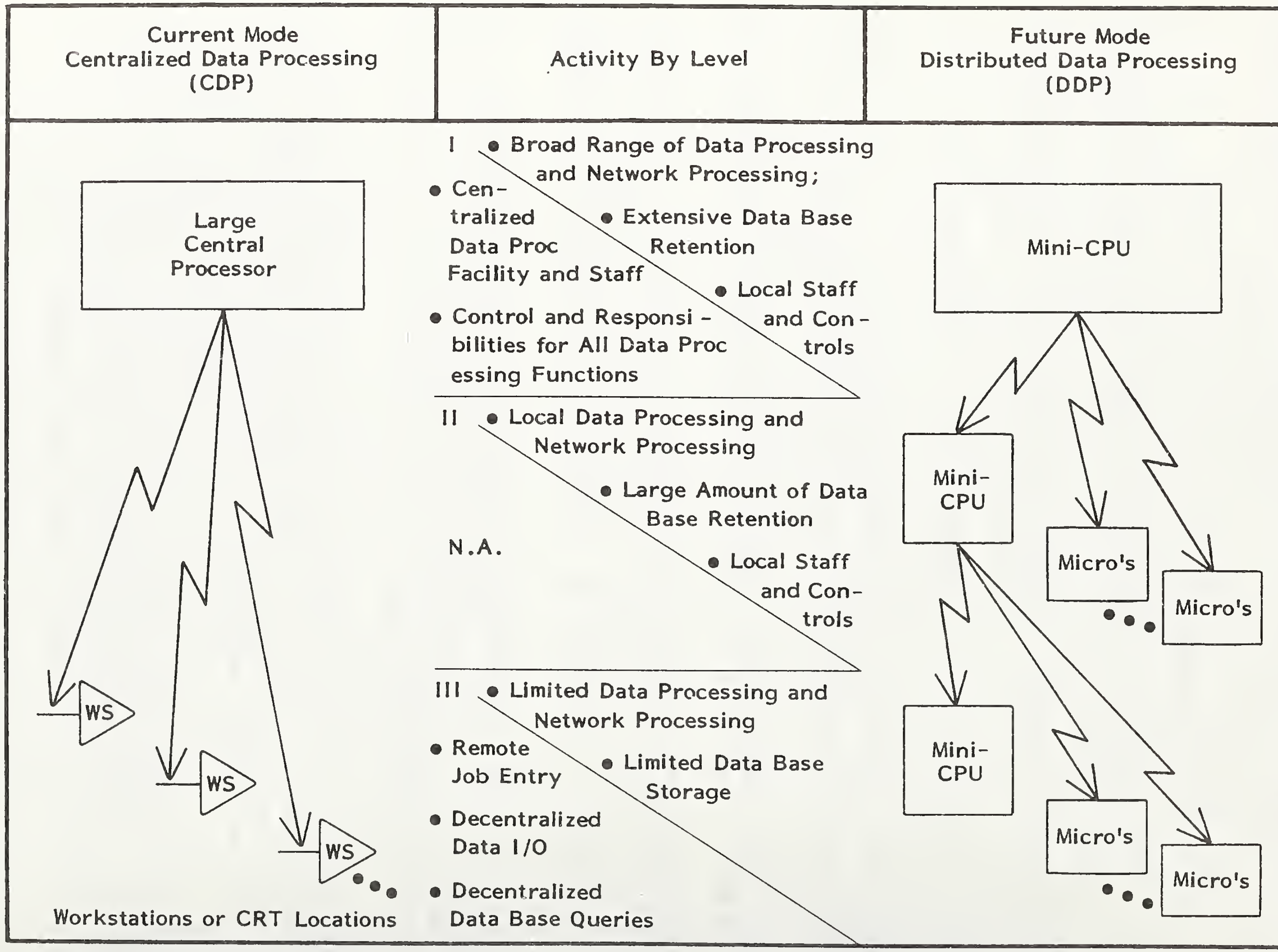


Figure 2.3 Proto-Typical Data Processing Models

activities that comprises the context of most Federal data processing [29]. We will then illustrate how descriptive models of a subset of those activities can be combined to describe a representative area-of-interest in both a CDP and DDP environment. In 2.4.2.2 we will use a case example to show how the use of the descriptive modeling technique can be used to analyze system vulnerabilities in either environment.

2.4.2.1 Data Processing Activities

The activities that make up Federal business-oriented data processing can be described by the 13 basic subsystems listed in table 2.14. Figure 2.4 shows how those subsystems are typically combined in a large data processing facility. The individual subsystems are described below:

1. Transaction Data Capture: the entry of data from individual transaction documents onto machine-readable media for further processing. The results of this procedure are a set of files which reside on various processing media and which are often accompanied by physical documents and control totals to provide an audit trail. The files are generally forwarded for processing under a subsystem 2 (transaction data aggregation) application.

   Examples include accounting, inventory, and timekeeping document entry, as well as the entry of corrections for errors detected in later stages of processing. In the project management support example used later in this section, data captured would include narratives, cost figures, milestones, and so forth.

2. Transaction Data Aggregation: the collection of individual transaction records, when the data entered are additive or cumulative. The results of this procedure are a set of master files updated for a given period and/or a set of merged transaction files for the period.

   Besides the various accounting vouchers where dollar amounts are cumulated, examples of transaction aggregation are found in inventory control, where stock balances are kept current and in employee timekeeping, where staff hours by project are aggregated.

3. Recordkeeping: the processing of updates or changes to information in master files (deferred update) or updates to an on-line database (immediate update). Note that the maintenance of historical data in a file (such as a personnel record showing previous position titles and salaries) is recordkeeping not transaction data aggregation, which only describes cumulative transactions.

TABLE 2.14 DATA PROCESSING SUBSYSTEMS

1. Transaction Data Capture
2. Transaction Data Aggregation
3. Record Keeping
4. Transaction Disbursement
5. Technical Data Preparation
6. Automated Data Capture
7. Analysis and Reporting
8. Data Retrieval and Analysis
9. Data Combination, Analysis and Reduction
10. Specialized-Data Model Execution
11. Integrated-Data Model Execution
12. Computer-Aided Task Performance
13. Software Development

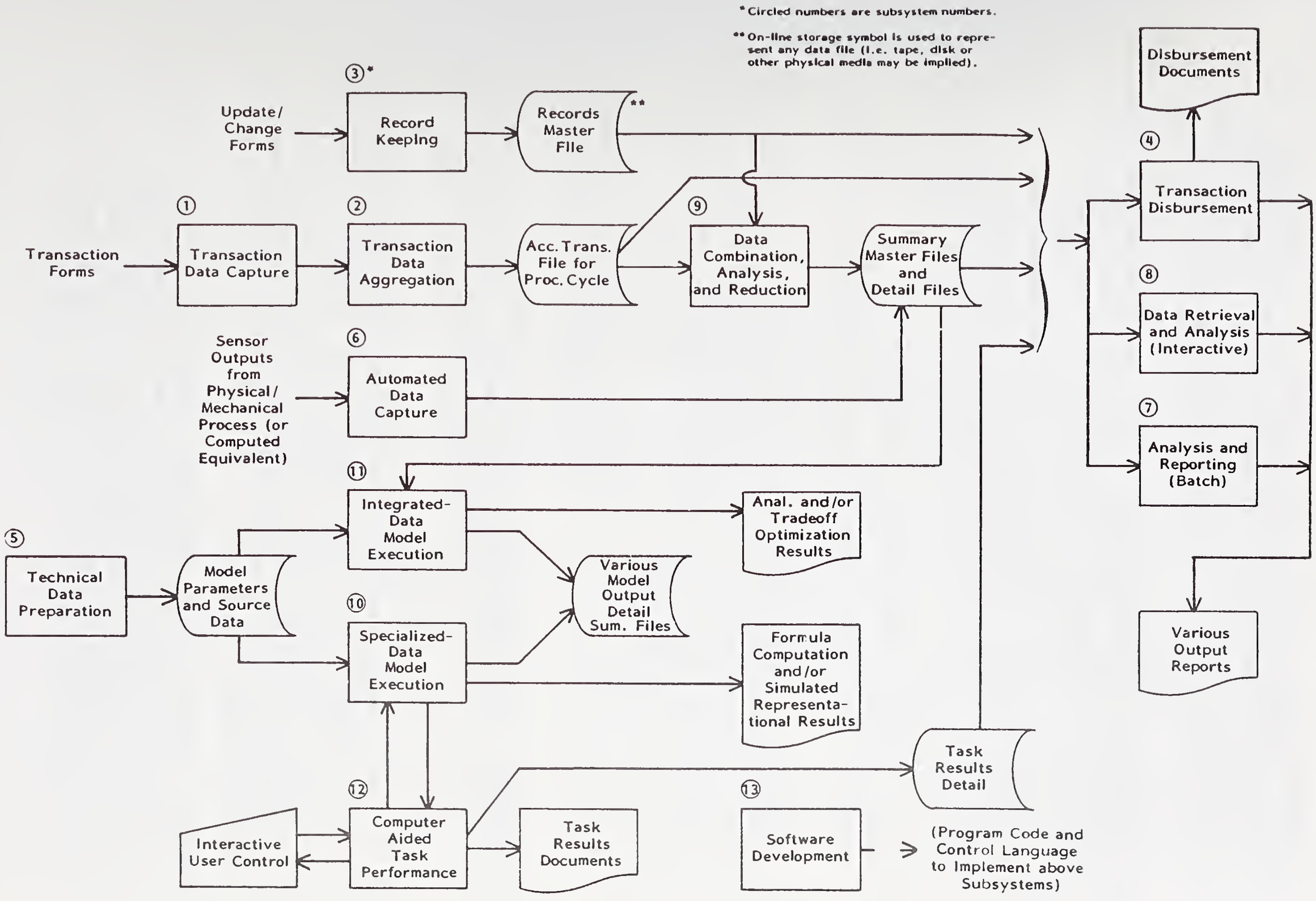


Figure 2.4 DP Operations Subsystem Interconnections (Illustration)

Examples of recordkeeping may be found in payroll and personnel systems, where changes to employee status or salary and additions/deletions of employees are recorded. In our project management support example, basic project data -- target milestones, names, addresses, security clearances, and so forth are recorded.

4. Transaction Disbursement: the preparation of transaction documents to be distributed. The most familiar example is preparation of checks.

5. Technical Data Preparation: the maintenance of data files by technical personnel, typically for use as inputs to computer models. Unlike the previous four subsystems, which generally involve formal processing controls and audit trails, the integrity of the data in this subsystem relies on the concern and attention to detail of the responsible analyst.

   Examples are data preparation for all manner of engineering, scientific, and economic models.

6. Automated Data Capture: the processing of a stream of real-time or recorded data samples to determine what events of interest have transpired and to report those events in a usable (or readable) format. This type of subsystem is typically found in manufacturing and engineering applications.

   Examples include the processing of satellite transmissions and the analysis of recorded data from engineering field tests.

7. Analysis and Reporting: primarily the preparation of routine, standard, periodic reports. Typically, these are "vanilla" COBOL applications, but they can also be sophisticated reporting systems utilizing a DBMS or other advanced technique.

   The term "analysis" reflects limited manipulation of the data (in addition to straightforward summary) which may be performed to simplify use of the report's contents.

   Examples include summary reports of project expenses and progress toward milestones and lists flagging cost overruns or schedule delays.

8. Data Retrieval and Analysis: the preparation of data listings and processed reports at the initiation of the end-user. This generally implies on-line, interactive access, although batch programs may be used in lieu of (or in addition to) on-line access. The two major uses for this subsystem are data item display and data analysis.

A. Data item display -- retrieval of status information or other data concerning specific items. Examples include the retrieval of on-hand/on-order information for such things as inventory items, status information on project expenditures, and employee data from a personnel database.

B. Data analysis -- the preparation of a variety of *ad hoc* or special-purpose reports by supplying input parameters to customized software or by using user-oriented data manipulation languages. This includes both generalized data manipulation languages, such as the query languages often incorporated into a DBMS, and specialized languages dealing with a specific job or task. The data may be stored in various file structures or maintained under a DBMS.

While data item display involves the retrieval and display of individual records, data analysis presents aggregate data derived from sets of selected records.

9. Data Combination, Analysis, and Reduction: the preparation of intermediate data files or special-purpose reports requiring data from more than one operational DP system or management database. The software that makes this possible may be viewed as a collection of utilities that can be applied by an analyst to gather data from different systems to perform planning calculations. Such systems often require the cooperation of different software groups, managers, and organizations for successful operations. They can be used either on a periodic or *ad hoc* basis.

   In the project management example, actual project data from the transaction data aggregation subsystem is integrated with planning data and basic reference data from the recordkeeping subsystem.

10. Specialized-Data Model Execution: the use of models that operated from "constructed" databases, such as the output files from either subsystem 5 (technical data preparation) or subsystem 9 (data combination, analysis, and reduction) that are usually tailored to the needs of the particular model. These models are normally used for planning, analysis and problem-solving, and often will be set up for use by specialists on an as-needed basis.

    A. Accounting model computation -- the use of standardized formulas and relationships to prepare estimates for management planning or operations activity. An example is the calculation of estimated retirement benefits for an employee, on the basis of salary and length-of-service data, using different date-of-retirement assumptions.

B. Representational model simulation -- the use of mathematical models to represent more complex processes than might be handled by a simple accounting model. These are used to predict outcomes on the basis of varying system inputs or of various assumptions concerning the process modeled or the nature of relationships among the variables. An example is the computer simulation of the responses of a proposed weapon system in different operational environments.

11. Integrated-Data Model Execution: the use of models that operate directly from operational data files or from slightly processed versions of those files, as opposed to tailored or highly aggregated databases (such as those utilized for models in subsystem 10).

A. Decision suggestion -- the use of a mathematical algorithm to suggest managerial or operational actions. A student/class scheduling model is an example of decision suggestion.

B. Trade-off optimization -- the use, for planning purposes, of mathematical models that find the combination(s) of resources or system parameters that maximize or minimize, within specified constraints, the value of some selected goal variable. An example is the determination of the mix of spare parts that provides the maximum expected aircraft availability for any specified level of additional investment in spare parts.

12. Computer-aided Task Performance: the use of a computer to enhance the ability of a person to perform a task by executing various operations under immediate and interactive control by that person. Included here are any applications where the computer acts to extend the capabilities of the user to perform some task in real-time. Both printing and CRT terminals, with or without graphics capabilities, may be used. An example is the use of computerized drafting systems.

13. Software Development: the use of text editors, compilers, and other system utilities to prepare either application programs, computer system software, or job control language. The output of this subsystem is the variety of programs and control statements necessary to implement the outputs of the previous 12 subsystems. This subsystem includes only those activities that directly involve DP operations [30].

Examples include all types of programs given as examples under subsystem 1 through 12. These may be written in one of the commonly-used programming languages or may be developed using special-purpose languages such as DBMS query commands.

2.4.2.2 Case Example: Project Management Support

Clearly, very few data processing applications utilize all of the subsystems described above. In order to characterize a specific application, it is necessary to identify (1) which of the subsystems are applicable and (2) how the identified subsystems interrelate. Descriptive models illustrating this procedure (figures 2.5 - 2.14) are shown at the end of the section.

In the case of centralized project management support, the applicable subsystems are:

- Transaction data capture (subsystem 1)
- Transaction data aggregation (subsystem 2)
- Recordkeeping (subsystem 3)
- Analysis and reporting (subsystem 7) and
- Data combination, analysis and reduction (subsystem 9)

Figures 2.5 through 2.8 are descriptive models of subsystems 1, 2, 7, and 9 respectively as they normally operate in a CDP environment. (Subsystem 3 is a combination of subsystems 1 and 2). Figure 2.9 shows the interrelationship of the subsystems as they centrally support project management.

In a decentralized environment, four of the five identified subsystems remain constant. There is one difference:

- In the decentralized setting, Data retrieval and analysis (subsystem 8) replaces the centralized Analysis and reporting subsystem (subsystem 7).

Even though the process functions and products (with that single exception) are essentially the same for the centralized and decentralized systems, descriptive models of the decentralized subsystems reveal that the different environments entail very different procedures. Figures 2.10 through 2.13 contain descriptive models of the decentralized subsystems. Figure 2.14 shows their interrelationships as they support decentralized project management.

Prototype descriptive models of all of the subsystems (developed for CDP environments) are contained in Fiorello, et. al [31].

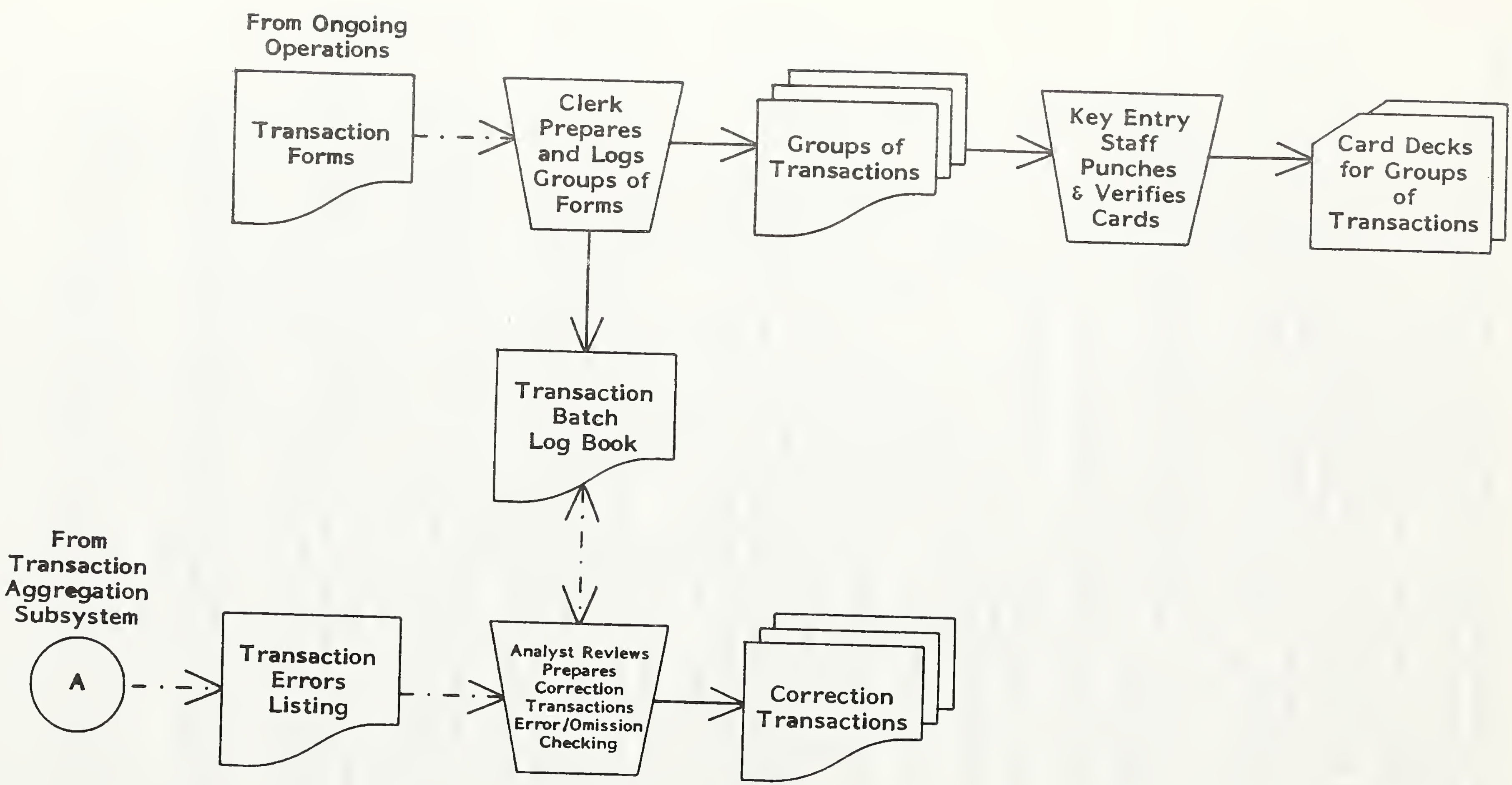


Figure 2.5 CDP Transaction Data Capture (Subsystem #1)

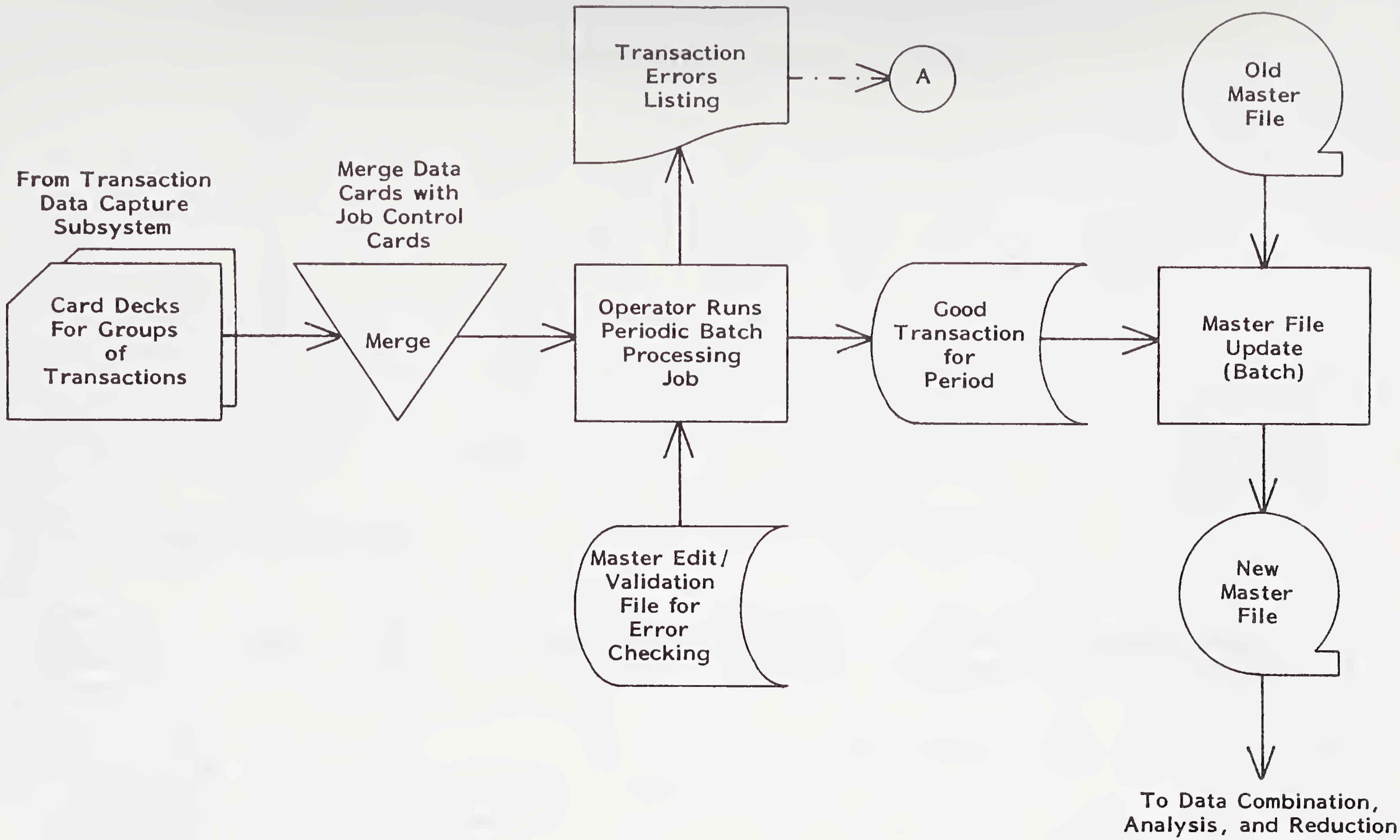


Figure 2.6 CDP Transaction Data Aggregation (Subsystem #2)

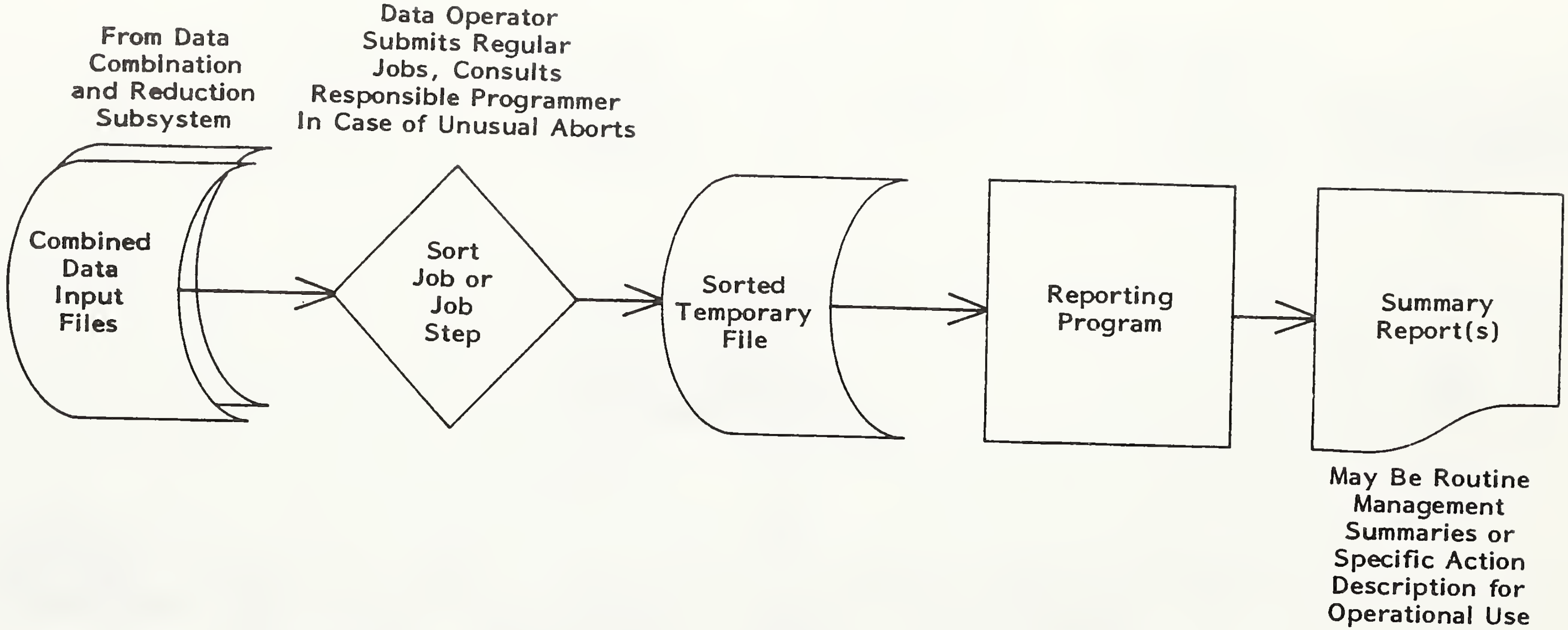


Figure 2.7 CDP Analysis and Reporting (Subsystem #7)

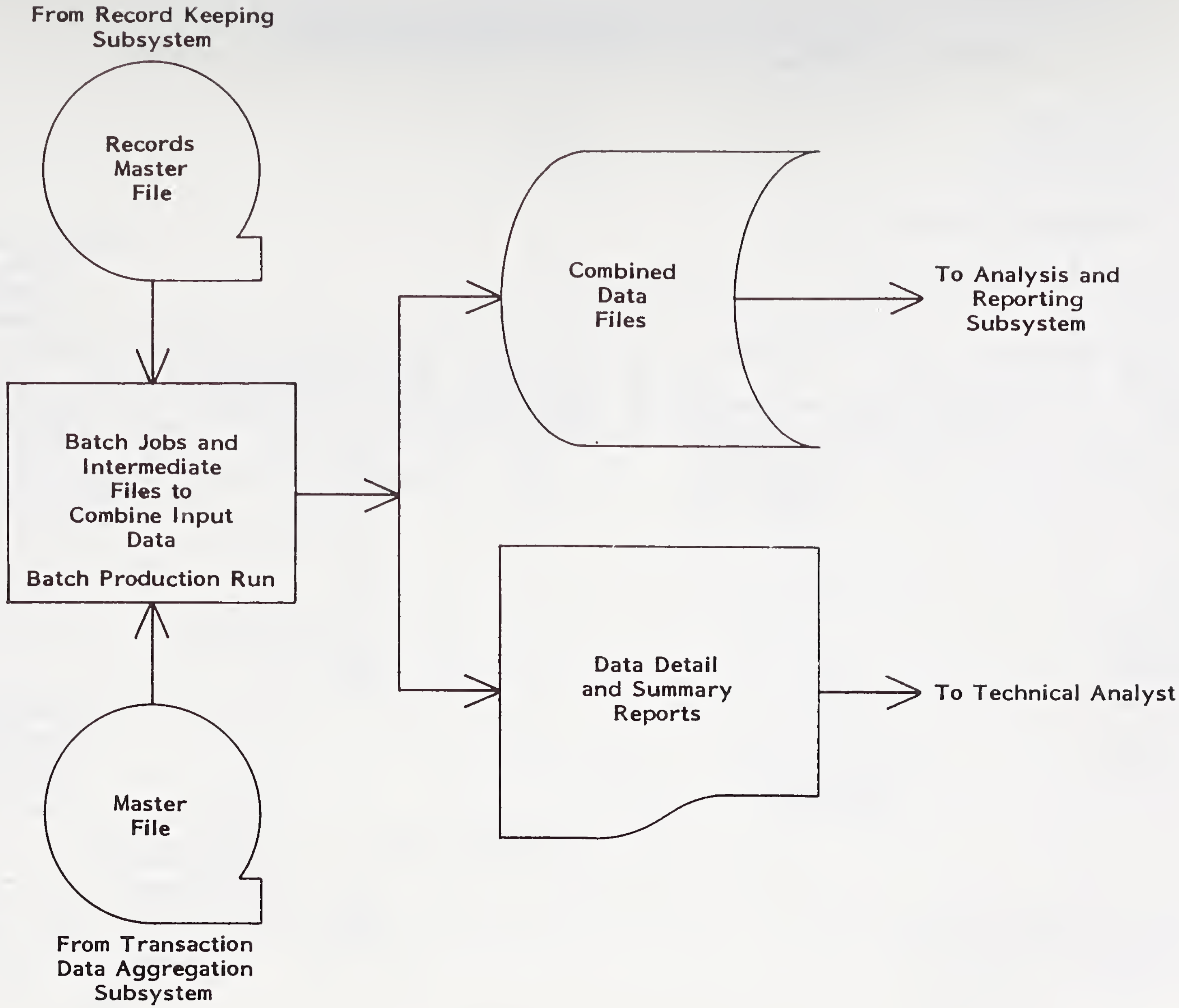


Figure 2.8 CDP Data Combination, Analysis and Reduction (Subsystem #9)

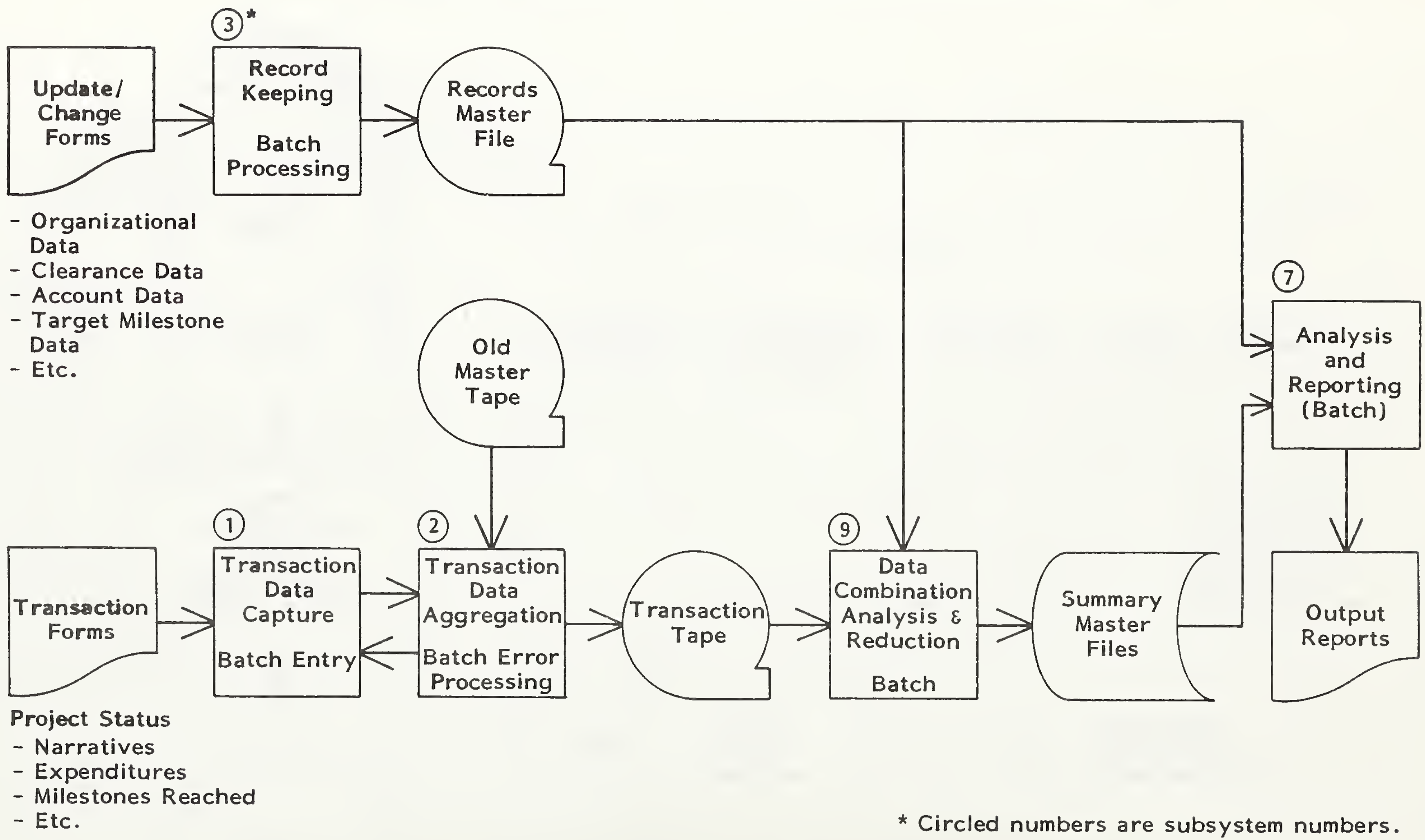
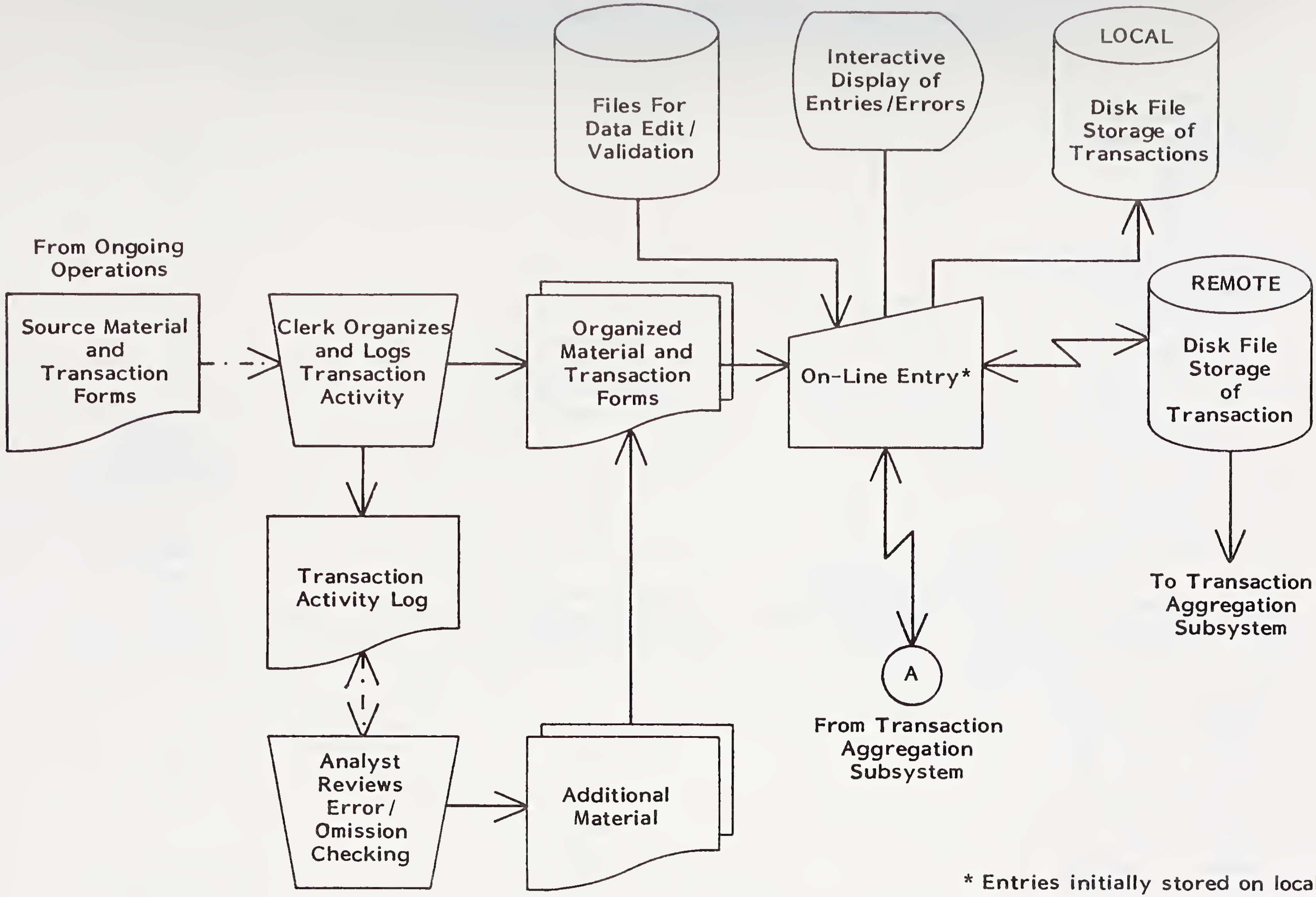


Figure 2.9 Centralized Data Processing for Project Management Support (Comprised of Subsystems (#1, 2, 3, 7 and 9))



* Entries initially stored on local disk with some error checking/validation. Local data periodically transmitted to remote disk.

Figure 2.10 DDP Transaction Data Capture (Subsystem #1)

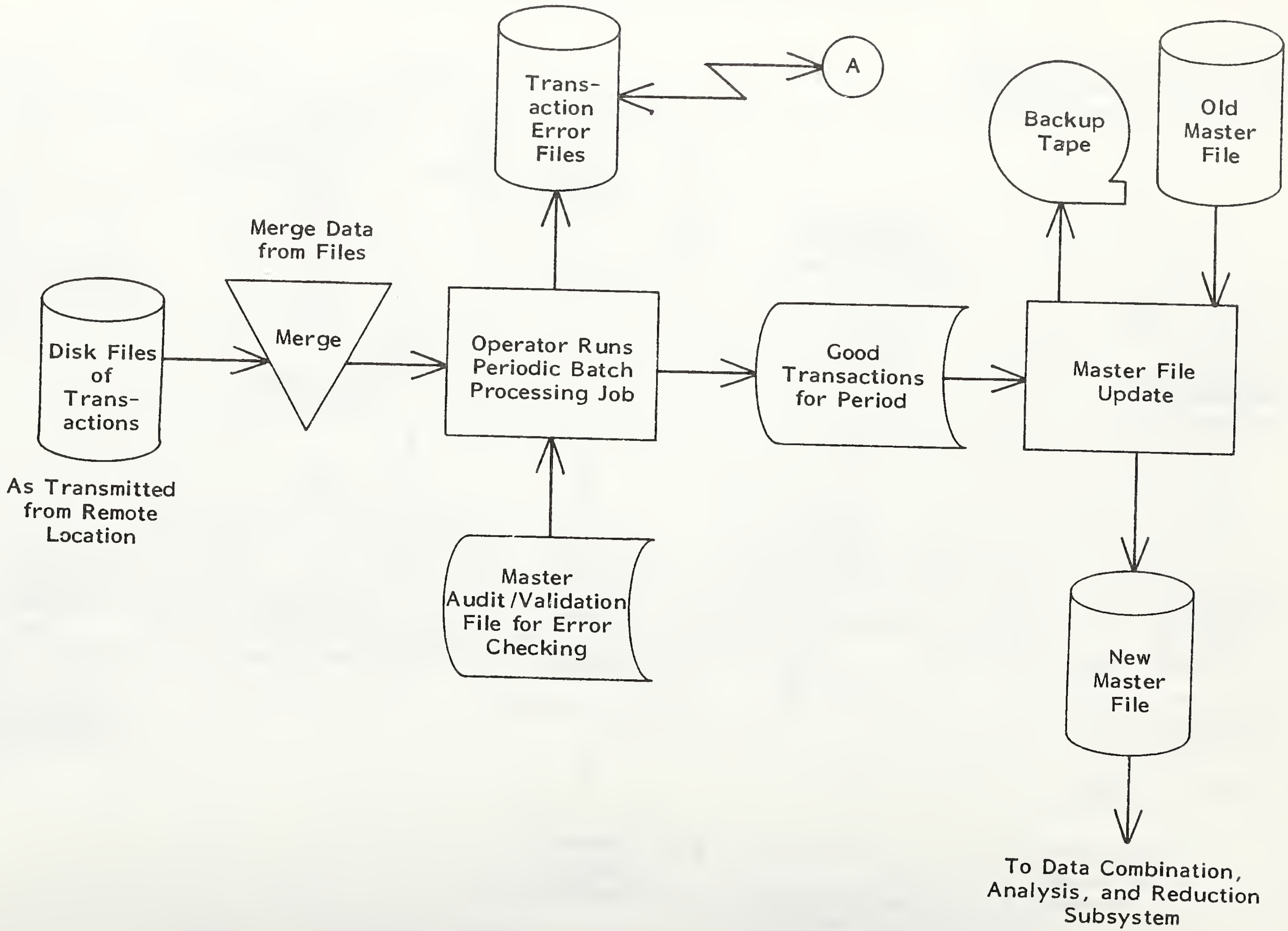


Figure 2.11 DDP Transaction Aggregation (Subsystem #2)

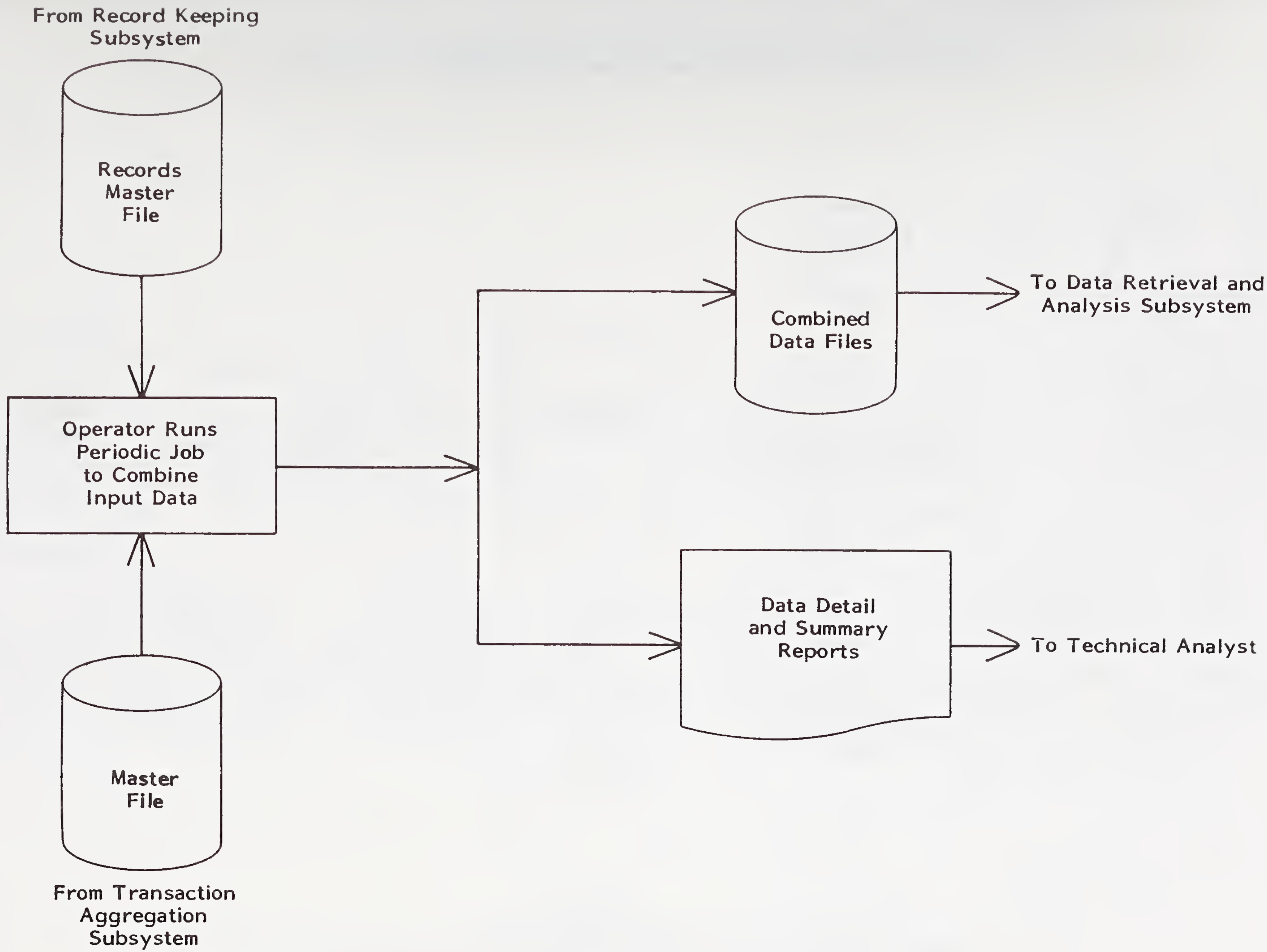


Figure 2.12 DDP Data Combination, Analysis and Reduction (Subsystem #9)

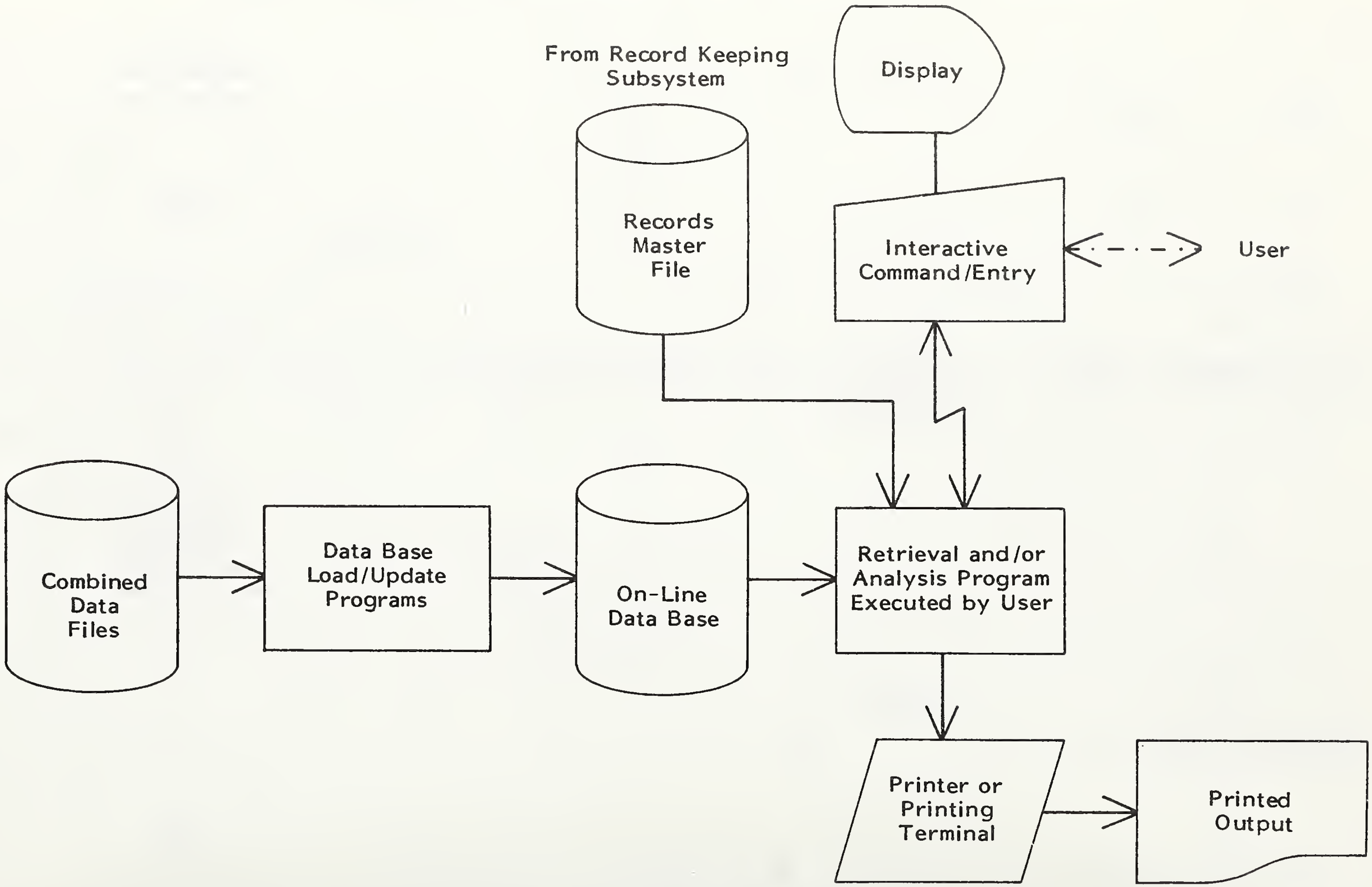


Figure 2.13 DDP Data Retrieval and Analysis (Subsystem #8)

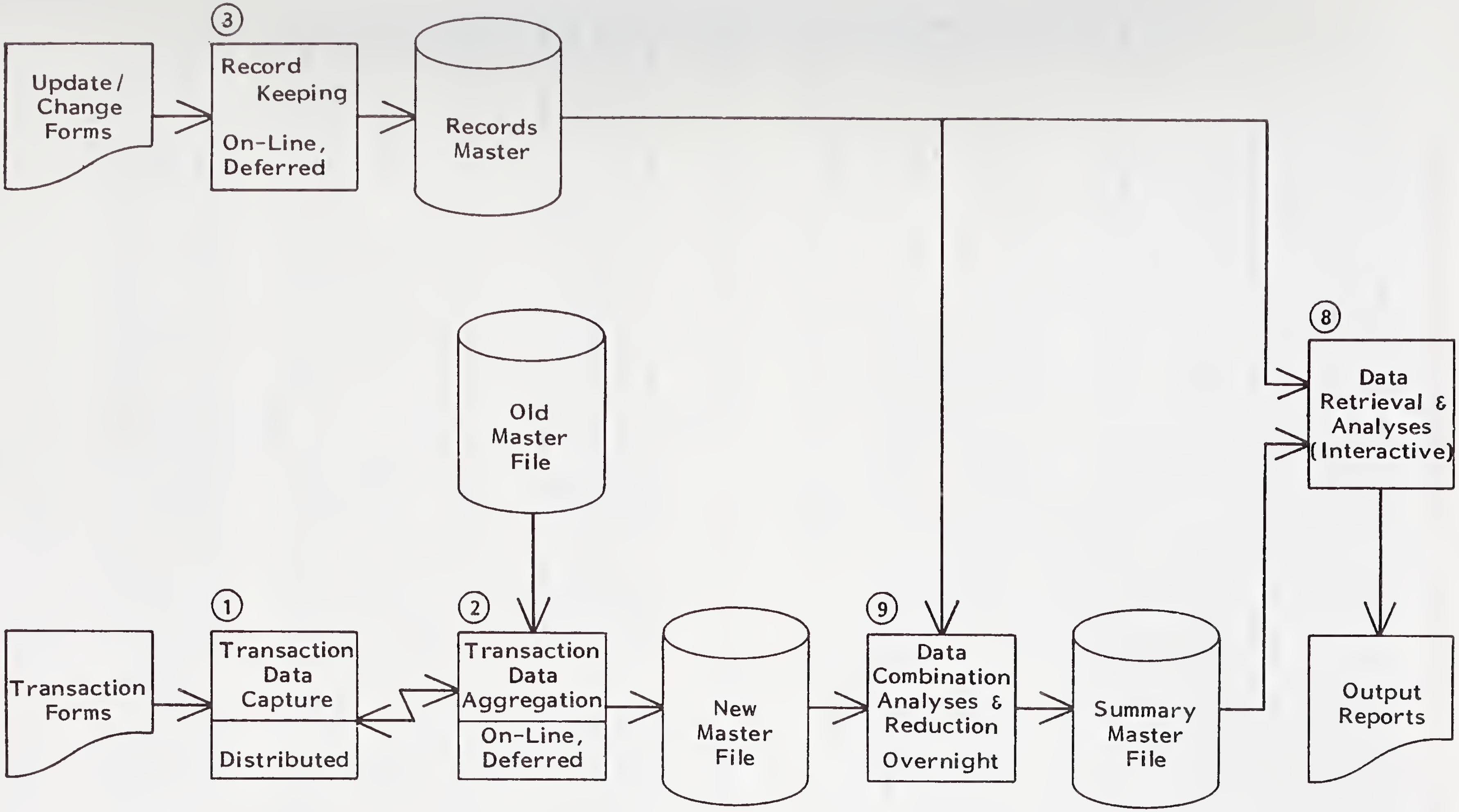


Figure 2.14 Distributed Processing Operations for Project Management Support (Comprised of Subsystems (#1, 2, 3, 8, and 9))

2.5 CASE EXAMPLE: A NEFARIOUS AND UNMERITORIOUS SCHEME

The discussion in section 2.4 described the use of descriptive models for analyzing computer system vulnerabilities. In this section we combine that technique with the analytic tools discussed in sections 2.2 and 2.3 in order to illustrate a powerful methodology for analyzing system vulnerabilities. For that purpose we postulate a hypothetical scalawag of a General Management (GM) employee bent on obtaining an undeserved merit increase, construct a profile based on material presented in section 2.2, and discuss how the evil intent may be thwarted in both decentralized and centralized environments. WARNING: To guard against the remote possibility that some copycat scalawags may be among our readers, we have deliberately omitted or changed some steps in the bonus-payment process.

The primary focus of this example is computer security vulnerabilities and safeguards associated with fraud and embezzlement. Given the hypothetical basis for the example, only a partial computer system risk analysis is possible. A comprehensive analysis would require details from site surveys and staff interviews that are beyond the scope of this example.

The particular hypothetical example was developed because it illustrates several points commonly found in cases of computer abuse:

- The perpetrator belongs to the organization being victimized.

- The computer system is violated by the perpetrator manipulating certain information within the system. This implies that the perpetrator has physical access to the system, probably through a terminal, and has obtained information regarding the security measures taken to protect data.

- The perpetrator, while unable to access the files used to generate the payroll, does have access to the information which is used to determine the salary classification of the staff. Therefore, timing is important, since any changes to appraisal information must be made before it is used to recalculate payroll. To obtain this information, the perpetrator must have knowledge of the personnel/payroll process within the agency.

- The chances of being detected are minimal until such time as records are audited or a new review is scheduled. Even then there is a good chance that such manipulation may go unnoticed for prolonged periods of time.

2.5.1 The Payroll-Change Model

A merit pay increase or bonus involves a payroll change. The process begins when a merit review is scheduled and held with an employee and supervisor present. The results of the review are then forwarded to the personnel department for review and processing. In our case example, we assume that the payroll system is automated and the payroll changes are computed based on the results of the merit appraisal. In such cases, personnel department employees enter and verify the information, file hard copies of the reviews in the employee's files, and forward a verification to both the employee and supervisor. This information now becomes part of the employee's automated records and is used to compute the periodic payroll amount and any applicable bonuses. In most cases, the appraisal information is not reviewed until the next scheduled review. In addition to generating payroll, a number of accounting reports are generated for the personnel and payroll departments.

Figure 2.15 is a macro-model of the process, showing the relevant subsystems. It is applicable to either centralized or decentralized environments. The subsystem references in this figure correlate with those shown in figure 2.4 (DP Operations Subsystem Interconnections).

2.5.1.1 Payroll Change in a Centralized Environment

Figure 2.16 (figures 2.16 - 2.19 are shown at the end of this section) is a "black box" model for the CDP version of the payroll change example. In this example, the employee and supervisor complete the merit appraisal and forward the results to the personnel department for processing. Prior to entering the data into the computer, the personnel department must obtain certain approvals and file copies of the review. The data are then summarized, entered into the computer, aggregated with other employee and department information, and analyzed. Once a new pay scale has been determined, the payroll records will be changed to reflect this information. Finally, periodic payrolls are run, checks generated, and summary reports distributed.

Figure 2.17 indicates the specific points of vulnerability in the system. It is possible to alter data at any of these points, given the right set of circumstances. For this CDP system and organization setting, the major computer security safeguards most relevant to fraud and embezzlement vulnerabilities include:

-- Separation of duties among the staff. For example, under no circumstances should the employee or supervisor be involved in the review, approval, or entry of the data, even if they are members of the personnel or payroll departments.

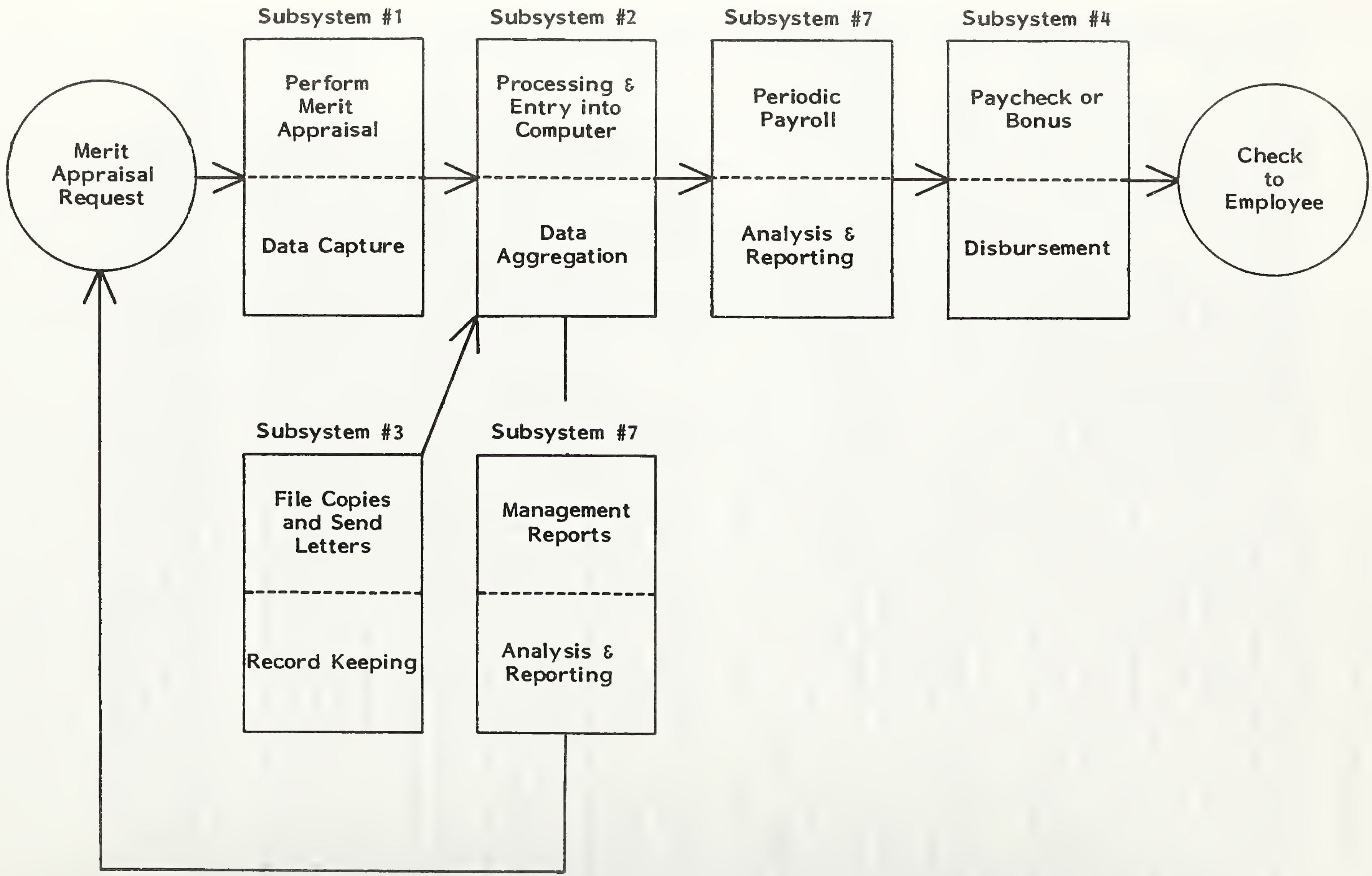


Figure 2.15 Payroll Change Processing: Macro Logic Model

-- Access to the computer system should be restricted to individuals and, if possible, to specific terminals. Passwords should be used to permit access only for designated persons and, for those designated, only to those functions which are necessary to perform their duties.

-- All staff should be trained in computer security procedures and informed as to the actions to be taken if a breach of these procedures is witnessed. Random audits should be instituted.

-- The check-generation process should require different individuals to prepare the forms, enter the data, and update the data.

-- Journals of all transactions should be printed and verified against the source documents. The journal should be signed by the person performing the validation.

-- The computer software should have built-in edits to flag information which falls outside predefined parameters. It is necessary to obtain transaction-approval before the computer system will accept this flagged data.

-- All data critical to the preparation of checks should be encrypted in order to foil the casual perpetrator. By requiring the additional effort necessary to decipher the data, a browser will most likely cease any efforts to violate the data.

2.5.1.2 Payroll Change In A Distributed Environment

In our hypothetical distributed environment -- as is the case in the real-Federal-world -- many reviews are performed at any given time and numerous personnel actions are always in progress. In order to handle this workload, functions are separated so that they may be processed more efficiently. Our hypothetical agency, adopting this principle with a vengeance, has decided that it will process personnel actions at the district level (many geographically separated offices) and payroll at the regional level, with ultimate control at the national level. The "black box" model of this concept is shown in figure 2.18.

A detailed descriptive model of the DDP model is shown in figure 2.19 with the principal points where data can be manipulated being indicated by the circled letters. Relative to the CDP settings, the DDP configuration has additional potential vulnerabilities. Since the staff size at any specific site will be small, it is more difficult to maintain full separation for staff functions (or conversely the convenience of cross training) for input, update, validation, and auditing. Likewise, the computer systems installed at each site will most likely be smaller than the single CDP system, resulting in fewer staff to operate and implement security safegards which are not normally inherent in the manufacturer's system. The introduction of a telecommunications network has additional potential for breaking into the system, since more processed data is likely to be transmitted over the lines.

2.5.1.3 Payroll Change Security Analysis

The purpose and functional steps for payroll change processing are the same in the DDP and CDP modes of operation. There are, however, differences in the ways the payroll change process is implemented and controlled, and where the data are processed, stored and transmitted. The basic issue is: How do these differences translate into claims processing fraud and embezzlement vulnerabilities?

A chart of the events comprising people-related computer misuse was presented in figure 2.2. This figure represented the components which lead up to computer misuse by people. In table 2.15 this same list of events is presented with a description of items which compose the event for the payroll-change model. The perpetrator is a general management employee of the agency who is motivated by a desire to increase his/her salary despite a merit review which dictates the contrary. Depending on which of the scenarios (below) is used, there are several means of accessing the system resources and several processes which can be used. The action is always to change the data in the personnel record so that the automated salary determination will set a higher salary. This is a strategy of manipulation of the data to achieve the impact of embezzling funds.

TABLE 2.15 VULNERABILITY PROFILE FOR PAYROLL CHANGE MODEL

This table is keyed to Figure 2.2, "Events Comprising People-Related Computer Misuse."

Perpetrator:	Management Employee
Motivation:	Material Gain
Access:	Authorized Terminals, either On-site or Off-site Communications Lines Computer Room after Hours Service Console
Process:	Direct Manipulation of Data Files Substitution of Storage Media Interception of Transmission Collaboration with Persons having Special Access Misuse of Legitimate Access to System

Action: Alter Personnel Data Prior to Transmission to Headquarters which Determines Ultimate Pay and Produces Paychecks

Strategy: Manipulation

Impact: Embezzlement of Funds by Receiving Unearned Income

Given the vulnerability points noted in table 2.15, the following questions must be answered:

- How can any of the staff associated with the descriptive model vulnerability points defraud the system?

- How can the vulnerabilities be controlled?

To arrive at answers to the above questions, the computer security analyst must construct vulnerability profiles for fraud and embezzlement using the computer misuse framework, prepare scenarios based upon the vulnerability profiles, and using descriptive modeling tools, describe how the payroll change fraud and embezzlement can be effected. Then, given a specific scenario, the magnitude of the vulnerabilities can be estimated and ranked in terms of degree of risk so that candidate safeguards and practices can be evaluated based upon their implementation costs and potential effectiveness in minimizing the risk of violations.

Several scenarios are presented below to illustrate techniques for violating the payroll-change model in a distributed environment:

<u>Scenario 1: Manager Manipulating System for Unearned Bonus</u>
In this scenario a manager at one of the remote sites desires to modify a poor or mediocre merit appraisal so that he/she can receive a bonus award which would not normally be forthcoming based upon the appraisal. Since he/she cannot alter the source document which is under the control of his/her supervisor, the approach to be taken is to manipulate the data after it has been entered into the local computer system but before it is transmitted to the regional payroll system. Two options are available to the perpetrator. If sufficient knowledge of the processing cycles is available, he/she can access the data files directly through either the personnel software or through specially written programs. This assumes that this scoundrel may obtain the access codes to the data files, which can be obtained through being alert as others log on, asking questions of friends who have access, walking up to a work station which is not properly logged off, or through a trial and error process (which is especially successful if the data is being transmitted to the payroll system). In order to successfully accomplish this task, the perpetrator must know when the transmission is to occur, at which points the line can

be tapped, communications protocols in use, and format of transmitted data. If the line can successfully be tapped, data can be diverted into a buffer where it can be manipulated and the altered data transmitted to the payroll system.

Scenario 2: Manipulation by Technical Staff Should one of the agency staff decide that he/she wants to change some personnel or payroll data and either works in the system operations department or is extremely friendly with someone who does, he/she can manipulate the system easily by accessing the data through the system's master account and accessing all information directly. Most small systems, such as those which are used in a distributed mode, require only one operator. Some have no requirement for a full time operator. In this case, the person with the master account can access any data on the system. With no other technical person to oversee the activities, data can easily be changed. It is even possible to guess the master account or overhear it passed to other employees where security is lax.

Scenario 3: Theft of Storage Media Since small systems have less requirement for operations staff, they are many times left open to many persons in the organization. Small offices may be using systems which are small boxes stored under a table or in a closet. If the data are stored on removeable media, it is not difficult for someone in the office to "borrow" the media late one night, take it to a similar system where the master password is known, change the data, and return it early the next morning.

Scenario 4: Theft of Backup Media Similar to the previous scenario, in this one the crook takes the backup media, whether it be tape or disk. This is more practical in systems where the main storage is not removeable. The media is then taken to a similar system, manipulated, and returned the next morning. The perpetrator then forces a system crash whereby data must be restored from the system backup, i.e., the media with the manipulated data.

Scenario 5: Usage of the Service Access Mechanism Many small systems go into a single user mode when service is being performed. In this mode, the person performing the service has access to all agency records and software that are on the system. If an employee were to work with the service person, he/she could access data while the system is in the service mode. This could be done either with the cooperation of the service or by distracting the service representative at a opportune moment.

Table 2.16 identifies computer security policy areas, which were presented in table 2.5. Within each policy area, one or more problems are described with possible practices which can be implemented to reduce the risk of security violations. Further, specific concerns for a distributed environment are identified.

TABLE 2.16

COMPUTER SECURITY POLICY AREAS ANALYSIS FOR THE PAYROLL CHANGE EXAMPLE

1. Identification	Problem: Lack of mechanisms to identify users. DDP Concerns: Each site will have its own user community which will impose its unique demands on the site's facilities. With a smaller user community it is often difficult to enforce policies regarding the protection of computer identification numbers. Practices: Install software and/or hardware which will process identification codes. Each user should be assigned a unique identification. Should more sophistication be desired, user identifications can be cross-referenced to applications.
2. Accountability	Problem: Data is not being verified after it has been transmitted. Problem: Payroll change is not being reviewed. Problem: Maintenance personnel have unrestricted access to system resources and leave console unattended or do not properly control access to the account. DDP concerns: The remoteness of the processing sites makes the verification process cumbersome. DDP concerns: The signoff process can be slow since the persons who must sign the forms are at two geographically different sites. DDP concerns: DDP sites which have limited personnel may not have the excess capacity to oversee maintenance personnel or to perform the additional work of backing up and restoring data. Practices: Produce hard-copy of data after transmission and compare received data to initial source document of a similar output from the sending site.

COMPUTER SECURITY POLICY AREAS ANALYSIS FOR THE PAYROLL CHANGE EXAMPLE

	Practices: Require at least one sign-off on payroll changes. Flag payroll changes which appear to be out of line with the employees' previous records and/or with other employees in the same job. Perform random audits of records.
	Practices: Backup data prior to service and restore it upon completion of the service. Oversee all actions of the service representative. Disconnect devices which contain sensitive data by using a keylock write protect, by unplugging from the system, by removing the media, or by setting a switch which deactivates the device. Remove all maintenance accounts from system or, at least, change the password once the service representative has left.
3. Authorization	Problem: Users who are authorized to use the system can access system resources for which they should not have authorization.
	DDP concerns: The smaller machines associated with a DDP site may not have the ability to restrict access to devices. In fact, many of the machines used in DDP facilities have no capacity for physical access restriction. It is not always possible to record audit trails due to lack of resources to store such information.
	Practices: Require passwords to access system devices. Mount devices in a restricted exclusive mode. Assign a table of authorized applications, files, and devices to users based upon their logon ID. Record and analyze audit trails which record transactions and the ID of the user making the transaction. Change passwords at random intervals and inform only those with a "need to know" of the new passwords. Record the ID of any persons attempting access, even if

TABLE 2.16 (continued)

COMPUTER SECURITY POLICY AREAS ANALYSIS FOR THE PAYROLL CHANGE EXAMPLE

	access is denied. Note that the National Bureau of Standards has issued standards for the assignment and control of user IDs and passwords.
4. Access Controls	Problem: Persons are using devices which are not in their area to access system resources which normally would not be at their disposal. DDP concerns: A distributed environment has been selected to put the computing capability closer to the person requiring the information. By locking terminals, information is being restricted to users, thus negating the initial purpose. Practices: Lock devices after hours, either within a room or using a device which attaches to the power supply. Key user IDs to physical devices so that they cannot use devices which are not assigned to their ID.
5. Operations Controls	Not Applicable to Payroll Change Example
6. Consistent Performance	Not Applicable to Payroll Change Example
7. Recovery-Restart	Not Applicable to Payroll Change Example
8. Auditability	Problem: Lack of enforcement of policies. Problem: Data is not entering the pay determination model with the same information input from the review document. DDP concerns: The smaller staff size and operations budgets of the DDP sites make audits less likely. If the headquarters or regional offices, which have larger budgets, perform the audits, the audits will be more costly as a result of increased travel costs.

COMPUTER SECURITY POLICY AREAS ANALYSIS FOR THE PAYROLL CHANGE EXAMPLE

	Practices: Always have more than one person responsible for security so that they can monitor and control the other's performance. Conduct audits of enforcement of security procedures at random intervals, preferably by an outside party. Educate both the operations staff and user community in the security procedures and what to do if they identify a breach of these procedures.
	Practices: Maintain audit trails. Compare information with original source documents prior to implementing the payroll change. Require the supervisor who completed the review to approve the payroll change.

2.6 CONCLUSIONS AND SUMMARY

As the changing technology influences the decision to move from a large centralized system to smaller, communicating distributed systems, a new perspective must be taken to reduce the risk of security violations, whether intentional or accidental. New systems are being developed at alarming rates with less time being spent to develop security features. Furthermore, the hardware used in the distributed systems requires less interaction from the user in order to keep it operating, which also results in fewer personnel with the technical knowledge to enforce security measures and identify violations.

The trends in technology that will lead from the centralized to the distributed system are then seen, through the subsystem descriptive models, to lead to different processing modes -- different numbers and types of people, location and types of hardware, communication methods and procedures, data storage media and location, operations activities and so forth. These same factors are those associated with the computer security model described in section 2.2 and tailored security controls and accountability procedures will be necessary for the systems resulting from the technology changes. The impacts on security policy and practices were discussed in the section 2.3.

DDP System security vulnerabilities to disruption, compromise, manipulation and errors include all those of concern in CDP systems, plus additional risks from telecommunication and the greater number of access-actions-process combinations to misuse the system.

As with CDP system security, the preference is for preventive controls as compared to after-the-fact detection practices.

The major policy areas (Identification, Accountability, Authorization, Access Controls, Operations Controls, Operations Consistency, Restart/Recovery, and Auditability) can all be implemented effectively, in the DDP setting, through the proper selection from the safeguards and practices noted in table 2.16 and the policies listed in table 2.6. In any one setting, the potential security problems must be identified, assigned priorities, and evaluated in terms of their costs and benefits (risk reduction). The overall security policy for a DDP system should be arrived at through a systematic process so that the effects of combinations of available safeguards and their interdependencies can be taken into account. [STAFF COMMENT]

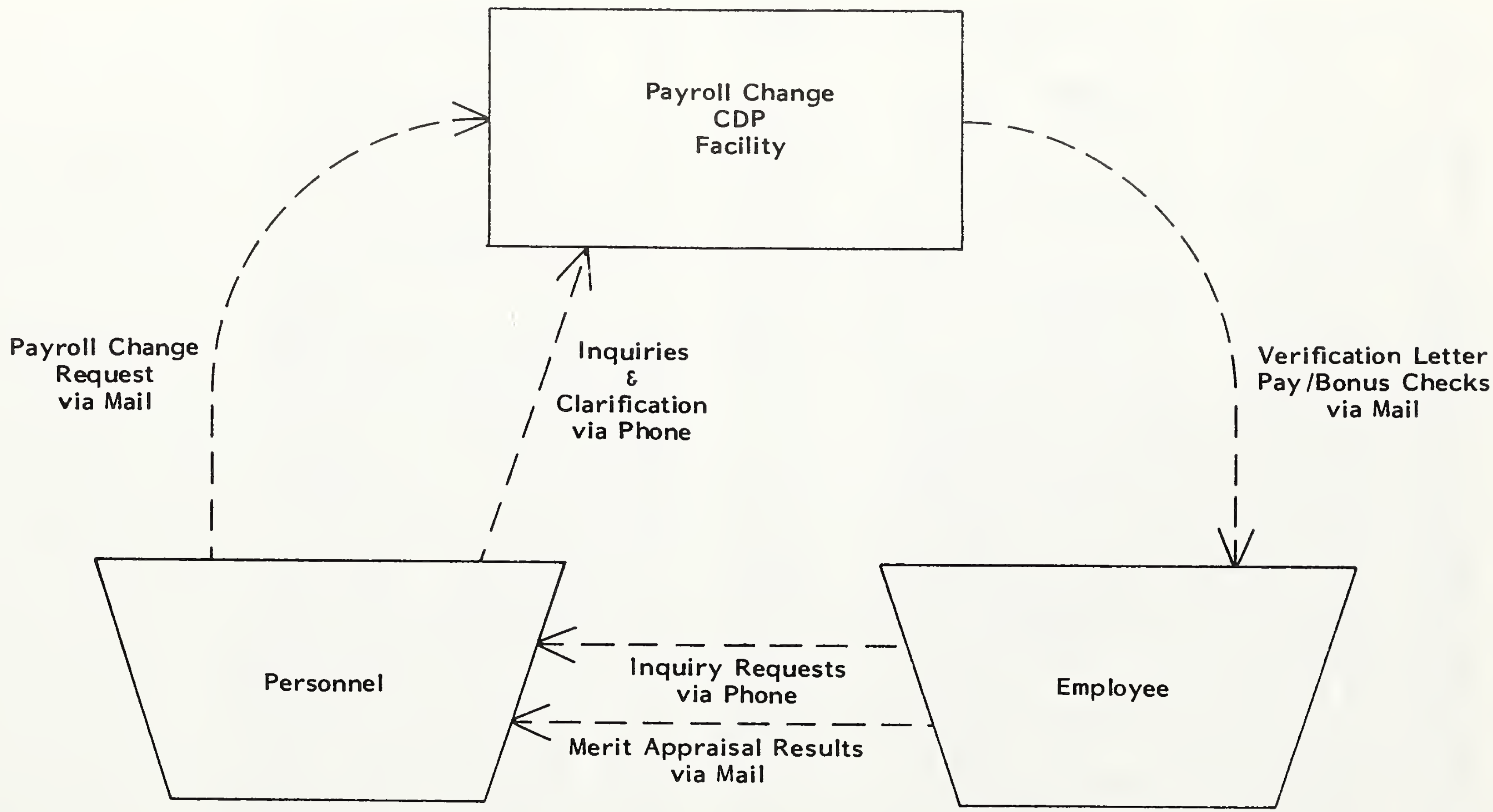


Figure 2.16 Payroll Change: CDP Macro Model

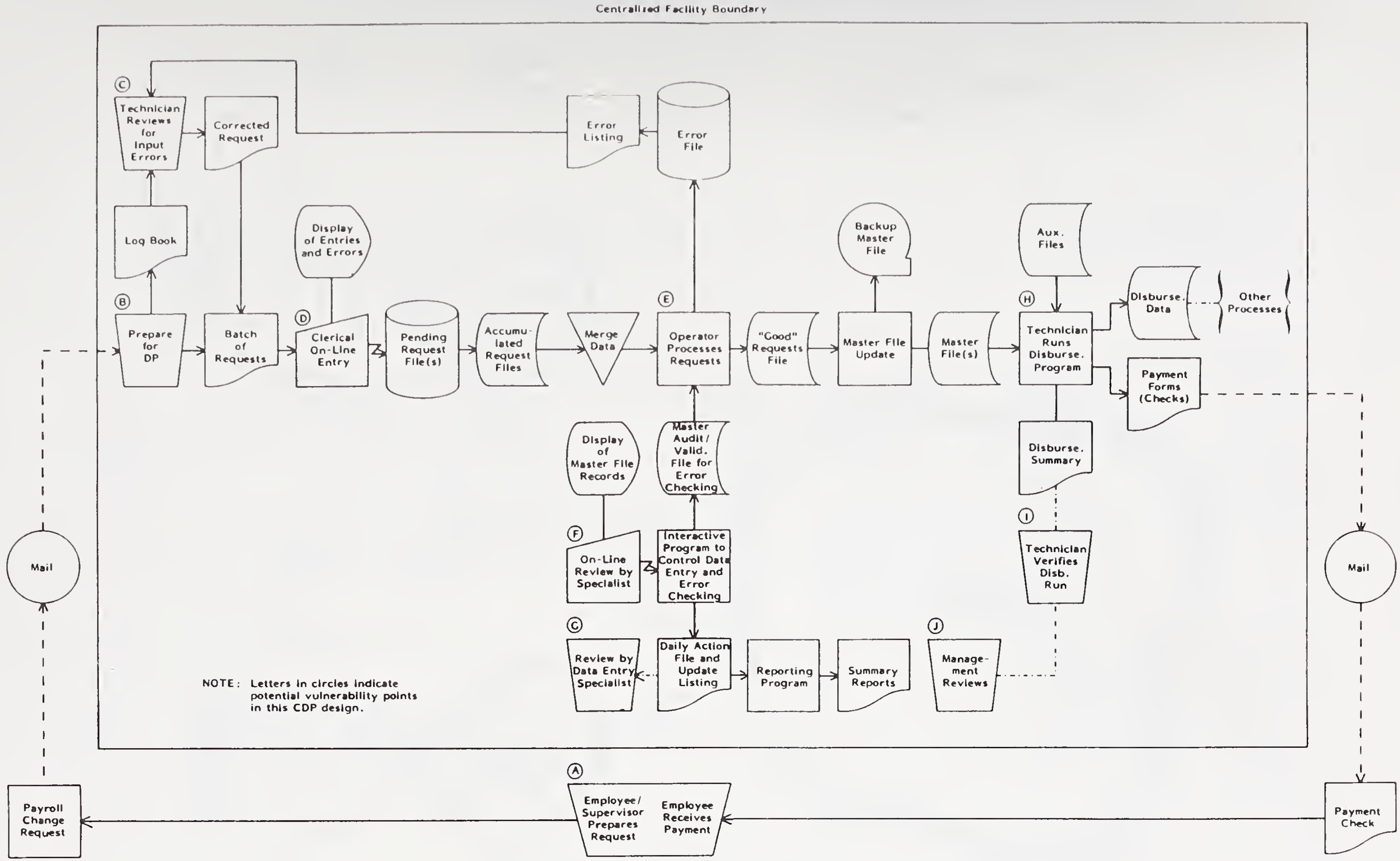


Figure 2.17 Payroll Change Processing (CDP) Descriptive Model

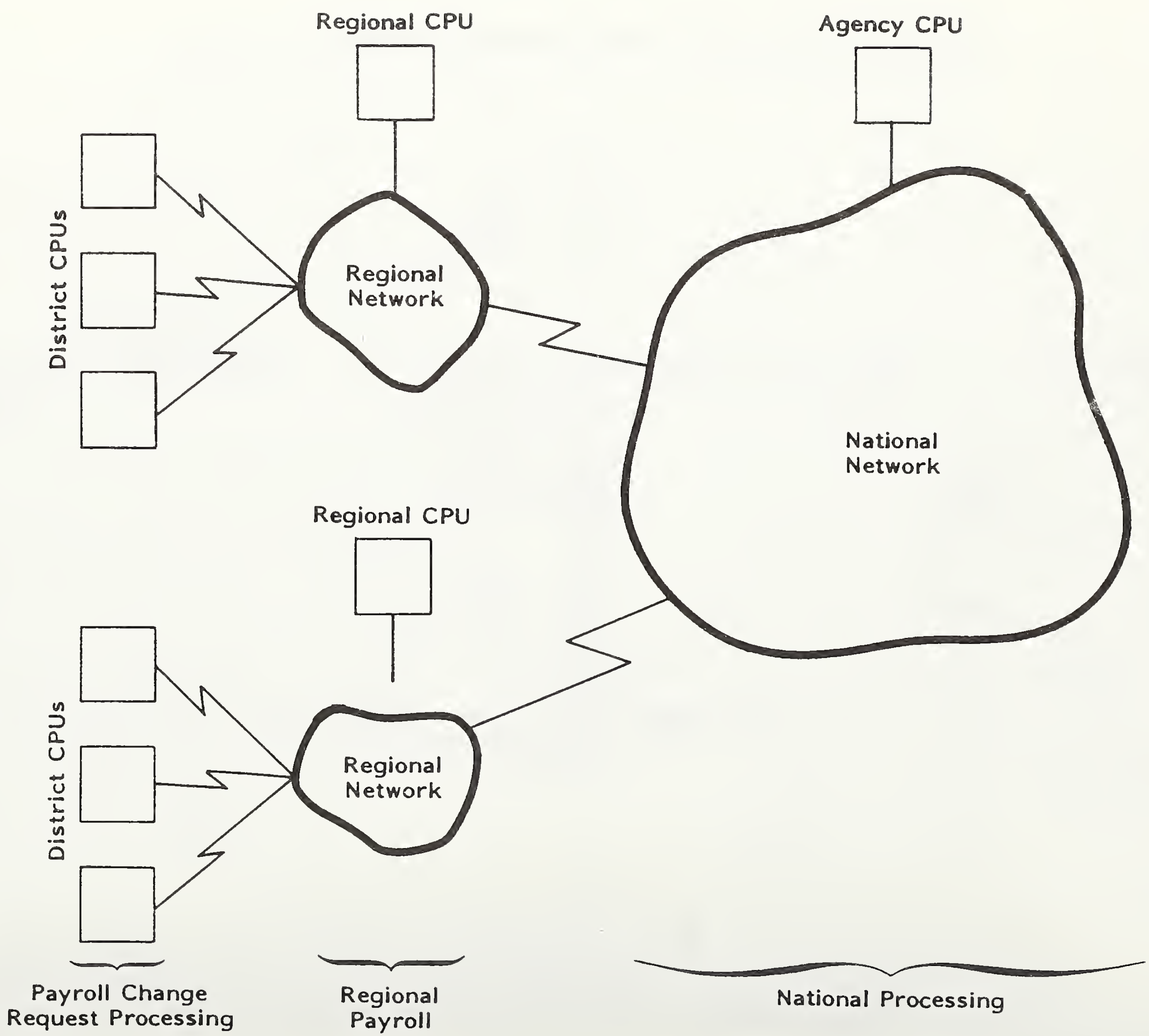
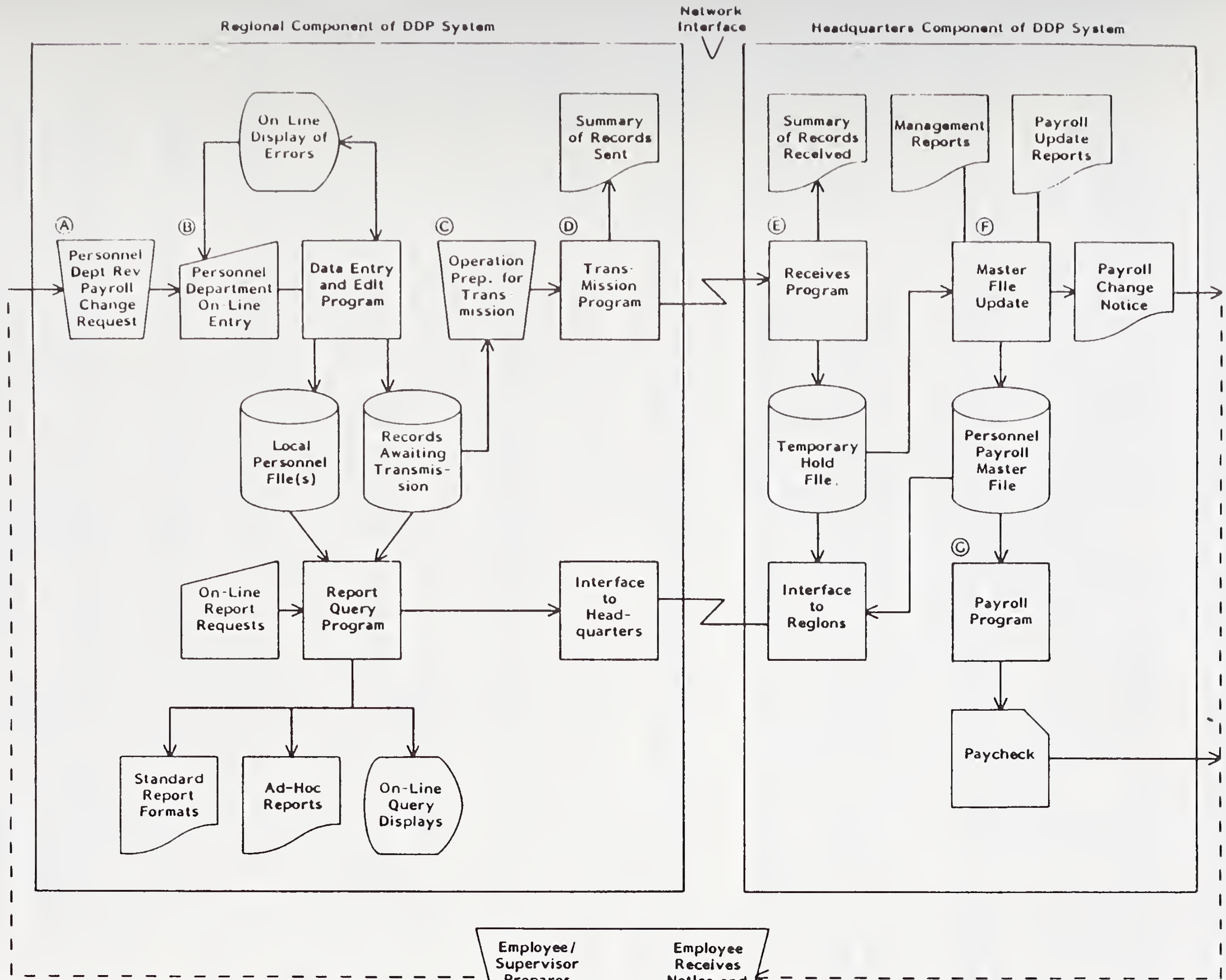


Figure 2.18 Payroll Change DDP Macro Model



NOTE: Letters in circles are vulnerability points for this DDP environment

Figure 2.19 Payroll Change Processing (DDP) Descriptive Model

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27. Kneer, D. and Lampe, J. "Distributed Data Processing: Internal Control Issues and Safeguards", *EDPACS*, Vol. X, No. 12, June 1983; Martin, J. *Design and Strategy of Distributed Data Processing*, Prentice-Hall, 1981; Steinauer, D. *Security Considerations for Small ADP Systems*, (Working Draft), NBS Internal Report, 1983; and Winters, C. "Auditing Data Communications Networks", *EDPACS*, Vol. X, No. 2, August 1982.

28. *Ibid*, Martin, J.

29. *Op. cit.*, Fiorello, M. et.al. (footnote 1).

30. Descriptive models of other aspects of software development (e.g., planning, documentation) can be found in Fiorello, M. et.al., op. cit. (footnote 2).

31. *Op. cit.*, Fiorello, M. et.al. (footnote 1).

STAFF COMMENT

STAFF COMMENT: The following note, from a Federal agency reviewer, was received too late to permit incorporation into the text of chapter 2. We feel, however, that the points are well taken and are therefore including it as a "staff comment".

That standards are needed is inarguable. The basis of communication is understanding and the basis of understanding is agreement on the meaning of symbols. Agreement on the meaning of symbols is a definition of the process of developing standards, the agreed upon meaning of the symbols.

Communication is the exchange of data and information. This data does not initially exist in the form of symbols that are recognizable, but must be translated into a lexicon which is mutually agreeable by those systems which are communicating. The simplest form of communication is a binary system; yet even this type of communication is incredibly complex, involving translation, broadcast, reception, and retranslation. Simplifying even this type and considering only the processes of translation and retranslation, we find that both must be unambiguous and consistent. Mathematicians speak of "one-to-one functions" that allow for unique inverses. That is, one symbol is directly translatable into only one datum or piece of information and that datum or piece of information can only be translated into one symbol. Notice that even in this simple system, symbols must be translated for broadcast and must be retranslated upon reception in a step that is different from the initial and final translations.

Three characteristics of any system are: Security, Reliability, and Continuity of Operations. Without any one of these, the system is unusable. Systems can be as simple as a single entity or multiple entities. For example, a computer program can be composed of one module or many modules. In either case, the system, in order to be usable, must have the three characteristics. Security consists also of three components: integrity, reliability, and accessibility. Integrity is that component that is concerned with understanding and whether or not a piece of information or data is interpreted at the receiving end in the same fashion that it was interpreted prior to transmission. Reliability is that component which relates to the number of times a system will operate in the way in which it was intended. Accessibility refers to the ability of different components of the system to communicate with each other. Although these components are similar to the characteristics of a system, the difference is scope. The components of security are related to each component of the system and each part of the system must be tested to ensure security, or, again, the system may be rendered unusable.

Each component of a system, then, must be able to communicate with every other (or other selected) component of the system as well as itself. The basis of this communication is the development of standards. Each component of a system may not need standards to communicate with itself at a given time, however, as time passes the symbols used by each component will change. Similarly, meanings for the symbols used by a given component developed in a vacuum will only by chance agree with those developed for another component. For example, in a computer program, subroutines may be developed in a vacuum (thought to be a great advantage of using distinct modules). However, unless the symbol is defined in each module or unless the meaning of the symbol has been standardized, the interpretation of the symbol X may be the slope of a line in one subroutine and may be the temperature of a piece of pipe in another, both subroutines being components of the same computer program. Even greater problems arise when two or more existing programs are merged into a new program or, when two or more systems are combined. Many examples exist of projects which fail because large amounts of code cannot be reconciled.

To return to the ultimate results of a lack of building in standards from the beginning, failure of a system will occur in any one of the three characteristics. Zeroing in on Security, failure will occur if any component does not possess integrity, is not reliable, or, allows either more or less accessibility to data or information than intended. Reliability and accessibility are fairly well covered in the ICST document. Integrity, however, is another problem.

Lack of integrity in a simple binary system leads to immediate misunderstanding. To most people, the word "gun" may induce a mental image which includes a threat to personal safety. To a photographer, "gun" poses no threat but, rather, a means for artistic satisfaction. Thus, to one person, a gun presents a vulnerability but it does not to another. The photographer might even be bewildered if it were so suggested. Identification of vulnerabilities in computer systems follows a similar pattern. A programmer knows what he means when he writes a line of code and can follow his logic through a program module. Another person, however, interprets part of the code and changes the rest to conform. Suddenly, the program works, but not in the way it was originally intended. The vulnerability may never be discovered if the code was not well-documented to include definitions of the variables. Or, a designer of a computer installation may not recognize the need for shielding because he cannot "see" the leakage of information through compromising emanations. To him, the vulnerability does not exist. In both cases, lack of definition has led to an information gap in the detection and elimination of vulnerabilities.

PART IV: MANAGEMENT IMPLICATIONS OF THE TRENDS IN INFORMATION TECHNOLOGY

Prepared by

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PREFACE

When the ad hoc steering committee first met to plan the contents of this year's forecast, we achieved a rare unanimity in deciding that a piece on the management implications of the new technologies should be an important component. This Part, which discusses those implications, is a distillation of the work of many people and organizations.

The initial "point of departure" papers were prepared by the International Data Corporation. Those papers provided the springboard for a two-day workshop in which 15 Federal agencies participated, for extensive comments by the members of the Arkansas Association for Users of Telecommunications and Information Systems (AUTIS), and for review sessions by managers from the Department of Commerce and Martin-Marietta Data Systems. This new material was incorporated into our first "circulation" draft, which was distributed to nearly 100 Federal, State and local government IRM offices. Many of the reviewers made substantial contributions to subsequent drafts. We would like to particularly thank Ray Oman, now with the Office of the Chief, Corps of Engineers and Roger Bedard and Thelma D. Jacobs of the U.S. Army Management Systems Support Agency, who provided us with draft material they were developing for their own agencies. We cribbed shamelessly from their documents.

The resulting "Management Implications" draft was then circulated to over 50 knowledgeable individuals in industry -- representing both large ADP users and vendors. Their written comments were incorporated into the document printed here. Further, about a dozen of those reviewers met in a workshop at ICST last September to discuss the material. A summary of that workshop is included in Part V.

MANAGEMENT IMPLICATIONS OF THE TRENDS IN INFORMATION TECHNOLOGY

1. INTRODUCTION

There are three dominant trends in information technology:

- o the continuing microprocessor revolution,
- o the increasing sophistication and usefulness of packaged software,
- o and the growing use of telecommunications networks.

Taken together, those three trends have major implications for the Federal automated data processing/telecommunications managers, for their "functional" or "program" counterparts and for senior policy makers. The financial managers, the heads of personnel departments, the people who manage the manpower programs, and the people who deal with issues of international trade -- we are all affected by the technology and we should all be prepared for its impact.

This section is divided into three parts. First, it briefly discusses the trends themselves. Next, it discusses some of the non-technical, organizational issues that arise from the trends. Finally, it highlights some of the more technical areas that require re-examination in light of the way the technology is going.

2. THE TECHNOLOGY TRENDS

Microprocessor technology is the deus ex machina that made the personal computer possible and it is the personal computer that is leading us into an entirely new information-technology environment. It is almost impossible to grasp the impact that this technology has had and will continue to have, but two facts will serve to indicate the scope: (1) personal computers are being accepted at a faster rate than was the telephone and (2) IBM is turning out one personal computer every seven seconds. Given the concomitant trends in software and telecommunications networking, the impact of information technology on the way we do business could easily approach that of the telephone.

Advances in software packages are the impetus behind the acceptance of the microprocessors. Software contains the instructions that tell the machines what to do. Until fairly recently, almost all software was written organization by organization, application by application. Programmers were the fount of all instructions. Then came VisiCalc and by 1982 there were about 500,000 users of that package. Mushroom-like, other application software packages sprang up on the shelves of computer stores, of bookstores and -- we expect in the near future -- supermarkets. There are spreadsheet packages like VisiCalc, editing packages like Wordstar, database management packages like DB-II. Microprocessor technology had been available for many years before it infiltrated the normal workplace to a significant extent. It was the appearance of the software packages that presaged the deluge. As such advances as moving graphics and videotex enter the mass market, the deluge is likely to inundate the executive suites. Such technologies offer instant information, easily assimilated; they are qualitatively different from the stacks of computer printouts previously presented to exasperated policy makers.

Even with the sophisticated application software packages, however, the stand-alone personal computers do not completely satisfy the needs of the end-users. For instance, the users of stand-alone equipment cannot work together on a document. Nor can they update the material stored with the institution's mainframe. For these uses, the networking technologies are required. These technologies will eventually free us from the isolation of the stand-alone personal computers. They will permit computers of all sizes to talk to other computers, to pool the data they contain, to quickly gather and analyze information stored all over the organization or even outside the organization, and to quickly update information stored anyplace on the network. Networks have been with us for a long time. The difference is that we are now seeing the development of standard communications "protocols" -- the rules by which data is transmitted among computers. These protocols permit computers to communicate over varying distances in increasingly sophisticated ways. Currently, many of these protocols are manufacturer-specific. However, the international standards organizations are developing protocols that will ultimately permit computers to be networked economically regardless of make and model (some stop-gap products are here already). In some ways, this development is analogous to the development of the application software packages since it means that we will no longer have to custom-engineer each network in its entirety. Standard, off-the-shelf components eventually will allow any computer to talk with any other computer -- for good or ill.

Taken together, these three technology trends have already led us from a state in which a large central computer was dominant to one in which it is commonplace for data to be processed at many locations in the organization and will continue to lead us to an environment in which the information <u>resources</u> will be distributed throughout the organization. That environment must be managed.

An illustration [1], taken from private industry, will serve to highlight just one aspect of the management difficulties facing us. The business-computing expenditures in one manufacturing company increased from $25 million in 1970 to $90 million in 1980. In 1970, the data processing manager had direct control over all of the $25 million expenditure. In 1980, the data processing manager directly controlled only 60 percent of the expenditures. In 1980, in that company, the amount of business-computing expenditure <u>not</u> centrally controlled exceeded the total amount of business-computing expenditure in 1970.

That illustration highlights the budgetary aspects of the situation. An analogous situation exists vis a vis information. That is, the organization's information resources will vastly increase. However, a growing proportion of that information will be dispersed throughout the organization. That is not necessarily a bad thing to happen since the dispersion creates an environment in which it is possible that (1) the combined pool of information will grow and (2) the information will be accessible to whomever needs it. But we must recognize that the shift will require organizational responses if we are to avoid both huge, unnecessary expenses and an electronic Babel of misinformation.

3. THE NON-TECHNICAL/ORGANIZATIONAL ISSUES

This Section discusses four issues that are common to every organization but which assume particular urgency in a rapidly changing high-technology environment. They are Management Structure, Planning, Personnel, and the Economic Impact of Change. These issues are closely intertwined and are presented separately only for the sake of clarity. It should not be inferred that the issues themselves are divisible.

3.1 MANAGEMENT STRUCTURE

The way the management of an organization is structured determines who will deal with the issues and the manner in which they will deal with them. There is no management structure that is "right" for all organizations or for any single organization for all time. But certain entities will always exist in one form or another within any organization that uses a lot of information and information technology. For instance, there will always be policy makers, managers responsible for information collection and distribution, computer/telecommunications operations managers, "functional" managers who direct the various mission activities of the organization, and staff members who draft the long-range/strategic plans.

The following discussion deals with some of those entities and the roles they play in managing information in an environment characterized by distributed information resources and dependent on computer/telecommunications technologies.

3.1.1 Policy Makers

This discussion of the role of the policy makers, draws heavily on a survey of 127 companies as reported by Richard L. Nolan [2] While his survey included only private sector organizations, most of his findings are equally relevant to the Federal Government. Nolan discovered that <u>the policy making function was handled most effectively by an Executive Steering Committee</u>, which included <u>the chief executive officer of the corporation</u> and between 5 and 10 executives drawn from all over the organization. There is (at least) one relevant difference between the makeup of a private sector executive committee and one established by the Federal Government. In the private sector, the policy makers are likely to have come up through the organization and, thus, are well acquainted with the operations and idiosyncrasies of their companies. In the Federal Government, the policy makers are most often political appointees without any long-term immersion in the organizations they direct. Therefore, a Federal executive steering committee should include both appointees with decision making "clout" and knowledgeable bureaucrats, including someone from the "business" side of the house (e.g., the comptroller) and someone with line responsibility for mission. While management-by-committee is not usually effective, in the distributed-resource environment it makes sense. Almost everybody is (or soon will be) affected by the technology trends and the various perspectives should be represented at the policy level if we are to avoid egregious actions. Again according to Nolan, the Executive Steering Committee should meet quarterly for one or two hours -- often enough to stay on top of the situation but not so often that the meetings wreak havoc with busy schedules. Nolan's survey identified five essential functions for the Executive Steering Committee:

1. Direction setting or the linking of corporate (or, in our case, agency) strategy and computer strategy. "It consists of setting objectives for the use of computers, formulating strategy to focus on...goals, devising policies to ensure that the organization's actions are consistent with these objectives, and reviewing and approving the long-range plan for computers...."

2. Rationing or the reconciliation of the commitment of agency resources to computers with commitments to other activities.

3. Structuring, which focuses on an appropriate organization design. This function deals with a number of issues critical to the management and use of the new technologies. Structuring will assume even greater importance as the technology becomes increasingly multi-functional, with capabilities that cut across organizational lines. Even now, organizations are dealing with limited multi-functional capabilities in bizarre ways. For example, one corporation has placed personal computers in the offices of all functional managers. However, the p.c.'s may only be used for computation; they may not be used as word processors. Word processing is the prerogative of the Word Processing Department. One can only wonder at the circumstances that led to rendering unto Word Processing sole responsibility for the Word but detatched the Number from Budget.

We will briefly discuss, here, three important issues related to the structuring function, i.e., centralization vs. decentralization, chartering, and the designation of core information systems.

A. Centralization vs. Decentralization

The term "decentralization" is not clearly defined and is variously used to describe a number of different structures. Understandably, this has led to some confusion. In some cases, "decentralization" is used synonymously with "distributed data processing", or a structure in which separate computers share the same information resources for their respective information processing functions: for example, a high performance network connecting a number of dedicated workstations which are tied into a central mainframe computer. In this definition, the processing is "decentralized", the database itself is "centralized."

At other times, the term has been used to describe "dis-associated processing", wherein specific functional units within the organization use their own computers to perform tasks (e.g., financial planning, forecasting, project management) without relationship to other parts of the organization.

In other cases, the term refers to the locus of budgetary control over the data processing function.

In still other cases, the term refers to the locus of substantive control over the use of data processing equipment. In these cases, "centralization" may refer simply to the use of agency or government-wide standards or, in the extreme, to actual line authority of the information resource manager.

Because of the catch-all quality of the terms, it is essential that the Executive Steering Committee decide -- at the outset of discussions -- what they mean by "decentralization." Without a common understanding of the terms, a great deal of time will be wasted in talking at cross-purposes.

B. Chartering

The Executive Steering Committee establishes charters for various organizational units -- for example, who has the charter for providing the staff of the Executive Steering Committee itself or who has the charter for defining the common agency-wide data elements. In a distributed data processing environment (where information resources are "centralized" and much of the processing is "decentralized") it is obvious that a common "data dictionary" is required. ICST has gone a long way toward specifying a Federal Information Processing Standard (FIPS) for data dictionary software. In addition, ICST has developed a number of data element standards for government-wide functions. However, many terms are agency-specific and cannot be dealt with on a government-wide basis. Granting the "charter" for determining the definition of agency-wide data elements is one of the most important functions of the Executive Steering Committee.

C. Designation of Core Information Systems

The structuring function also deals with the designation of the core information systems which must be designed, operated, and maintained on a uniform basis as well as the related decisions on the organization of the computer, telecommunications, and records management functions. This topic will be dealt with further when we discuss the analyses of the data architecture. For now, it is only necessary to point out that the selection of elements for the core system has enormous implications in a distributed processing environment. At present, in most cases, important information is held by individual "owners" (often functional managers) for a specified period before it is due to be reported to the next level. This time lag allows the owner to "play the float" -- or indulge in the classic organizational technique of postponing the day of reckoning by withholding negative information until the "due date." Thoughtful designation of "core" elements to be entered into the system in "real time" will allow the information "owners" and their superiors to have all of the available data virtually simultaneously. Note that this does not imply that they all <u>will</u> know everything simultaneously -- it means only that the data will be available for their perusal.

Questions of who has access to what information is also part of this function. As a general rule, top management will have authorized access to all non-classified material. All management will have authorized access to information pertinent to its functional responsibilities. Other personnel will be authorized on "need to know" bases. The general guidelines on who falls into what category of access is a matter of approval by the Executive Steering Committee.

4. <u>Staffing</u>, which for the most part speaks for itself. It should be noted, however, that the Federal Government has had difficulty in coming to grips with the concept of Information Resource Management. Much of the source of that difficulty lies in the way we typically staff our IRM offices which are often no more than renamed management information system offices. This issue will be discussed in some detail under 3.1.2. It is sufficient to point out here that the guidelines for staffing the IRM office will, to a large extent, determine whether or not the organization does, in fact, manage its information resources.

5. <u>Advising and Auditing</u>, which keeps the information activities on track. " Through advising, the committee assists top computer managers with problem solving [such as] the failure of a vendor to deliver a piece of hardware on schedule...." The audit function evaluates the agency's performance in using computers. Nolan recommends that the audit be performed annually by an outsider to ensure objectivity. While this is, in principle, a good idea, its feasibility in the Federal environment is moot. Government-wide, both the definition and allowable amount of "consulting" contracts are being reevaluated. Should this type of audit fall under a new definition, it may not be feasible to contract out for the service. We

suspect that interpretations of any new definition will vary from agency to agency (as is the case with the current definition). If outside contracting proves infeasible or -- for whatever reason -- undesirable, there are at least two outside-the-agency alternatives which should be considered, i.e., FEDSIM or an exchange of auditing services between two or more agencies.

One more function should be added to the five described by Nolan, i.e.:

6. Methods of budgeting and financing for the distributed systems that supply information to the central offices (the "bottom-up" information systems), including the use of shared resources such as telecommunications systems.

3.1.2 Information Resource Managers

These are the people who are responsible for managing the collection and dissemination of information throughout the organization.

In the absence of definitive evaluation techniques to measure the value of information resource management to the Federal Government there is some understandable scepticism over whether IRM is in fact a valid approach or whether it is just another passing fad. Without the "bottom line" measures that are available to industry, it is difficult to reach a persuasive conclusion. However, if we assume that industry's experience is analogous to Government's, we are amply justified in moving ahead with the implementation of IRM. In a 1982 study [3], SRI found that companies applying a formal information resource management approach outperformed those firms in the rest of the study sample by an average of 300 percent on three key financial measures: return on equity, return on total capital, and net profit margin. Thus, while we have not yet developed credible surrogates for the private sector's financial measures we do have some assurance that IRM is a reasonable direction.

Federal agencies have been having trouble defining the role of the information resource manager and part of that trouble is rooted in history. In many agencies, "information resource management" seems to be a new name for "information technology management" with a little bit of management information system administration added to the position description. The failure to adapt to a true information resource management mode reflects the difficulty in moving from the individual applications common to the large central computer "batch" environment to the totally integrated system that the new technologies make possible.

In order to make the adjustment to IRM it is necessary to understand how IRM differs from management information system (MIS) administration [4]. IRM considers both manual and computerized information systems for all users in an organization, while MIS focuses on computerized information systems that support management. IRM goes beyond the MIS concept. It uses the analysis of organization-wide information requirements to drive information systems planning and policymaking. MIS, while it considers needs, concentrates on the technology. The organization-wide focus of IRM provides a perspective on the universal interconnection of devices and integration of systems that is not central to MIS. Thus, while MIS administration may form part of the IRM system, it is by no means the totality of IRM.

Many Federal IRM offices are almost entirely managed and staffed by data processing professionals. Very few IRM staff members "grew up" in mission-oriented units or service-oriented units (such as the library). This staffing has tended to give a disproportionate MIS flavor to our IRM approaches.

Last February, ICST held a workshop to address the issues raised by the technology trends. The conference was planned and managed by a team of consultants chosen for their expertise in technology trend projection and in the Federal data processing environment. Participants came from IRM offices all over the government and appeared to reflect the composition of those offices. Almost all of the participants were data processing professionals; they were all dedicated, competent people who have been wrestling with IRM issues over the past few years. But, in the absence of workshop leaders who were versed in IRM, they were unable to come to grips with the <u>concept</u> of information resource management. For example, they developed the following list of candidates which should be considered for common policy, staff direction, and organizational alignment within an integrated information resource management system.

1. Design, operation, and maintenance of <u>routine administrative and business systems</u> (specifically those supported by general purpose, commercially available computers, i.e., the traditional ADP/MIS function).

2. <u>Telecommunication</u>, i.e., voice, data, text, graphics (specifically, that utilized by the routine administrative and business systems).

3. <u>Records Management</u>, both current and archival (specifically, those generated by the routine administrative and business systems).

4. <u>Libraries</u>

5. <u>Publications</u>

6. <u>Reproduction</u>

7. <u>Forms Management</u>

8. <u>Reports Management</u>

9. <u>Mail</u>

While that list is an extremely useful one for the intermediate stages of reorganization toward true information resource management, it does not define the role of the IRM which is to:

- o Identify who has what information, who needs what information, and how channels of information flow can be constructed so as to get the information, in a timely fashion, into the hands of those who need it.

- o Develop and maintain whatever mechanisms are necessary to satisfy the information needs of the organization.

The workshop results, which reflect the absence of functional managers from the roster of participants as well as the absence of "real" IRM personnel among the workshop leaders, highlights the necessity for broad-based staffing of our IRM offices. This is not to say that experienced data processing professionals should be "written out" of key roles in the IRM offices. Without their active participation, we would likely encounter calamities such as the accidental loss of databases and unauthorized distribution of confidential material. The point is that a wide variety of experience and expertise is required and data processing professionals alone cannot do the job.

Certainly the candidate list produced by the workshop participants would be among the mechanisms required to satisfy the information needs of the organization. But that list satisfies only a fraction of an organization's information needs. Management scientists have been developing systematic methods for identifying information needs but there is little evidence that IRM personnel are acquainted with their existence -- let alone that they have used them. One exception is the Evaluability Assessment methodology, developed by the Urban Institute, which has seen some limited, but promising, application for this purpose [5] Looked at from the perspective of the organization's information needs, it is clear that the functions of the office of the IRM should include:

- o Formulation and dissemination of technology assessments and forecasts (more about that in the discussion of Planning)

- o Analysis of technical issues as they relate to strategic objectives

- o Translation of key policy, management, and technical issues into the variety of "languages" understood at the various levels of the organization

- o Maintenance of agency-wide data interfaces -- including both technology-dependent interfaces and more traditional interfaces such as the library

- o Analysis and acquisition of the technology system architecture -- this includes the long-range acquisition plans

- Identification of an agency-wide data dictionary relying, where applicable, on Government-wide standards

- Development and maintenance of the "core" data systems identified by the policy makers

- Responsibility for disaster backup facilities

- Implementation of periodic needs assessments

Needs assessments are addressed below, in the discussion of the analyses of system architectures (section 3.2.4).

3.1.3 Computer/telecommunications Operations Managers

In the integrated environment under discussion, the operations managers are responsible not only for keeping things running, but also for providing the IRM with technologically sound evaluations of strategic decisions. The functions of the Operations Managers should include:

- Evaluation of the <u>tactical</u> impact of strategic decisions. That is, what will be the effect, for instance, of a decision to decentralize on acquisitions, budget, personnel and space requirements and so forth.

- Evaluation of the system architecture analyses prepared in the IRM office in terms of its impact on the current system

- Maintenance of the telecommunications networks and the central ADP facility

- Administration of the "core" information systems

- Maintenance of data integrity

- Responsibility for training staff in concepts of

  - Computing
  - Records Management
  - Security
  - Equipment and software acquisition and maintenance

- Responsibility for in-house user meetings (and, if possible, publication of user newsletters)

- Provision of user-oriented documentation for all centrally purchased or developed software packages

3.1.4 Functional Managers

In a distributed resource environment, the roles of the functional managers are critical to the success of information resource management. A great deal of information is generated and processed at this level and flows up through the organization. The responsibilities of the functional managers should include:

- A good lay knowledge of the capabilities of the technology available to the department
- Assurance of the integrity of data generated by end-users
- Evaluation of the impact of strategic decisions on agency missions
- Acquisition of personal computers. The extent of this responsibility depends on the nature of the agency's decentralization. In those agencies where central budgetary control is maintained, the functional manager's responsibility is limited to approval of requests for acquisitions.
- Documentation of *ad hoc* pilot projects (more of this in section 3.2.3)

The responsibility for assuring the integrity of data generated by end-users is particularly important when end-users are allowed (or required) to update data stored on the mainframe. Consider, for instance, a not-unlikely requirement for frequent updates of status on funds or personnel. Such a requirement would call for equally frequent interactive data submission by personnel in the functional areas affected without the traditional time allowed for error correction. In a "batch" environment, it is standard procedure to institute a series of audits before material is entered into the institutional database. The functional managers must provide a similar level of assurance in the distributed environment, developing new quality control techniques as necessary.

3.1.5 *Planners*

Most large organizations have a quasi-independent strategic planning office which, in theory, formally gathers and analyzes data, formulates The Plan, "sells" it to the policy makers, and disseminates it throughout the organization for implementation. Evaluation of the results of the implementation becomes part of the data stream that feeds into the subsequent cycle of The Plan formulation. In practice, this seldom works either in government or in private industry [6].

Because the planning function is so closely related to the function of the IRM, we suggest that it be located in that office. However, arguments can be made for its location in the budget office, the office of management and organization, or even established as a unit on its own. Wherever it is located, however, a major stumbling block to an effective planning process is the concept of a quasi-independent planning unit that does nothing but plan. Without a working relationship with the policy makers (a relationship not necessarily related to the planning function) it is doubtful whether the planners can get close enough to the policy makers to sell tomorrow's newspaper, let alone a strategic plan. It would be well to consider locating other functions (such as staffing the Executive Steering Committee) with the planners.

It is equally important that the planners have working relationships with the functional managers. This is difficult, but not impossible, in an environment of distributed resources. Planning personnel normally assume that when The Plan is not correctly implemented, the failure is due to the recalcitrance of functional managers. More often, the case is that The Plan is not amenable to implementation. If strategic planners are to be effective, they must know how their organization works. It would be well to consider locating a function like program reviews in the planning office.

With all that, care should be taken to locate only stable, predictable functions in the planning office. The planners should not have "firefighting" responsibility. If they are continually involved in firefights, the planning will never get done.

It is not important that the planners have the official designation of "Planner." It is important that the planning function exists, that responsibility for planning be assigned, and that the planners occupy an organizational linch-pin position between the functional managers and the policy makers.

3.2 PLANNING

Whether, and how well, an organization takes advantage of the new technologies will depend in large measure on the effectiveness of its planning process. A too-common approach to planning is one in which an organization's overall information systems plan is a collection of individual project plans collated into what amounts to little more than a numerical sum. This type of plan, typical of the large central computer environment of the past, often results in a number of loosely coordinated systems with considerable hardware, software, and data redundancy as well as incompatibilities. Not uncommonly, very few of the system users (or even the "owners") are aware of what is available throughout the system.

At the other extreme is the attempt to wrap nearly all new development into a huge and inflexible system that would take three to five years to develop and would require all available resources. That approach is prone to excessive overhead, vulnerable to incorrect assumptions and decreasing technology cycles, and likely to go over budget and beyond schedule while failing to provide what is really needed.

An effective planning system requires a number of integrated components (discussed below) that are used as tools to continually monitor and update the institution's plans. The process of planning for change is particularly difficult in the Federal environment where success and failure is often measured in terms of implementing a plan which may have become as obsolete as last year's technology. The agencies which will be most successful in planning will be those which are able to streamline their approval processes and to adapt their management structure to this new environment.

3.2.1 Technology Forecasts and Assessments

Until recently, technology forecasting was often handled as an incidental adjunct to the acquisition process. However, the new technologies have real impact on the strategic objectives of the organization and the rate of technological change may have a devastating impact on the budget. Therefore, technology forecasting has become an indispensable tool for the planners. There are upwards of 70 techniques available for forecasting [7], falling into the three general categories of time series and projections, models and simulations, and qualitative and holistic methods. The techniques serve different purposes and are accomplished at different levels of expenditure. However, it is doubtful that any of the techniques are as useful for planning purposes as a frequently updated "expert" forecast (one of the holistic methods) combined with forecasts of market structure and an organization's own assessment of its current resources.

While "expert" forecasts tend to be somewhat less expensive than those that rely on computer-based simulations, they are nonetheless costly -- a knowledgeable, well-presented "expert" general ADP technology forecast bought in the price-range of $50,000-$100,000 is considered a good buy. It therefore makes sense for agencies to band together to fund a cooperative forecast, like the one sponsored by ICST, which concentrates on areas of mutual interest. This leaves agencies free to develop their own special-interest forecasts and to detail the implications of the coming technologies for the individual agencies. Agency documents should include:

- Areas of special technological interest (e.g., supercomputers)
- Areas of technological stability and skills requirements (and shortfalls) within the organization
- Capital investment requirements and, insofar as possible, benefit ratios
- An index of current applicable guidelines and regulations, and
- An index of Federal and industry standards with fallback plans for cases where needed products do not comply

3.2.2 Technology Transfer

The trends in information technology have led to a situation in which increasing numbers and kinds of people are:

- o using computers,
- o aware that they are affected by the organization's use of computers,
- o in possession of application-specific information related to computers
- o involved in the computer-acquisition decision process,
- o responsible for the dissemination of computer-generated information

It follows that increasing numbers and kinds of people had better be included in the planning process if the plans are to be implementable and implemented. Planning should not be done solely by the data processing professionals -- indeed, it should not be done solely by the IRM's staff. Rather, the planning process should include the policy makers, operations managers, and functional managers. It is up to the IRM to <u>manage</u> the process, not to go it alone.

The concept of technology transfer has to be expanded from a model that envisions the technologically-smart data processing professional "selling" a plan to the decision-maker and "educating" the functional managers to that of a model in which the decision-makers, functional managers, and data processing professionals each contribute the relevant information contained in their respective areas of expertise. The data processing professional will never (or at least <u>should</u> never) "sell" a plan that the policy makers do not need and the functional managers cannot use. Mixed-bag seminars and workshops are effective vehicles for this type of technology transfer.

In addition, we are beginning to see instances where some functional personnel are more familiar with the potential of their microcomputers than are the data processing professionals, whose experience may be limited to the mainframes. Even in technical dp matters, technology transfer is a two-way process.

3.2.3 Pilot Projects

Pilot projects are not necessarily scheduled, planned efforts. In this era of end-user computing, virtually every desk-top computer in the hands of a professional leads to some sort of ad hoc pilot. Endless discussions, which have centered around whether these "renegade" pilots should be encouraged or discouraged, have produced a number of trenchant comments. The following comments came from the February workshop mentioned earlier.

- A successful end-user pilot on database development will be the absolutely right answer for that end-user's shop and absolutely wrong for the institution.

- In terms of time and resources expended, a pedestrian success may be worse than a failure.

- Small group pilot projects are similar to under-funded small business successes. Upgrading the pilot to a standard agency system demands refinement, documentation, and training by the operations staff. Operations managers soon learn that they cannot afford too much success with pilots.

- End-user computing will not end the backlogs in the data processing shops although the nature of the backlogs will change. Most central organizations will continue to retain responsibility for agency-wide data collection and applications such as payroll, general ledger, various financial consolidations, and employee database maintenance and reporting. Added to these retained functions are the increasing requirements for user training and general hand-holding. Thus, while the capabilities of the microcomputers will eliminate many small database requirements in the backlog of the central shop, some backlog will continue to exist. This is a major point which planners need to recognize.

- Functional managers are more upset about ad hoc desk-top pilots than are the data processing managers because they have more to lose.

However interesting these discussions may be, they have about as much point as discussions centering around whether to stop the ocean tides. "Renegade" pilots are going to occur in increasing numbers as more professionals understand the capabilities of the newly-available technologies (i.e., personal computers, applications software packages, computer networks). The real question is how the pilots can be harnessed so that their power is of benefit to the organization.

One method might be to reward promising pilots with help from the central data processing shop, contingent on the resources available to that shop. A competition for central help should not be used as a vehicle to stop projects deemed less promising; such actions would simply serve to limit the number of competition entries rather than the "renegade" pilots themselves. However, formal competition would serve two useful purposes. First, it would give the most promising projects the greatest chance for success while shaping them into a form that might be efficiently expanded for organization-wide use. Second, it would surface pilot plans from all over the organization and minimize duplication of effort.

A second method would be to reward, through citation or cash bonus, documentation of successes and failures alike. While this goes against the grain of our success-oriented society, the analysis of failure can be at least as instructive as the trumpet of success.

Whatever methods are used to harness the "renegade" pilots, it is essential that the functional managers be brought into the process. As the last comment from the workshop points out, they have the most to lose if operations get out of control. Conversely, they have the most to gain if the pilots are successfully harnessed.

Apart from the "renegade" pilots, the central shop should consider a more formal approach to pilot projects. Again, the participation of the functional managers is crucial.

However the pilots are handled, they should be documented and publicized as they proceed. Because of the propensity of the functional managers to experiment with their micros, it is imperative that they be acquainted with both the potential and pitfalls of what they have in mind. Widely disseminated documentation of pilots-in-progress will help mightily.

3.2.4 Analyses of System Architectures: Needs Assessments

Formal analyses of system architectures, including requirements for computation, word processing, and communications are essential to adequate planning. The discussion of technical issues will deal with the analyses of the system architecture in a little more depth. For now, we will confine our remarks to the general topic of needs assessments.

There are needs and there are needs and none of the needs should be neglected.

- o Every large organization has overall information needs that directly relate to the organization's strategic objectives.

- o Within any organization there are individual units (e.g. office units) that have specific needs.

- o Some organizational needs can be satisfied through the use of information technology
  -- The technology requirements comprise a third level of "need"

In order to specify correctly the technological requirements, the first two levels of need must be assessed and their organizational relationships understood.

Some vendors now include needs assessment methodologies as components of integrated office automation packages. These methodologies usually include the use of surveys relating to word processing, administrative support, professional performances, secretarial productivity, network design, and so forth. The survey results will normally indicate a "need" for enhanced services such as electronic mail, mixed media input, teleconferencing, and electronic document communications.

For the most part, the methodologies concentrate on quantitative data (e.g., how much paper flows from Department A to Department B, how much time executives spend in face-to-face meetings). Once the assessment is complete, the recommended system is designed to perform more efficiently the time- or paper-intensive tasks. For instance, electronic mail is often recommended for paths of frequent paper-flow; teleconferencing as a substitute for face-to-face meetings. These kinds of needs assessments are fine as far as they go, but they do not go far enough.

Two things determine the idiosyncratic ways that an organization conducts its business: the predilections of the people who are in the organization and the tools that are available. The new technologies provide additional tools and in order to make good use of them, it is necessary not only to examine what we do but also why we do it. For example, some face-to-face meetings are held for the purpose of exchanging information. Teleconferencing would cut travel time but it would not -- by itself -- improve the quality of the information exchanged. However, given the database, an appropriate database management system would address that issue. For instance, a spreadsheet package would do admirably for a conference of budget analysts; technical conferees would require something else.

Needs assessments should always do more than point the way toward doing the same thing more efficiently. They should provide the basis for performing a function more effectively.

3.2.5 Analyses of Data Architectures

The architecture of an institution's data system is analogous to the architecture of its computer-communications system. That is, the data system has a "backbone" of institutional data, which is relatively stable just as the communications network provides a relatively stable "backbone" for the computer/communications network (again, more on this when we get to the technology issues in section 4.2). For example, payroll and personnel data are contained in "backbone" systems which, while they must be maintained, are not subject to frequent, violent upheavals. Other information is of a more volatile nature; its form and content changing as strategic objectives evolve and as people --with their infinite variety of work habits and biases -- move in and out of the organization.

The analysis of the data architecture should focus on several areas:

- o Who needs what information? Who has what information? How can the information be brought from where it is to where it is needed? (Nearly the position description of the IRM).

- o What is the backbone information administered by the central data processing shop and what information should be distributed? What are the appropriate interfaces, in terms of people, hardware, and software, between the centrally administered and the distributed information?

- o What information properly "flows down" through the organization? What information comes "bottom-up?" What bi-directional channels need to be constructed?

- o Where are the information "sinks?" (That is, where does information disappear, never to be heard of again?) Who is authorized to drain those sinks?

3.3 PERSONNEL

Personnel issues encompass a variety of areas including:

- o Training, job descriptions, and career paths
  - Compensation and turnover
  - Motivation
  - Retention and recruitment

- o Security clearances and practices

- o The "fear of/resistance to" syndrome

- o Contracting out

Some of these areas are covered at length in last year's technology forecast, in OMB Circulars A-76 and A-120, and in the computer security section of this year's forecast. The remarks here will be confined to some issues that either aren't raised in those documents or where particular emphasis is needed.

The technology trends imply that the future will require a skill-mix which is different from that which is currently present in the Federal Government. Specifically, we expect:

- o Fewer, but more highly skilled, analyst/programmers at the system integration and telecommunications/networking level

- o Substantially fewer COBOL and FORTRAN programmers. It is arguable whether our current force of such programmers, steeped in the methods of program logic, can be retrained to use the functional capabilities of the new integrated software

- o Greater information manipulation and management skills in the overall workforce

- o A shift in data entry personnel from the central data processing shop to the functional units
- o A significant increase in user support personnel
- o An increase in administration, management, and planning personnel

Problems of recruitment and retention (in what will, for many years, be a "seller's market) are serious and may ultimately prove insoluble in the absence of integrated planning -- and the implementation of the plans -- by OMB, OPM, and the Executive agencies.

3.3.1 Training

Highly focused, traditional training is valuable in selected situations. It is particularly useful when application packages must be selected and hands-on experience with the various options is desirable or when changing skill-mix requirements dictate changes in career paths and specific skills are needed in order to follow them.

Further, at least in the short term, traditional training is vital if we are to take full advantage of the array of application software available to us. While this report has identified sophisticated, user-friendly software as one of the three dominant technology trends, it is important to realize that a trend is not a full blown actuality. The microprocessor software industry is still in its infancy. Except for a few notable exceptions, it is still user-hostile and difficult to learn. In many cases, end-users must still digest a 200+ page manual before pushing the first key. This bespeaks the necessity for training programs to accompany the placement of most application software packages -- at whatever level they are placed. **[STAFF COMMENT 1]**

Traditional skill-development training, however, is not sufficient in an era in which the focus is on the applications to which the technological tools lend themselves. Policy makers, operations personnel, and end-users alike are apt to be ignorant of the potential of the technologies; standard, hands-on courses are unlikely to enlighten them. For that, non-traditional, innovative training is required. Such training is inherent in activities like the workshops and seminars discussed earlier under technology transfer (3.2.2). Other non-traditional training mechanisms include attendance at trade shows, industry association meetings, and standards groups. If these non-traditional training mechanisms are to be effective, however, it is important that they be extended to policy makers and program personnel and not be limited to data processing staff. For the latter group, such mechanisms are part of the job; it is only for the former groups that they constitute training.

Every agency has a collection of horror-anecdotes that spring from the application of new technologies to old tasks. Even at the risk of perpetuating a "Please Don't Eat the Daisies" syndrome, agencies should consider collecting pertinent anecdotes and circulating them to staff members who are learning to use the new equipment. As it happens, more misfortunes occur than can possibly be predicted:

- In one agency, the Personnel Department was plagued by widespread "leaks" of confidential material. Investigation showed that the staff habitually left their floppy disks on their desks overnight after carefully locking up the hard copies.

- In another agency, clerical personnel stapled the floppy disks to the hard copies so that they wouldn't get lost or separated.

3.3.2 Job Classification and Career Paths

As end-user terminals and "congenial" application software packages become ubiquitous, a changing combination of skills will become necessary within certain job series. For some professionals, such as budget analysts and scientists, the ability and willingness to use the technology may significantly enhance performance. For secretaries and clerical assistants, these abilities will expand the scope and nature of their work and enhance their value to the agency. As data and word processing functions become increasingly intermeshed, clerks and secretaries are becoming capable of providing extensive administrative and research assistant type of support. Yet existing position classification standards build in no incentives for taking on responsibilities for automated data input, retrieval, or manipulation. Without classification standards that recognize the value of such expanded capabilities and responsibilities, employees in low grades and in dead-end job series will simply take their newly acquired skills to private industry where they are more highly valued.

In addition, the new software packages are blurring the distinctions among clerical, administrative, budget, and research assistant personnel. Most discussions of future requirements for skill mixes (including this one) emphasize the changing requirements for data processing personnel (for example, fewer COBCL programmers will be required). It is likely, however, that the most significant changes will occur in other parts of the organization. For instance, spreadsheet tools, like VisiCalc and SuperCalc may lead to decreasing requirements for lower-GS-level budget analysts. Concomitantly, the creation of intermediate job classifications would create new career paths for the current dead-enders.

3.4 ECONOMIC IMPACTS

The economic impacts of the trends in technology pervade the organization. They show up in the numbers and skill mix of employees in the budget shops, the libraries, the line organizations -- in every cranny of the organization that either processes data and words or uses the processed data and words. Notwithstanding, traditional information technology cost/benefit analyses usually measure the impact of the technologies on the data processing/communications shop. This is as futile as measuring the economic impact of the telephone at the exchange.

As the technologies have exploded out of the dp shop and into the offices, people have begun to recognize that cost/benefit analyses should relate to more than the price of equipment -- that productivity throughout the organization is the real issue. But that realization has not solved the problem -- it has simply identified it. We still do not have any sure handle on what to measure, where to measure, or how to measure.

For example, SRI International has estimated that one impact of office automation on management and professional productivity is the saving of two hours out of an eight hour workday. This estimate was arrived at through a study of how managers and professionals spent their time and how much of that time various "enhancements" would save. However, there is no certainty that the two "saved" hours would be productively used or that lower costs would result.

There are a number of more-or-less satisfactory tools for determining productivity when the technology offers a substitute method for performing an old task. These tools are typically used in offices that focus on keeping the cost per transaction low: e.g., accounting, records management centers, payroll.

We know of no satisfactory methods for measuring the costs and benefits when the new technology permits a new function, nor do we know of any satisfactory techniques for predicting <u>where</u> all of the important economic impacts will appear.

It may be worthwhile to work with functional managers engaged in ad hoc pilot projects in order to get some clues as to "where". Careful observation might enable us to identify unanticipated economic impacts in the limited environment of the pilot. From that, it may be possible to extrapolate analogous areas in the organization-as-a-whole. That is, we may be able to pinpoint some areas where previously unrecognized impacts might occur.

The problem is not in recognizing what we are doing wrong, but developing methods for doing it right. ICST has begun work on the development of more satisfactory cost/benefit analytic techniques [8]. But the effort is expensive and progress is slow. Like technology forecasting, this may be a fruitful area for cooperative efforts.

The problem of measuring the impact of the technology trends is overriding. As we have just noted, it is difficult to measure the costs and benefits when new functions are permitted or to predict where impacts might occur; it is next to impossible to measure "mushy" things such as the quality of decisions induced by an automated decision support system. Despite that, however, reasonable people would probably agree that the wrong decisions vis a vis required skill mixes or the direction of organizational growth would have more serious adverse economic impacts on the organization than would the acquisition of the wrong piece of equipment. Nonetheless, there is a consistent demand for quantitative justifications. For example, the workshop mentioned earlier produced the following advice.

> Senior executives, working through IRM and program managers should demand a quantification of automated "quality" improvements, compared to "previously acceptable quality" and its cost (one time and recurring) anytime an overall budget request exceeds established guidelines.

There are a number of quantification techniques available, including risk analysis, decision analysis, sensitivity analysis, modeling, and simulations that work more-or-less well depending on what is to be quantified. But it is important to recognize that some areas remain intractable to measurement. It is equally important to recognize that the inability to measure it does not imply that the cost or benefit is nonexistent.

> The glass is falling hour by hour, the glass will fall forever,
>
> But if you break the bloody glass you won't hold up the weather [9].

3.4.1 Acquisition Costs

Within the data processing shop itself, certain steps can be taken to reduce the costs associated with the decreasing technology cycles. Alternatives to outright purchase such as leasing, leasing with option to purchase, lease-to-purchase, and sale/lease back arrangements should be explored.

Institution-wide licensing agreements for software packages should also be explored as a method for limiting the spiralling costs of software.

3.4.2 Use of the Budget Process

Strategic planning, to have any meaning, must be integrated with the budget process. The issues of worker productivity, costs and benefits of technology insertion, and quality of information all hit the bottom line at budget time. Then, the question is whether the predicted budget (cost) is politically acceptable as a national priority.

An examination of the budget process indicates that proposed increases may be more acceptable under one line of the budget rather than another. For example, if office automation requires an average equipment investment of $10,000 per employee (as some estimates assert), that cost may be politically more acceptable in the mission program budget than in the central data processing budget. Allocating the cost to the mission program, however, could result in budget expediency driving organizational form. Should analysis show that the decentralization of budget is wrong for the organization, politically acceptable alternatives to mission program budgeting -- such as full cost reimbursement by the users to the data processing shop -- should be sought.

4. THE TECHNOLOGY-RELATED ISSUES

So far, we've discussed the impact of the technology trends in the context of management concerns that would exist even if the technology had never been invented. Management structure, personnel, planning, and the economic impacts of change are generic management issues. There are other concerns, however, which are directly linked to the technologies. Among them are the growing population of end-users "computniks", the impact of computer networking, software investments, and the decreasing technology cycles. In this section we will offer a few remarks on those issues.

4.1 END-USER COMPUTING

End-user computing is the relationship between people and technology in which individuals, located at their own workstations, interact directly with the computer to process their own information [10]. The concept of end-user computing has grown from one which envisioned people working at stand-alone stations, manipulating data for their own, discrete uses, to that of many people, working at interconnected terminals, drawing on a store of common data, and adding to or changing that store.

This expanded concept includes not just data processing professionals, secretaries, and budget analysts, but also encompasses managers and professionals from all over the organization. By the 1990's, computer literacy is likely to be indistinguishable from basic literacy. The notion that managers and professionals would not use a keyboard, taken for granted only a year or two ago, is daily contradicted by hundreds of thousands of managers (including us) who use their own workstations for everything from simple word processing to sophisticated simulations.

This trend does not signal the end of the central data processing shop -- large "batch" runs will still be performed centrally and the central shop will still be the keeper of the institution-wide records that are available through networks. However, many of the functions of the data processing shop will be distributed through or supplemented by other units within the organization.

The impending ubiquity of end-user computing has important corollaries for both the functional managers and the data processing professionals. Among them are:

- o Functional managers have more to lose than do data processing managers if operations get out of control due to the use of unverified procedures or data.

- o Data processing managers will find themselves dealing with increasingly sophisticated clients who will be

  - more understanding of and responsive to software development steps such as requirements analyses,
  - insistent on participating in decisions regarding hardware and software acquisitions, and
  - very intolerant of failures due to ineptitude and "stonewalling" in the interests of turf protection

- o Data processing professionals within the IRM office will become increasingly concerned with data protection and integrity since the control function becomes increasingly difficult as computers proliferate. The central shops will employ a variety of controls which may include

  - standardization of microcomputer software packages including the testing of packages which are candidates for certification
  - definition of documentation standards
  - adoption of an agency-wide data dictionary

[STAFF COMMENT 2]

4.1.1 Compatibility

The term "compatibility" was initially used in microprocessing to indicate the ability of a device or board to interconnect with a particular bus. The term had a precise meaning that was clear, and nearly unambiguous, to practitioners of the "micro art."

However, as end-users began to acquire their respective micros, they began to yearn for the ability to swap floppies (both data disks and programs), and "compatibility" became the term for doing that. With the introduction of the IBM-PC and its subsequent popularity, "compatibility" was adopted by salespeople and advertisement writers to describe the relationship of their computers to the IBM product. The word has now taken on an almost universal meaning. It is often preceded by a modifier of degree (e.g., "very", "reasonably"); less frequently by a functional descriptor (e.g., "hardware compatible"). Table 1.1 lists some of the common "compatibilities". The left-hand column contains the terms used; the right-hand column their meanings. Be aware, however, that the creative ability of the various sales forces outstrip our ability to keep up with the terminology. By

TABLE 1.1 COMPATIBILITY AND COMPATIBILITY

"Degree" Modifiers	Usual Meaning
Completely compatible	Will run almost every program which will run on an IBM-PC. Almost all system boards designed for the IBM-PC will be plug-compatible. Most of the hardware will be the same or equivalent to the IBM-PC with the possible exception of the ROM, which is copyrighted by IBM.
Very compatible	Will run 2/3 to 3/4 of the programs that run on an IBM-PC but the system boards may not work. These machines typically use the 8088 or 8086 chip but have either a significant cost advantage or offer advanced features not available on the IBM. Display characteristics may be similar but time differences are often encountered.
Reasonably compatible	Defined by one writer to indicate that the machine in question will run all of the top ten business software best sellers.
Marginally compatible	Will run a smaller fraction (less than 2/3) of the programs written for the IBM-PC. Few of the system boards will work.
"Functional" Modifiers	
Hardware compatible	Accessory cards built for the IBM-PC can be installed (bus- compatibility).
DOS compatible	The "compatible" machine uses MS-DOS rather than PC-DOS. In most instances, the data disks produced on one machine can run on the other. Complex program packages cannot be swapped. Unless "homegrown" programs are the issue, this may not be a problem since software licenses often require that separate copies of the package be purchased for each machine in any event.
Software compatible	Will run at least half of the programs that run on the IBM-PC.
Disk compatible	Can read data disks but not programs.

the time this report is published, yet more terms will have been coined. The relevant point is to know what kinds of "compatibility" your users need and to make sure that they get it.

The reasons for incompatibility arise mainly from the ROMBIOS (read-only memory, basic input-output system), interfaces, and timing. The IBM-PC ROMBIOS is copyrighted and complete emulation of the BIOS has been difficult to achieve, although there are some recent claims of success. Recently IBM has been reported as advising software vendors to avoid calls to the BIOS. This implies an intent to change it. Timing and interfaces are hardware design choices which were deliberately selected differently from the IBM choices in order to improve the performance of the "compatible" over the IBM-PC or to reduce the cost. The tradeoff, of course, is loss of complete compatibility.

Another aspect of compatibility is "future compatibility". IBM has, in effect, promised that new machines will be "upward compatible"; that is, programs, data, and text produced on an IBM-PC will be usable on newer IBM models. For the "compatibles", this represents another hurdle. It is an important consideration to large users of PC's who must be concerned with configuration management.

4.2 NETWORKS AND ARCHITECTURE

The new technologies have given us the ability to compose large systems out of multiple hardware components linked with many-kilobyte-per-second communications and distributed operating system software. The "backbone" of these systems is composed of the physical networks, their architectures, and their operating systems. Included in the "backbone" are the distribution mechanism of the network (e.g., media such as "twisted pair" or coaxial cable), the set of rules, or "protocols" that govern the exchange of messages, the operating system software that makes the whole thing run, and the "link" technology (usually software) that ties remote systems to the mainframe databases.

Key to understanding the importance of this "backbone" to future use of the networks is the realization that (1) "backbone" components are the targets of standardization efforts, (2) "backbone" modules such as the internet protocols determine how much diversity the system will allow, and (3) the "backbone" determines the reliability of end-to-end message transfer.

As aspects of the networks become standardized, those aspects become "relatively" stable -- "relatively" because changes will continue to occur; these changes are likely to be evolutionary rather than explosive. However, the individual components of the system will continue to experience explosive innovation and their technology cycles (discussed below) will become increasingly shorter.

As in the case of end-user computing, the increasing use of networks has implications for both the data processing managers and functional managers. Among them are:

- o Data processing managers must distinguish between the "backbone" of the system and its individual components

  - In developing a system, it is essential to choose the "backbone" carefully: mistakes will be costly and will limit future uses of the system.

  - It is important to examine individual components for their potential impact on network selection and upgrade -- expensive components could result in the implicit selection of a "backbone" with consequences well beyond the immediate decision.

  - _If_ the organization makes the right decision concerning the network "backbone", it may be possible to go through multiple replacements of nearly all the individual hardware components while preserving the basic architecture of the system and still taking advantage of technological improvements. (In the appendix to this section of the technology forecast, we will include some samples of GSA contract clauses which can be useful in implementing this strategy).

- o System design should have the following characteristics: [11]

  -- Compatibility with
    - existing agency communications systems
    - agency databases
    - agency office systems

  -- Open architecture
    - avoid being locked to a single vendor, manufacturer-specific standards, or a single line of peripherals

  -- Provisions for growth
    - horizontally, by adding additional devices in a modular fashion
    - vertically, by increasing functionality as new office systems become available

- o Managers must realize that their end-user "computniks" will develop ad hoc networks which may extend beyond their own organization. To the non-data processing professional, "networking" is the term used for extensive interaction, for the purpose of information exchange, among people -- wherever they are -- with the same professional interests. It is inevitable that these non-electronic networks will discover and utilize the telecommunications networks. This development will have drastic implications for institutional databases.

4.2.1 Local Area Networks

Local Area Networks allow the integration of systems which are physically located in a small area, i.e. a single building or campus. As such, they may support a large number of users and applications (e.g., the Main Commerce Building) or a small office (e.g., ICST's Information Processing Group). Typically, there will be a requirement for several integrated LAN's of varying sizes. The different sizes usually bespeak different requirements, and while the complete system will almost certainly be designed incrementally, each increment should allow for the requirements of future integration [12].

At the individual office level, the LAN should permit peripheral sharing and multitasking. When more stations and applications are involved, the LAN should support both peripheral and information sharing (two or more people use the same files on the hard disk), permit multitasking, have security controls, and have an organization capability. When more than six computers are involved, multitasking becomes awkward and communications capabilities should be present as well as gateways to wide area networks (WANs). In the larger systems, integration becomes a very important factor -- the LAN must be compatible with existing systems. The system design must consider integration with various terminal and PABX networks, security systems, and other LANs.

At all levels, a LAN should: [13]

- o support any microcomputer already in place
- o be expandable and reconfigurable without incurring downtime and major expense
- o <u>not</u> come to a dead stop because of a single failure

All LANs normally include:

- o A distribution medium
  - -- Coax
    - - Broadband: Multiple channels supported on same cable; most economical if installation requires video, voice, and data channels; cost is high per linear foot, low per channel-foot in multichannel installation
    - - Baseband: Single signal; easier to install than broadband; requires little maintenance

-- Twisted pair: Single channel supporting relatively slow data rates, shorter distances; sensitive to interference; cheap; adequate for most small LANs

-- Fiber optics: Data LANs currently support only single channel (greater capabilities coming soon); impervious to interference; emits no interfering signals; enormous bandwidth; nearly impossible for intruder to tap; difficult to tap for authorized modifications; limits possible topologies; expensive

- A switching mechanism

- A network management capability

- Gateways to other networks

- Interfaces to allow host processors, personal computers, terminals, workstations, voice switching systems, and shared peripherals to connect to the network

There are three basic topologies normally employed for LAN distribution: bus, star, and ring. Their characteristics, advantages, and disadvantages are shown in table 1.2. As LANs have become easier to use and install, retailers (as distinct from manufacturers' representatives) have become an important source. LAN documentation is therefore an important consideration. Most LANs offer a wide choice of configuration and user options. The documentation should explain the ramifications of the various options.

4.2.2 Micro-to-Mainframe Links

Particular attention should be given to the "link" technology -- the micro-to-mainframe connection. It is this software that allows data to be passed from the mainframe database to the micro (downloading) and permits the micro user to alter the mainframe database (uploading). Commercial developers of communications software for mainframes recognize, and are beginning to produce, "generic" micro-to-mainframe links. (An indication of the size of that potential market is the fact that 86 percent of the Fortune 1000 companies plan to provide end-user access to the institution's mainframe).

Contrary to some expectations, this technology is not likely to come from vendors specializing in micro software. It is part of the mainframe software and its selection is part of the responsibility of the operations manager [14].

One obvious difference between a mainframe and a micro is that the mainframe's storage and retrieval capacities are bigger and faster. There is no feasible way that the entire memory of a mainframe can be downloaded to a 256K micro nor is there any compelling reason to want to do so. The institution needs all

TABLE 1.2 LOCAL AREA NETWORK TOPOLOGIES

Type	Characteristics	Advantages	Disadvantages
Bus	Nodes connected to same transmission medium All stations hear all messages Usually baseband or broadband coax Speeds to 50 mbps Medium priced -- between ring and star Single or dual-cable with "head-end" remodulator	Reliable -- failure of one device will no affect the rest of the network Easy to expand -- devices can be tapped into the cable	Variable delay -- throughput decreases as usage increases. Best with low volume, bursty traffic
Ring	Continuous loop with cable lines connecting each pair of devices All stations hear all messages Speeds to 10 mbps Usually twisted pair or baseband coax	Predictable fixed delay directly affected by the number of nodules/devices Cost per station lower than other topologies	Lower reliability -- if one station fails, whole network may go out Expansion may require changes to communication Recovery may be difficult
Star	Central node with other stations linked via point-to-point connection Messages sent to specific locations Used by PABX and hierarchical computer systems Usually twisted pair or coax	Network dependent on central node -- not affected by device failures Cable may be in place Low incremental costs for additions	Expansion requires cable to central node High initial cost if new cable is required May experience blocking or contention delays

Source: AT&T Information Systems

of the records. The end-user, however, only needs a small percentage of them at any given time. It is therefore essential that the link technology permits end-users to select that portion of the database immediately required.

In addition, the end-user should be able to get the needed information through simple queries -- a capability that requires sophisticated mainframe software.

Table 1.3 provides a download/upload checklist for the selection of link technologies.

With all of the moving to-and-fro of data, system security is an obvious concern. Table 1.4 provides a security checklist.

The acquisition of appropriate link technology is very nearly an art form. Currently, there is no product standard, no consistency in packaging, and no norm for pricing. Mainframe software prices range from $1,000 to $80,000; the micro portion ranges from $2,000 to $8,000. Additionally, there are usually minimum costs. That is, you will be charged for a specified minimum number of micro links whether or not you use them. These "minimums" are among the "hidden" costs that can seriously affect the price of entry. Some other hidden costs are:

- o The boards -- are they included in the price?
- o Productivity software (e.g., spreadsheets)
  - Are they included in the price?
  - If you already have it, do you have to buy it again?

[STAFF COMMENT 3]

4.3 SOFTWARE INVESTMENTS

The investment in existing software is a powerful counterforce to the acquisition of new technology. The costs of converting the software from one system to another can be prohibitive. However, studies of the cost of conversion often omit the offsetting costs of maintaining the old software -- costs which may be significantly lowered when converting to a new system for which tested software packages are available.

To get an idea of the costs associated with software maintenance, consider the GAO finding that 70 percent of total software costs are related to maintenance. In 1980, total software costs were estimated to be $2 billion; there are projected to be $8.1 billion in 1985 and $23.4 billion in 1990. Those numbers argue that conversion -- particularly conversion to tested software packages -- may be less costly than commonly estimated. Maintenance costs should be reviewed during the annual budget process to determine when maintenance of an obsolete application system has crossed the cost threshold which justifies redesign.

TABLE 1.3 Selection of Link Technology

Download

Does the link technology allow record selectivity?
Can individual fields within records be extracted?
Can the user access production databases?
Is the selection process real time?
Can the user specify selection criteria at the micro -- or does the data processing shop do it at the mainframe?
Can the user summarize amount fields?
Can summarizations be used as criteria for the final selection process?
Can the user select data from multiple databases?
Must the data accessed be single-vendor?
Is the data presented in micro format, with extraneous characters removed?

Upload: Updating Mainframe Databases

Does the software have an upload capability?
Can the user upload micro-generated transactions?
Can the user manipulate and summarize data before the upload?
Can the user upload without re-formatting?
Can the user update production databases in real time?

TABLE 1.4 Link Technology Security

Is the system secure at the:

- -- database level?
- -- terminal or PC level?
- -- user ID level?
- -- password level?
- -- record level?
- -- field level?
- -- partial field level?

Can each PC be secured by:

- -- location?
- -- time of day?
- -- days of the week?
- -- period of time?

Is there a security log?*

* A set of records displaying attempts to violate security: includes database, functions, personnel and terminal ID's, date, and time.

Software investments may be divided into two categories: existing application systems and proposed systems. These will be discussed separately.

4.3.1 *Existing Software Application Systems*

The strategies for existing software may also be divided into two categories: "stranded" software, which operates in a dead-end hardware architecture with no available compatible upgrade and that which has "upgradable" software. Both types will face obsolescence of the application system software design, but the solution begins at different departure points.

Stranded software. The issue in moving stranded software to a new hardware architecture is whether the conversion should be accomplished in one step or two. The software will have to be rewritten in either event. The question is whether the rewrite will be a "literal translation" to the new architecture, with later, evolutionary redesign of the system or whether the redesign and conversion will be done in one big lump. In the first case, the converted system will have added capacities which will gradually be turned into real capabilities. In the second case, the capabilities will be realized immediately.

The two-step approach is favored -- in part because it permits elements of redesign to be tested individually and phased in as they are proven and partly because of the trauma involved when users are presented with a totally new system. Retraining, in that case, is a major, costly consideration.

The Air Force, with its Phase IV base level logistics systems and the FAA with its flight control system have both opted for the two-step approach.

Software with compatible upgrades. When a compatible upgrade is available, the software need not be rewritten. However, the evolutionary vs. one-step issue still remains and the argument still favors evolution. GSA and ICST both recommend the evolution of major applications, arguing that first priority should be given to retaining the integrity of current systems. That is, agencies should engineer incremental improvements as stepping stones to reach any desired software application enhancement. The Social Security Administration is following this approach.

4.3.2 *Proposed Software Application Systems*

As implied earlier, the preferred strategy for proposed software application systems is to use existing Government or commercial software application packages that meet the requirements with little or no modifications. Indeed, this is more than a "preferred" strategy: OMB Bulletin 83-18 requires that a search for such packages be made when independent administrative applications costing more than $2.5 million are being considered. However, such a search should be made even when that threshold has not been reached. Time-tested packages are worthwhile for all but the most trivial applications.

There are commercial application packages for almost every conceivable purpose, from inventory control to hardware performance analysis. The International Data Corporation (IDC) estimates that there are about 300 commercial packages for payroll/personnel alone. Table 1.5, developed by IDC provides a list of sources of information for locating packaged software.

It should be emphasized that upward- compatibility is as important vis a vis proposed software applications as it is in the case of hardware. This is equally true for large computers and personal computers. In all cases, it is prudent to investigate the upgrade plans of competing vendors.

4.4 DECREASING TECHNOLOGY CYCLES

During the 1990's, at a time when it seems that the project development cycle is lengthening, the technology change cycle is decreasing -- to the point that the rate of change has resulted in a 2 to 3 year replacement cycle. To protect against the very real possibility of "instant obsolescence", the organization should:

- o Select a system "backbone" before deciding on individual components,
- o Insert contract provisions that allow for multiple replacements, and
- o Engage in continuing technology and market forecasting activities.

Appendix B to this Part contains three clauses from GSA's Model RFP which provide planning flexibility over the system's life.

TABLE 1.5

SOURCES OF INFORMATION FOR LOCATING PACKAGED SOFTWARE

<u>Directories for Software</u>

DataPro Applications Directories
DataSources
Data Decisions
I.C.P. Software directories (International Computer Program Company)
ADAPSO Membership Directory (Association of Data Processing Service Organizations)
Auerbach Applications Software Reports
Minicomputer Software Quarterly
RSI Catalog of Minicomputer Software

<u>Hardware Manufacturers</u>

Product literature
Software vendor lists
User group libraries
National Association of Office Products

<u>National Accounting Firms</u>

<u>Publications</u> (Advertisements therein)

Professional accounting journals
Data processing journals
Trade journals (User's industry)

<u>Government Supported Agencies</u>

University of Georgia
Federal Software Exchange
National Association of State Information Systems

<u>Other Users</u>

Encyclopedia of Associations (User's industry)
DataPro Directory of User Groups and Trade/Professional Associations

<u>Search Publications/Services</u>

Computer hotline user groups
Sofsearch

FOOTNOTES

1. Nolan, Richard L. "Managing Information Systems by Committee", *Harvard Business Review*, JulyAugust 1982, pp. 7279.

2. *Ibid*

3. Wood, Charles Cresson. *Information Resource Management*, SRI International, Report 672, November 1982, p.l.

4. *Ibid*, p.4

5. See Fiorello, M., Eirich, P. L. and Kay, P. *Toward an Improved FIPS Cost-Benefit Methodology, Phase 1: Descriptive Models Data Processing Operations*, NBS Special Publication 500-10, National Bureau of Standards, January 1983 and Nay, J. and Kay, P. *Government Oversight and Evaluability Assessment*, Lexington Books, D.C. Heath and Company, Lexington, MA, 1982.

6. *op. cit.*, Nay, J. and Kay, P., footnote 5.

7. Stanford Research Institute. *Handbook of Forecasting Techniques*, 3 volumes, U.S. Army Engineer Institute for Water Resources, 1975 and 1977.

8. *op. cit.*, Fiorello, M., Eirich, P.L., and Kay, P., footnote 5 and Fiorello, M., Chipman, M. L, Kay, P., and Powell, P. *Toward an Improved FIPS Cost-Benefit Methodology, Phase 2: Descriptive Models General Purpose Applications Software Development and Maintenance*, NBS Special Publication 500-16, National Bureau of Standards, June 1984.

9. Macneice, Louis. *Bagpipe Music*, 1937.

10. Kay, P. and Powell, P., eds. *Future Information Processing Technology 1983*, NBS Special Publication 500103, National Bureau of Standards, August 1983.

11. AT&T Information Services, Communications Management Institute, 1984.

12. Durr, Michael. "Negotiating the Network Maze," *Micro Communications*, June 1984, pp. 32-36.

13. *Op. cit.*, footnote 11.

14. This discussion of "link" technology is based on material contained in a talk given by Frank Dodge, President, McCormack & Dodge Corporation, to the IDC Executive Conference, Phoenix, Arizona, May 5, 1984.

STAFF COMMENTS

2.3.1.1

STAFF COMMENT 1

The high return on investment in the area of training in the use of end user computing tools is quite often overlooked.

Computer literacy has now become essential for most knowledge workers. The training task is monumental. If the dp organization is to be responsible for providing the training, it must be provided adequate resources.

2.4.1

STAFF COMMENT 2

Two clear recommendations follow from the "corollaries" cited:

1. Policies need to be developed which clearly define the responsibilities (and associated authorities) regarding the acquisition and management of hardware and software, and

2. Interdisciplinary skills should be cultivated -- functional managers need to know more about data processing so that they can apply the appropriate controls internationally; data processing professionals need to know more about the end users' business to fully understand their needs and provide the appropriate support.

2.4.2.2

STAFF COMMENT 3

There are a number of difficult problems that stem from implementing the LAN technology. Those problems include:

1. Lack of standardization yet in the marketplace

2. Increasing complexity of the application, making end user compilers less accessible to non-computer professionals

3. The necessity for technical support from traditional ADP shops which put a low priority on the microcomputer technology and which have not yet gained technical expertise

4. The necessity for the traditional mainframe shops to do conversions of mainframe databases before the data can be accessible to the microcomputer end user

5. The cost implications of using microcomputers to access mainframe databases -- if it is primarily a computer terminal application, terminals are cheaper than microcomputers

CLAUSES FROM GSA'S MODEL RFP

GSA'S Policy and Regulation Division maintains three nonregulatory guidance documents for the acquisition of ADP equipment systems by agencies. The three documents are:

- o General Instructions to Offerors Governing Proposal Preparation;
- o Guidance to Federal Agencies on the Preparation of Specification, Selection, and Acquisition of Automatic Data Processing Equipment Systems; and
- o Solicitation Document for ADP Equipment Systems (the Model RFP).

These GSA procurement documents have been developed jointly with industry; therefore, they represent acceptable Brooks' Act policy and industry considerations.

Outlined below are clauses from the Model RFP (Revised through change) which provide planning flexibility over the system's life.

SECTION H - SPECIAL CONTRACT REQUIREMENTS

H.1. FIRMR 201-4.1110-1 WARRANTY EXCLUSION AND LIMITATION OF DAMAGES

Except as expressly set forth in writing in this agreement, or except as provided in the clause entitled, "Commitments, Warranties and Representations," if applicable, and except for the implied warranty of merchantability, there are no warranties expressed or implied. In no event will the Contractor be liable to the Government for consequential damages as defined in the Uniform Commercial Code, Section 2-715, in effect in the District of Columbia as of January 1, 1973; i.e.,

Consequential damages resulting from the seller's breach include:

(a) Any loss resulting from general or particular requirements and needs of which the seller at the time of contracting had reason to know and which could not reasonably be prevented by cover or otherwise; and

(b) Injury to person or property proximately resulting from any breach of warranty.

H.2 REPLACEMENT PARTS AVAILABILITY

The Contractor guarantees that replacement parts for each machine in this contract will be available for the systems (items) life stated in I.2. The Contractor shall notify the Government 180 days before the end of the systems (items) life as to the continuing availability of parts subsequent to this period. If parts will not be available from the Contractor, then the Government may require the Contractor to furnish data that is available to assist the Government to obtain such parts from another source.

H.3 ENGINEERING CHANGES

(a) After contract award, the Government may solicit, and the Contractor is encouraged to propose independently, engineering changes to the equipment, software specifications, or other requirements of this contract. These changes may be proposed to save money, to improve performance, to save energy, or to satisfy increased data processing requirements. However, if proposed changes relating to improved performance are necessary to meet increased data processing requirements of the user, those requirements shall not exceed the contract requirements by more than 25 percent. If the proposed changes are acceptable to both parties, the Contractor shall submit a price change proposal to the Government for evaluation. Those proposed engineering changes that are acceptable to the Government will be processed as modifications to the contract.

(b) This H.3. applies only to those proposed changes identified by the Contractor, as a proposal submitted pursuant to the provisions of this clause. As a minimum, the following information shall be submitted by the Contractor with each proposal:

1. A description of the difference between the existing contract requirement and the proposed change, and the comparative advantages and disadvantages of each;

2. Itemized requirements of the contract which must be changed if the proposal is adopted, and the proposed revision to the contract for each such change;

3. An estimate of the changes in performance and cost, if any, that will result from adoption of the proposal;

4. An evaluation of the effects the proposed change would have on collateral costs to the Government, such as Government-furnished property costs, costs of related items, and costs of maintenance and operation; and

5. A statement of the time by which the change order adopting the proposal must be issued so as to obtain the maximum benefits of the changes during the remainder of this contract. Also, any effect

on the contract completion time or delivery schedule shall be identified.

(c) Engineering change proposals submitted to the Contracting Officer shall be processed expeditiously. The Government shall not be liable for proposal preparation costs or any delay in acting upon any proposal submitted pursuant to this clause. The Contractor has the right to withdraw, in whole or in part, any engineering change proposal not accepted by the Government within the period specified in the engineering change proposal. The decision of the Contracting Officer as to the acceptance of any such proposal under this contract shall be final and shall not be subject to the "Disputes" clause of this contract.

(d) The Contracting Officer may accept any engineering change proposal submitted pursuant to this clause by giving the Contractor written notice thereof. This written notice may be given by issuance of a modification to this contract. Unless and until a modification is executed to incorporate an engineering change proposal under this contract, the Contractor shall remain obligated to perform in accordance with the terms of the existing contract.

(e) If an engineering change proposal submitted pursuant to this clause is accepted and applied to this contract, an equitable adjustment in the contract price and in any other affected provisions of this contract shall be made in accordance with this clause and other applicable clauses of this contract. When the cost of performance of this contract is increased or decreased as a result of the change, the equitable adjustment increasing or decreasing the contract price shall be in accordance with the "Changes" clause rather than under this clause, but the resulting contract modification shall state that it is made pursuant to this clause.

(f) The Contractor is requested to identify specifically any information contained in the engineering change proposal which the Contractor considers confidential and/or proprietary and which the Contractor prefers not be disclosed to the public. The identification of information as confidential and/or proprietary is for information purposes only and shall not be binding on the Government to prevent disclosure of such information. Offerors are advised that such information may be subject to release upon request pursuant to the Freedom of Information Act. (5 U.S.C. 552).

If the Government is liable for loss or damage of a machine, the Contractor shall have the option to restore the machine to its previous condition, in which event the Government shall pay the Contractor to perform such restoration at the Contractor's then-current prices, terms, and conditions. If the Contractor elects not to restore the machine, the Government may, at its own expense, restore the machine to its previous condition. If, however, the machine is lost or damaged beyond repair, the Government shall pay the Contractor the same price for the machine as the Government would have paid if it had purchased the machine on the day prior to the loss or damage under the provisions of this contract. This clause shall govern risk of loss or damage, notwithstanding any other provisions of this contract relating to title, payment, or ownership.

I.2 TERM OF CONTRACT

Although the Government contemplates use of the system(s) (Hardware and Software) for the sytems life of ____ months from date of award, the term of this contract is from date of award through September 30, 19__.

I.3 CONTRACT OPTIONS TO EXTEND OR INCREASE QUANTITY

I.3.1 Option to Extend the Term of Contract

This contract is renewable at the prices stated in Section __ of the contractor's proposal, at the option of the Government, by the Contracting Officer giving written notice of renewal to the Contractor by the first day of each fiscal year of the Government or within 30 days after funds for that fiscal year become available, whichever date is the later; provided that the Contracting Officer shall have given preliminary notice of the Government's intention to renew at least ____ days (30 days unless a longer period specified) before this contract is to expire. Such a preliminary notice of intent to renew shall not be deemed to commit the Government to renewals. If the Government exercises this option for renewal, the contract as renewed shall be deemed to include this option provision. However, the total duration of this contract, including the exercise of any options under this clause, shall not exceed ____ months.

I.3.2 Option for Increased Quantity

The Government may increase the items called for herein by the quantities stated elsewhere in this contract and at the unit prices specified in Section __ of the contractor's proposal. The Contracting Officer may exercise this option at any time within the period specified in the contract by giving written notice to the Contractor. Delivery of items added by exercise of this option shall be in accordance with the delivery schedule set forth in Section __.

I.3.3 Option for Acquisition of Evaluated Optional Features Not Procured at Time of Award of Contract

The Government may exercise the option to acquire the evaluated optional features stated in the contract at unit prices specified therein. The Contracting Officer may exercise this option by giving written notice to the Contractor at any time prior to the expiration dates set forth in Section __ of the Contractor's proposal. Delivery of the evaluated optional features added by exercise of the option shall be in accordance with the delivery schedule set forth in Section __.

PART V: TECHNOLOGY FORECAST WORKSHOP SUMMARY

PREFACE

In September of this year, a group of experts from ADP/telecommunications supplying and using companies met at ICST to review and comment on two Parts of this document, i.e., the telecommunications technology forecast (Part 1) and the "management implications" material (Part IV). To that end, the group split into two workshops. This Part summarizes the results.

Chapter 1 contains the summary of the technology workshop. The major portion of the summary was prepared by the workshop leader, Robert Conley, Acting Assistant Secretary for Electrical Systems and Information Technology, Department of the Treasury. We have augmented his summary slightly in order to reflect the discussion which took place at the plenary session following the workshops.

The results of the "management implications" workshop, summarized by Mark Samblanet of Aurora Associates and Peg Kay of ICST, are contained in Chapter 2. Regrettably, there was not enough time to address all aspects of the management implications document. The summary is keyed to the sections of Part IV which were addressed.

As noted in the preface to Part 1 of this document, the industry participants felt that they should be involved earlier in the formulation of subsequent forecasts. It is a generous and appreciated offer. We look forward to an early and continuing relationship.

1. PARTICIPANTS

The following people participated in the conference:

Mr. Don Brown
E.I. Dupont DeNemours Company, Inc.

Mr. Doyne Carson
Micro Industries

Mr. Robert Decker
SOHIO

Mr. Plato Demos
Union Carbide Corporation

Mr. Jerry Fogel
Grumman Data Systems

Mr. Armin Gumerman
Northwestern Mutual Life Insurance Co.

Mr. Harry Klancer
Bell Communications Research

Mr. Edward Matthews
Northern Telecom, Inc.

Mr. Robert Medvedeff
POSP, Inc.

Mr. Paul Milbury
Northwest Pipeline

Mr. John North
AT&T Technologies

Ms. Shirley Prutch
Martin-Marietta Data Systems

Mr. Richard Hill
Honeywell

Mr. Harold Jones
Tenneco, Inc.

Mr. Patrick Jordan
GTE Data Service

Mr. Marvin Rahm
Dow Chemical

Mr. Russell Robb
Atlantic Richfield Company

Mr. LeRoy Rodgers
Digital Equipment Corporation

Mr. Thomas Vande Hei
Honeywell

Mr. Robert Atkins
Institute for Computer Sciences and Technology

Mr. Ross Bainbridge
Institute for Computer Sciences and Technology

Mr. James Burrows
Institute for Computer Sciences and Technology

Dr. Robert Conley
Department of the Treasury

Ms. Carol Edgar
Institute for Computer Sciences and Technology

Ms. Peg Kay
Institute for Computer Sciences and Technology

Mr. Ted Manakas
Institute for Computer Sciences and Technology

Ms. Patricia Powell
Institute for Computer Sciences and Technology

Mr. Mark Samblanet
Aurora Associates

Dr. Stanley Winkler
Institute for Computer Sciences and Technology

Mr. Frederic Withington
Arthur D. Little, Inc.

2. SUMMARY OF THE WORKSHOP ON THE TELECOMMUNICATIONS TECHNOLOGY FORECAST

The consensus of the group is that the forecast is a good summary of the technology today. However, its treatment was considered too elementary given the complexity of the subject and the external influences which are already evident.

Phrased another way, the technology cannot be linearly extrapolated to the future given influences of user involvement and systems applications which do not allow telecommunications to be addressed in isolation. Further, the treatment does not prioritize the importance of the various technologies and is useful to only a limited and technically sophisticated audience. [Ed. note: Part I of this document is indeed addressed to such an audience].

The working group concluded that the next decade was one of conflict. That is:

- o standards versus technology change

  - The development of these standards will necessarily have user involvement and user benefits: technologists cannot develop them in isolation.

- o security of information versus access to information

  - With trends of rapid asset transfer/control and increased user acceptance of technology and therefore more influence by users. We will have to develop mechanisms to reduce the conflicts. There will certainly be compromises as we go along.

The three major areas driving technology advancement as seen by the working group are:

- o continued development of a digital communications plant

  - The technologies to support the plant will grow.

  - Transparent to the user, it will become more inexpensive and more integrated into our day-to-day operations.

- o expanded applications of the Private Automated Branch Exchange (PABX) switch (perhaps being the workhorse of the local area networks)

  - Perhaps as much as 90 percent of our current telecommunication is voice: we now have the technology to add data.

  - This is the most economic way to go over the next generation as, for example, we integrate our buildings.

- o developments in digital mobile communications

  - Important in industries such as trucking and crisis control, the mobile communications systems will dovetail with the digital plant.

As a consequence of these factors, the technology of devices supporting digital communications will continue to evolve.

The promise of the great future supported by digital technology can only be achieved if the user becomes an intelligent user and demands standards and greater control than in the past era when the technology drove the user. This will be, in the working group's opinion, the largest non-linear impact on technology development and applications over the next decade.

The group also contributed valuable staff comments which we included in Part I, Future Telecommunication Technology 1984.

3. SUMMARY OF THE WORKSHOP ON THE MANAGEMENT IMPLICATIONS OF THE TRENDS IN INFORMATION TECHNOLOGY

MANAGEMENT STRUCTURE (Section 2.3.1, Part IV)

The workshop participants concluded that organizational structures will flatten in response to the introduction of the new technology at the individual workers' desks. An important result of this organizational evolution will be a shortening of the links between top management and operating level management. There was a consensus, however, that -- contrary to popular wisdom -- middle management will not be the first layer affected by the technology. The "shrinkage" will probably be seen first at the secretarial and clerical levels.

The reason for this will be the model provided by the new high tech companies. The workshop's "small, high tech" representative noted that his company (about 70 people) has no secretaries at all. The professionals do their own typing, keep their own calendars, and so on.

The workshop participants noted that there are many such small companies which are (1) experiencing explosive growth and will soon become big companies, (2) are being acquired by large companies, or (3) have personnel who migrate to large companies. As the small companies get larger, they will sooner or later realize that it is cheaper to use clerical help for many of the clerical-type functions. Professionals are very expensive data entry clerks. However, the greater impact will be on the large companies which will find that they can do without much of the support help they currently have. Ultimately, they will adopt the ethic of the small companies or small company personnel that they acquire.

Eventually, middle management will also shrink, enabling the shorter links between top and operational management referred to above.

The technology will also affect the functions of the planners. We will discover that we can either gather a great deal more information of the same type that we now gather, and analyze it much more drastically than we now do; or we can take the time we are now spending on that function and use it in other ways. Different companies will go in different directions and the directions taken will be evolutionary; initially, they will not be the results of conscious decisions on the part of the companies. Eventually, some "precipitating event" will occur (a recession, a new CEO, etc.) and the de facto decision will be analyzed and either accepted, rejected, or (more likely) amended somewhat.

Again, contrary to conventional wisdom, the distribution of resources will not cause more information to flow up in the organization. The major effect will be that the technology will help to better the information at the operating level where it is needed. By and large, top management planning is done on the basis of external rather than internal information. That will continue.

The workshop participants rejected the suggestion that there will be a lot of people who will be able to tinker with the "core" data. That will not happen unless and until that information can be monitored and controlled. The information systems shops (wherever they are located within the company) will change from being data processing shops to ones which are responsible for policy, for rules and regulations, and for the handling of utilities such as the telephone.

PLANNING (Section 2.3.2, Section IV)

The participants agreed that there will be a lot more people involved in planning. We will see a central information systems shop (like the one described above) but much of the data will be processed in a sub-unit -- department or division. That will have the effect of returning accountability to the place where it has always belonged. Because of economic considerations, the processing of data (and accountability) migrated to the central processing shop. The new technologies will permit their return.

The problem of interfacing the MIS plan with the business plan will continue to exist. The group -- not altogether facetiously -- surmised that this was because the MIS people never know what the business plan is and suspect that it exists only as a myth.

The most significant impact on planning at the strategic level will not be on how we do our planning but, rather, on what we plan. When we decide, for instance, things like "Are we going into a new business?", the decisions will be greatly affected by the technologies available to help get us into that business. The insurance and banking industries provide prime examples of that impact. The technology has afforded them new market opportunities. [Ed. note: This has obvious parallels for government agencies which are afforded significantly different options for performing their missions].

PERSONNEL (Section 2.3.3, Part IV)

We will find that the technology allows us to do things in a new way. As a consequence, there will be new responsibilities and those responsibilities will be distributed through the organization. That suggests that we will need new skill mixes, which will have to be defined.

Jobs will shift. For example, users are beginning to do the accounting; the accountants are becoming the financial officers. Shifts like that will occur often, with users taking on functions that they hadn't had before and the people responsible for those functions moving to different levels in the organization.

Insofar as retraining is concerned, the participants agreed that the retraining was most needed in the personnel offices. Classification problems have arisen in all of the companies large enough to have hard and fast rules. As jobs or functions get rolled together, the ossified personnel departments have no way of handling the situation -- the technologies are simply moving faster than the classifiers.

As the jobs shift, particularly in the data processing shops, we are faced with some <u>apparent</u> decisions; namely, Fire or Something Else. We can retrain some of the people to perform the new functions (communications, in particular) or we can replace them or we can decide not to change. These decisions are more apparent than real. Replace with whom? Where are the replacements going to come from? "Don't change" is not really an option because the companies that stand still will not be able to survive in a competitive environment.

A mid- to long-term solution to the "replace" dilemma is to pressure the universities to train their students for the jobs available. Right now, the participants find that the schools are not turning out the graduates they need -- the telecommunications experts and managers. Nor are they producing the business analysts (rather than programmers) that the information systems shops are going to require.

While "don't change" is not a feasible option, "change at a slower pace" may be mandated by our inability to replace.

ECONOMIC IMPACTS (Section 2.3.4, Part IV)

The participants did not feel that the acquisition of "gear" was going to have significant economic impact. The personal computers are coming down in price so quickly that nobody is really going to try to control those acquisitions. One of the supplying company participants remarked that they try to keep their prices just below the threshhold where controls begin. [Ed. note: the potential for counter-strategies and counter-counter-strategies is mind boggling].

The acquisition of software will have more impact but even that is not the major concern.

There will be considerable impact at the point of total communications costs -- at the network level. That is where the significant controls will be instituted. One of the participants quoted the dp manager of a large brokerage firm as saying, "Go out and buy your microcomputer. I don't care what you do with it. But the minute you hook it up to <u>my</u> computer, you will follow <u>my</u> instructions, <u>my</u> groundrules, and <u>my</u> overall control."

The most significant economic impact, however, relates to the earlier discussion about what we plan. The greatest impacts will result from other people's business decisions. If somebody decides to use the technology to go into a new business, our businesses are going to have to decide whether to take advantage of their technology. And that is where the largest economic impacts will be felt.

PART VI: FUTURE INFORMATION PROCESSING TECHNOLOGY 1983 REVISITED

1. THE 1983 TECHNOLOGY FORECAST REVISITED

The 1983 forecast was a consortium effort by a number of Federal agencies. It was funded by ICST and the Defence Intelligence Agency (DIA) with assistance and contributions from the Department of Energy, United States Department of Agriculture, United States Environmental Protection Agency.

Part I of the 1983 forecast, prepared by Arthur D. Little, Inc., contains three primary sections with forecasts through 1997. The first addresses the underlying technologies for information processing and includes a discussion of processor modules, logic and storage components, input/output technologies, and software. The second addresses the changes in the information industry and market and discusses the forcing factors, recent acquisitions and joint ventures, and the emerging structure of the information industry which are causing the changes. The third primary section integrates the underlying technologies and industry change into forecasts of the overall nature of future information processing products and systems.

Federal agencies and ICST personnel were asked to review and comment on Part I. Fourteen agencies and technical specialists from ICST responded. The comments were discussed with Frederic T. Withington of Arthur D. Little, Inc. who prepared Part I. Many comments were incorporated into Part I. Others were felt to be beyond the scope of the forecast or there was a difference of opinion on the subject, comments in these two categories are included in Part II.

ICST sponsored a teleconference to have private industry representatives review Part I of the 1983 forecast. The participants were divided into four topic areas: distributed processing, general-purpose computer systems, office systems, and compatibility and transferability of software. Each group gave a summary of their discussions; Part III of the 1983 forecast is a transcript of the summaries.

Part IV, funded by DIA, and prepared by Arthur D. Little, Inc. gives estimates of future system costs through 1997. The cost estimates were derived by applying assumptions to the forecasts in Part I and are, therefore, necessarily uncertain but are useful for long-range system planning.

Part V, prepared by International Data Corporation (IDC), discusses the current and potential rules and regulations in the Federal environment and how they may affect the Federal inventory of ADP equipment.

Part VI, prepared by Aurora Associates, Inc., discusses management aspects of end-user computing with particular emphasis on the mangement of change. It builds on work done at the Environmental Protection Agency.

Ted Withington of A. D. Little, Inc. was contacted to find out if there were any changes to Parts I and IV of the 1983 Technology Forecast. The major directions are still on target, however, there are a few areas which have not progressed as expected. The cryogenic (Josephson Junction) technology which was forecast to have considerable but distant promise (section 2.2.3.2, p. 43) is still being pursued by some but, since IBM stopped work in this area, the outlook is not optimistic. Magnetic bubble technology (section 2.2.3.3, p. 44) falls in the same category in that expectations have not been met.

Figures 2.10 (p. 41) and 2.11 (p. 42) and table 2.1 (p. 51) show costs of semi-conductor memory. Since the prices of semi-conductor memory are dropping faster than was thought when the 1983 Forecast was prepared, this needs to be taken into account when referring to this information.

In the 1983 Forecast, the availability of optical storage (section 2.2.4.3, p. 48), in volume, was projected to be available in three to five years. It is now expected later than this time frame.

Affecting the hardware (sections 2.1.2.1, p. 14; 2.1.3.1, p. 17; and 2.1.4.1. p. 20) and the estimates of systems cost (section 1, p. 151, and tables 3.1, p. 155, and 6.1, p. 159) is the current opinion that although the evolution is still toward modular systems, this evolution is slower than believed when the 1983 forecast was prepared.

A summary of information system product forecasts which appeared in the 1983 forecast as figure 5.1 remains valid and is included for reference, as figure 1-1 in this section. The table of contents from the 1983 forecast is also included.

Contributing Technologies	Product Class	Effect of Industry Structure on Product Evolution	Products by Time Period of General Availability		
			1982 - 1987	1987 - 1992	1992 - 1997
• System Architecture • Programming Language Evolution • Modular, Microcoded Operating Systems • Improved Semiconductor Electronics • Gallium Arsenide and Superconductor Logic • Novel Processor Architectures	General-Purpose Computers	• Retarded by requirement for software compatibility	• In transition to modular, bus-oriented architecture • Modules absorb software functions	• Modular architecture mature • Module operating system functions embedded and automatic • Preconfigured application modules	• Proliferation of module types • Integration of bit-stream and encoded data, text, voice and images
	Supercomputers	• Advanced by trend toward specialized subsystem vendors • Retarded by requirement for software compatibility	• Vector and array processors achieve 1,000 MFLOPS speed • MIMD and Data Driven Processors in early delivery	• Vector and array processors achieve 5,000 MFLOPS speed • Software to tailor novel architectures to applications evolves	• Best application-tailored systems achieve 100,000 MFLOPS equivalent (?)
	Other Special-Purpose Computers	• Advanced by trend toward specialized subsystem vendors	• Limited protocol translators • Small array processor subsystems	• Image processors	• Knowledge-based processors (?)
• Opto-electronic Recording • Improved Magnetic Recording • Extract DBMS with Multiple User Views	File Processors	• Advanced by trend toward specialized subsystem vendors • Retarded by requirement for software and data set compatibility	• Extract and multiple-view DBMS • Associative file searchers • Storage hierarchy management systems • Read-only and archival video disk systems	• Multiple-view data base machines for text and data • Video disk-based office file systems	• File processing systems integrating bit-stream and encoded data, text, voice and images
• Easy-To-Use Interactive Software • Graphic and Image Processing Software • High-Resolution Flat Displays	Intelligent Terminals and Desktop Computers	• Advanced by evolution of interface standards • Retarded by vendor need to master multiple industry areas • Retarded by lack of suitable retail distribution structure	• Integration of most terminal, word processor and desktop computer types • Addition of high-resolution color graphics capability and video disk	• Modular multi-function workstations integrated with networks	• Incorporation of knowledge-based techniques to provide "personal assistant" capabilities(?)
• Speech Recognition	Voice Processors	• Retarded by capital investment requirement • Retarded by vendor need to master multiple industry areas	• Digital voice-data PABX's proliferate • Digital voice message systems	• Digitized voice message systems with voice commands • Integration of voice storage with office file systems	• Limited continuous speech recognition systems(?) • Integration into multi-media networks
• Optical Character and Image Recognition • Non-Impact Printing	Automatic Document Processing Systems	• Retarded by vendor need to master multiple industry areas • Advanced by evolution of interface standards	• Non-impact printers with communicating capability • Inexpensive OCR page readers	• Integration with report production and office file systems • Color hard copy imaging	• Integration into multi-media networks
• Fiber Optics	Videoconferencing	• Retarded by capital investment requirement	• Limited growth of intra-company dedicated links • Public centers in major cities	• Switched video lines available in major cities	• High-resolution, multiple-media service on dedicated links • General availability of switched video lines(?)
• Local Area Networks	Networks	• Advanced by combining of information producers and distributors • Advanced by evolution of interface standards • Retarded by capital investment requirement	• Local area nets mature • Electronic mail becomes general • Limited multi-protocol services proliferate	• Evolution of multi-media narrow-band services; dedicated to customer by carrier • Local area nets combine with digital PABX	• Automatic world-wide network management for customer by carrier

Source: Arthur D. Little, Inc.

FIGURE 1-1 SUMMARY OF INFORMATION SYSTEM PRODUCT FORECASTS

TABLE OF CONTENTS

GLOSSARY

Prepared by

Institute for Computer Sciences and Technology
U.S. Department of Agriculture

GLOSSARY

Following publication of the 1983 Technology Forecast, it was suggested that a glossary of terms would be valuable for readers. Being too late for 1983, terms from the 1983 companion forecast and terms in this forecast are included here. The Department of Agriculture provided a starting point; it was expanded by ICST.

The material for most of the following terms was extracted from the following sources:

________, *American National Dictionary for Information Processing*, FIPS 11-2, National Bureau of Standards, 1982.

________, Glossary of Micrographics, TR2-1980, National Micrographics Association, Silver Spring, MD.

Ralston, Anthony, Ed., *Encyclopedia of Computer Science and Engineering*, Von Nostrand Reinbold Co., 1983.

Schmittroth, John, Jr., and Martin Connors, eds., Telecommunications Systems and Services Directory, Gale Research Co., Detroit, MI, 1984.

Sippl, Charles J. and Roger J. Sippl, *Computer Dictionary*, Howard W. Sams and Co., 1982.

Stone, Harold S., *Introduction to Computer Architecture*, Science Research Assoc., Inc., 1975.

acoustic coupler

An acoustic coupler is a modem designed to connect directly to the handset of a voice telephone. It enables digital terminals to communicate with remote devices using the analog lines of the public telephone network. It does this by converting digital signals to analog before transmission, and analog signals to digital upon reception. Acoustic couplers are typically used for relatively low-speed transmission (1200 bps or slower).

analog signal

An analog representation of an information signal is a representation by means of a continuum of physical variables; for example, through translation or rotation, voltage or resistance. Analog signals are represented by continuously oscillating waves, unlike digital signals, which are represented by discrete, discontinuous coded signals.

array processor

An array processor consists of many separate processing elements, each capable of carrying out basic arithmetic calculations under the control of a master program, parallel.

associative processor

An associative processor a type of parallel processor with an associative (content addressable) memory. See parallel processor.

asynchronous processor

An asynchronous starts each operation as a result of a signal that the previous operation has been completed or that parts of the computer required for the next operation are now available. Contrast with synchronous computer.

asynchronous transmission

Asynchronous transmission refers to the transmission of data character by character, with no fixed interval between characters. The transmitting terminal supplies a "start" bit preceding each character and a "stop" bit following each character. Sometimes called start/stop transmission, asynchronous transmission is generally slower and less efficient than synchronous transmission.

audio frequencies

Audio frequencies are message transmission frequencies which can be heard by the human ear, generally between 15Hz and 20,000Hz.

automatic data processing (ADP)

ADP is the branch of science and technology concerned with methods and techniques relating to data processing largely performed by automatic means.

bandwidth

Bandwidth is the difference between the highest and lower frequencies of a telecommunications carrier. It describes the information-carrying capability of a channel or line.

baseband network

A baseband network link carries a single data stream over the linkage medium, though the single stream may represent multiple messages through the use of time-division multiplexing (TDM). A baseband network typically has a bandwidth of 10-100 megahertz (mHz).

baud

Baud is a measure of transmission speed in telecommunications, equal to the number of signal changes per second. When a signal change represents one bit, the baud rate's equivalent to bps (bits per second). However, since a signal change can in some modems represent groups of more than one bit, baud and bps are not always identical.

bit slicing

Bit slicing is a technique which interconnects identical components to construct an arithmetic logic unit (ALU), e.g. two 4-bit chips interconnected form an 8-bit ALU.

bit stream

A bit stream is a stream of bits, continuously transmitted at a constant rate, for which separation into the characters represented is done in the terminal devices.

bps (bits per second)

Bps (bits per second) is a measurement of data transmission speed. It is equivalent to baud when one bit is depicted by one signal change. When bps is measured by the thousand, the abbreviation kbps is often used; when it is measured by the million, the abbreviation mbps is used; and when it is measured by the billion, gbps is used. A transmission rate of two million bits per second can thus be variously transcribed as 2,000,000 bps; 2,000 kbps; 2 mbps; and .002 gbps.

broadband network

A broadband network link permits the transmission of multiple simultaneous signals over a single medium through the use of frequency-division multiplexing (FDM). Broadband network techniques take advantage of the large bandwidth of such media as fiber optics and community antenna television (CATV) links. A broadband link might simultaneously carry voice, data, and video signals. Broadband transmission is contrasted with baseband transmission.

bus

A bus is a path over which information is transferred from any of several sources to any of several destinations. A bus family is a group of signals considered together, e.g. an address bus consists of all the signals needed to define any of the possible memory or I/O locations in the system.

bus network

A bus is a network topology in which all nodes are linked through the same length of cable, with two open ends. The protocol requires that, while each node broadcasts to the entire network, individual nodes recognize their own address code and intercept only those messages so addressed.

C-band

The C-band comprises the frequency bands in the 4 to 6 gigahertz (GHz) range that are used by most communications satellites to receive and transmit signals.

Carterfone Decision

In 1968, the United States Supreme Court ruled in favor of the Carterfone Company, whose founder, Thomas Carter, had brought suit against the public telephone companies. Carterfone sought to be allowed to provide direct connection of their acoustically coupled telephone instruments to the public telephone network--without the interface of the data access arrangement (DAA) device then required by the telephone companies. The Carterfone Decision is generally considered to mark the birth of the interconnect industry.

CCITT facsimile classifications

The CCITT (International Telegraph and Telephone Consultative Committee), a permanent body of the International Telecommunication Union which deals with telephone, telegraph, and related services, has defined the following four classifications of facsimile transmission devices: 1) Group I devices are analog facsimile devices which operate at six minutes per page using frequency modulation (FM) techniques. CCITT has also provided in Group 1 for a four-minute speed as a manufacturer's option. 2) Group 2 devices are analog facsimile devices which operate at three minutes per page using amplitude modulation (AM). CCITT has also provided in Group II for a two-minute speed as a manufacturer's option. 3) Group III devices are digital facsimile devices which operate at one minute per page utilizing techniques of redundancy reduction, such as rapid skipping of white space. 4) Group IV devices and high-speed (56 kbps or more) digital facsimile devices are designed to use public packet-switched networks.

cellular radio

Cellular radio is an advanced mobile telephone system which provides communications by dividing a metropolitan area into smaller geographic units, or cells, each served by a small transmitter and a controller. Each cell can reuse channels assigned to mobile communications, greatly increasing system capacity and service quality. When a portable telephone user crosses from one cell to another while talking, a central computer in the cellular system automatically reroutes the conversation from one transmitter to another, eliminating interference between callers and allowing each channel to be used several times simultaneously. Traditionally, radiotelephone service in cities has depended on a single large transmitter capable of handling only a few dozen calls at a time. The U.S. Federal Communications Commission has established a phased application process from wireline and nonwireline companies.

central office (CO)
Central office (CO) refers to a common carrier location where customer lines terminate into a switching capability which can connect the local lines to one another or into the long distance network.

central processing unit (CPU)
A CPU consists of the control, arithmetic, and logic unit and the main storage.

Centrex
Centrex is a service which allows business subscribers to directly dial extensions from outside the company and to directly dial outside numbers from the extensions. The switching system is a type of PBX system and is usually located in the telephone company's central office, though it can be located on the customer's premises.

channel
A channel is a route for electrical transmission between two or more points. A channel is not necessarily a wire; it may be a radio carrier or a light wave. A channel may also be called a circuit, line, link, or path.

channel capacity
Channel capacity is the maximum number of bits per second which can be accommodated by a channel at a specified error rate, determined by the bandwidth modulation scheme and certain types of noise.

circuit switching network
A circuit switching network is a communications network in which stations are provided with a direct link (through a system of switches) for the duration of their interchange of information. An example of this is the public voice telephone network. Other types of switching networks include the message switching network and the packet switching network.

class of service

PBX telephone systems may provide a class of service capability that enables each station to have preprogrammed access to all or only some of the system features; e.g., depending on the class of service, the station may be limited in long-distance calling capabilities.

coaxial cable

Coaxial cable is a telecommunications conducting link consisting of a central conductor with a shielding cover, around which is another conducting braid and a protective coating cover. Coaxial cable can provide high bandwidth, permitting high speed, wideband communication capabilities.

CODEC (coder-decoder)

A CODEC (coder-decoder) is a device or circuit which converts (or codes) an analog wave form into digital code and, conversely, decodes the signal back into analog wave form. An example of the usage of CODECs is in the voice telephone receivers of PBX systems that carry and process all traffic in digital form.

common carrier

A common carrier is a company which provides telecommunications facilities to the public. American common carriers are regulated by the Federal Communications Commission (FCC) if interstate and by the state public service or public utility commission (PSC or PUC) if intrastate.

communication

Communication is the process of transferring information from one person, point, or device to another.

Communications Act of 1934

The Communications Act of 1934 established the U.S. Federal Communications Commission (FCC) and gave it responsibility for regulating national and international communications. The Act was adopted by Congress to ensure that U.S. citizens had adequate access to nationwide and worldwide telecommunications services at reasonable rates. Under this authority, the FCC has the authority to require common carriers to establish interconnections with other carriers, provide through routes and charges deemed necessary or in the public interest, and prescribe the allocation of such charges. The FCC was granted power over consolidations and could periodically evaluate common carrier' property. Although the Communications Act of 1934 gave the FCC authority over interstate and foreign communications, it reserved the regulation of intrastate communications and exchange services to the states.

contention

Contention is the condition on a multipoint communication link when two or more terminals seek to transmit simultaneously. An important part of network protocol is the resolution of contention. Some methods of line contention resolution include polling, CSMA/CD, and token passing.

CSMA/CD (carrier sense multiple access with collision detection)

CSMA/CD (carrier sense multiple access with collision detection) is a contention-arbitration protocol used in some data communications networks, including the Xerox Ethernet network. The CSMA/CD protocol consists of two rules for terminals seeking to transmit on a network: 1) if the network channel is in use, defer the start of transmission; 2; if the channel is clear, begin to transmit. If two or more stations begin to transmit at the same time, both or all "back off" and attempt transmission again after different waiting intervals.

customer provided equipment (CPE)

Customer provided equipment (CPE) describes telecommunications equipment purchased or leased by the user from vendors other than the operating telephone companies.

DAA (data access arrangement)

Until the Carterfone Decision by the FCC in 1968, AT&T did not allow the connection of non-Bell equipment to the switched network. From 1969 to 1976, AT&T required that a data access arrangement (DAA) device be acquired from them for placement between the non-Bell equipment and the telephone lines. In 1976, the FCC implemented a certification program allowing telecommunications equipment vendors to build the equivalent of the DAAs into their own equipment. As of June 1, 1977, all new devices, including those from Bell, are required to be registered with the FCC, so that the need for DAAs has been eliminated.

database

A database is a collection of data fundamental to a system or enterprise.

data link control (DLC)

A data link control (DLC), also called a line discipline, is a protocol or set of rules governing the orderly transfer of information on a data network. Functions of a DLC include: establishing and terminating a connection between two stations; error detection and connection routines, including retransmission when necessary; and providing control functions such as status requests.

decision support system (DSS)

Applications in a MIS that directly support the making of specific decisions is called a DSS . See management information system (MIS).

demodulation

Demodulation is the reconversion of received analog sine waves of various frequencies, which can be transmitted over analog communications lines, back into their original digital form.

digital service unit (DSU)

A digital service unit (DSU) is a signal converting device, analogous to but different from a modem. The DSU is used to interface data communications devices to fully digital lines. The DSU does digital code translation and/or supplies communications coding to meet the needs of the digital network at both the sending and receiving devices. Unlike modem devices, the DSU encoding and decoding is completely in digital form for transmission over fully digital lines.

digital signal

A digital signal is the representation and transmission of information coded as discrete discontinuous bits.

digital termination service (DTS)

Digital termination service (DTS) basically consists of a centrally located, omnidirectional microwave transceiver that communicates with remote user stations via shared 1.5 mbps full-duplex channels. DTS systems will basically be used as local loop bypass facilities.

direct broadcast satellite (DBS)

Direct broadcast satellite (DBS) is a satellite stationed in geosynchronous orbit that broadcasts television signals received by small dish antennas atop homes or buildings. Video programming is distributed by the satellite directly to the rooftop antennas; up to 40 channels of broadcast satellite service could be made available to the public. Proposed services are generally aimed at rural or urban areas not presently served by cable companies.

direct inward dialing (DID)

Direct inward dialing (DID) is a feature available on some PBX systems which enables outside callers to dial directly to an internal extension without going through the console attendant. The DID capability requires the use of special DID trunks which are provided by the local telephone company. DID trunks are generally available only in large blocks.

distributed processing

Distributed processing (also known as distributed intelligence) involves the use of computers or intelligent terminals at a number of sites that share the control, storage, and/or computing functions of the central computer system, thus giving the end user data processing capabilities. The various stations, or networks nodes, are connected by telecommunications lines. A related term, distributed network, refers to a network architecture in which nodes, or communications processors, are connected directly or indirectly to each other and share the communications processing functions.

earth station
An earth station is the physical equipment used to send data communications to a satellite (called the uplink) and/or receive data communications from a satellite (called the downlink).

electronic mail
Electronic mail is a generic term describing the use of digital computer and other technologies (e.g., facsimile) in the generation and transmission or distribution of messages. It includes store-and-forward capabilities which can effect economies through off-peak time transmission. There is a growing number of electronic mail network capabilities for limited user groups and through the public networks.

emulator
An emulator imitates one system with another, primarily by hardware, so that the imitating system accepts the same data, executes the same computer programs, and achieves the same results as the imitated system.

end-to-end
An end-to-end protocol governs the interaction from the source computer to the destination device and vice versa; i.e., a program in the source machine exchanges messages with a similar program in the destination machine. The transport layer (fourth layer) of the ISO reference model of Open Systems Interconnection (OSI) is an end-to-end process, as are layers five to seven. In contrast, layers one to three of the ISO model specify intermediate, or subnetwork interactions between a device and its immediate neighbor. Layers one to three are referred to as chained, while layers four to seven are end-to-end.

ESS (electronic switching system)
ESS (electronic switching system) is one of a growing number of telephone company central office switches utilizing solid state devices and microprocessors. Capable of operating in millionths of a second, ESS makes possible new user services.

end-user
End-users are the ultimate customers or recipients of computer services. With the advent of software specifically designed for non-computer professionals, the number of end-users using computers has enlarged.

facsimile transmission
Facsimile transmission is a technique of transmitting and receiving document pages (text, diagrams, and pictures) over telecommunications links. Historically, facsimile has been an analog technique through which the facsimile device electromechanically scans the page to convert the variations in black and white, or tone, to electronic signals. Newer facsimile devices use digital technologies with improved scanning and transmission speeds and higher resolution. The CCITT has

established standards for analog and digital facsimile transmission.

fiber optics

Fiber optics is the science and technology dealing with the transmission of light through extremely thin fibers of glass, plastic, or other transparent material. Fiber optics is increasingly being used for telecommunications links because the medium can provide large bandwidth, freedom from electrical interference or noise, and low attenuation over long distances.

footprint

A footprint is the area of the earth's surface to which a satellite can transmit. Some parts of the footprint need more powerful or larger earth station facilities to achieve satisfactory signal strength. The footprint is a satellite in geostationary orbit cover about one-third of the earths' surface.

frequency

The frequency of a wave or oscillation is stated as the number of cycles or completed alternations per second.

frequency division multiple access (FDMA)

In satellite communications, frequency division multiple access (FDMA) refers to the use of frequency division to provide multiple transmissions to a satellite transponder simultaneously. To utilize FDMA technology, a special frequency, specific to the station concerned, is allocated to each earth station. These frequencies are spread over the total bandwidth of a particular satellite transponder. Each station occupies only a part of the transponder capacity, but does so permanently. One transponder can therefore handle transmissions from a number of earth stations at the same time. Compare with time division multiple access.

frequency division multiplexing (FDM)

Frequency division multiplexing (FDM) is a multiplexing system which divides the available transmission frequency band into narrower bands, each used as a separate channel. Some of the band must be reserved for guard bands between the channels.

Frequency modulation (FM)

Frequency modulaltion is a mode of analog transmission in which the frequency (rate of change) of the carrier wave is changed to correspond to changes in the signal's wave.

front-end processor (FEP)

A front-end processor (FEP) is a dedicated computer or system of computers that has the task of controlling and scheduling message traffic to and from multiple communications lines and terminals. The FEP can relieve the micro processor from input/output interruptions, and typically performs such tasks as error detection and user validating checking.

full duplex (FDX)

Full-duplex (FDX) transmission, sometimes referred to as duplex, provides for telecommunications transmission in two directions simultaneously. Voice telephone communications over the switched network is full duplex. Full-duplex transmission is analogous to a two-way street.

gateway

A gateway is a capability for crossing the boundary from one network into one or more other networks, e.g., from the local area network into a public network.

gbps (gigabits per second)

Gbps (gigabits per second) is a rate of data transmission equal to 1,000,000,000 bps (bits per second).

general-purpose processor

A general-purpose processor is capable of doing any job that its programmer can break down into suitable basic operations.

geosynchronous orbit

An object in geosynchonous (sometimes called geostationary) orbit circles the earth once in a 24-hour period. Thus the object appears stationary with respect to a particular location on the earth. Most communications satellites are in geosynchonous orbit, so that the earth antennas can be fixed rather than tracking. The altitude of a geosynchronous orbit is approximately 22,300 statue miles or 35,900 kilometers.

half duplex (HDX)

Half-duplex (HDX) transmission is "either-way" telecommunications transmission. Transmission is possible in both directions, but only one way at a time. When the communications device at one end has completed its transmission, it must advise the device at the other end that it has finished transmitting and is ready to receive. Citizens Band (CB) radio is an example of half-duplex transmission. Only one station can communicate at a time; the transmitting party signals "Over" to the receiving party, indicating that the transmission direction is to be received. Half-duplex transmission is analogous to a single-lane bridge on a two-way road.

handshaking

Handshaking is the general term describing the exchange of predetermined signals between two communicating devices. Handshaking permits one device to determine whether another is ready to receive or transmit data.

HDLC (High-Level Data-Link Control)

HDLC (High-Level Data-Link Control) is an International Standards Organization protocol that defines how information packets should be passed over a communications facility. The SDLC protocol of IBM's Systems Network Architecture (SNA) is a subset of and conforms to the HDLC requirements.

high definition television (HDTV)

High definition television (HDTV) is a new television technology that uses nearly double the amount of scanning lines of conventional television (1125 lines compared to 515 lines), a larger channel bandwidth, and a wider screen to significantly improve picture quality.

integrated services digital network (ISDN)

Integrated services digital network (ISDN) is a concept in which an end-to-end digital network carries both data and voice in the same channel. Based on the telephony integrated digital network (IDN), ISDN progressively incorporates additional functions and network features, including those of any other dedicated networks, so as to provide for existing and new services. ISDN services are expected to include digitized voice, facsimile and graphics, video, telemetry, videotex, software and data transfer, electronic mail, and data base access.

intelligent terminal

An intelligent computer and/or communications terminal (also known as a smart terminal) is a terminal which includes storage and programming capabilities. A dumb teminal, on the other hand, is a communications terminal with no inherent storage and programming capabilities.

interconnect industry

The interconnect industry describes the large and growing community of vendors of telephone data telecommunications equipment (other than operating telephone companies), designed to be interfaced with (interconnected to) the public switched telephone network. Such interconnection has been permitted only since the Carterfone Decision.

interface

The interface is the common boundary between two physical devices or two distinct communications systems. The interface may be mechanical, such as the RS232 standard defining the physical plug connection between devices; or it may be a software program, as, for example, the interface allowing messages to be passed between systems operating with different protocols and/or speeds.

internetworking

Internetworking (also called internetting) is the connection of two or more distinct networks.

interpreter

An interpreter is a computer program used to translate and to execute each source language statement of a computer program before translating and executing the next statement. The source language is the language in which the program is written.

ISO reference model

The International Standards Organization (ISO) has promulgated a reference model of Open Systems Interconnection (OSI) to support international standardization of network terminology and protocols. The OSI model has seven levels or layers, each of which performs a well-defined function. From the lowest level to the highest, the OSI levels are: OSI Layer 1 (physical layer); OSI Layer 2 (data link layer); OSI Layer 3 (network layer); OSI Layer 4 (transport layer); OSI Layer 5 (session layer); OSI Layer 6 (presentation layer); and OSI Layer 7 (application layer). The individual layers are described in separate entries in this glossary.

kbps (kilobits per second)

Kilobits per second (kbps) is a rate of data transmission equal to 1000 bps (bits per second).

knowledge-based system

A knowledge-based system stores and utilizes effectively large amounts of knowledge in programmatically-oriented applications and is an intelligent assistant for scientists and technologists, e.g. a system which aids medical doctors in diagnosis. Also called an expert system.

Ku-band

The Ku-band is the frequency band of 11-14 gigahertz (GHz) reserved for direct broadcast satellite (DBS) transmission and other next-generation satellite services.

large scale integration (LSI)

LSI is characterized by the technology incorporating up to a thousand gates per chip. Very large scale integration (VLSI) is characterized by having over a thousand gates per chip.

laser

A laser (Light Amplification by Stimulation of Emission of Radiation) is a device which uses an active material to convert energy to light, a source of energy and optics to direct the light through the active material repeatedly to amplify it, and optics to direct and focus the light into a fine, hairline coherent beam. Laser beams have narrow bandwidth, high directional capability, and can travel long distances with very little divergence or loss. They are increasingly being used through fiber-optics links in telecommunications. An example of the usage of laser beams is for very high speed transmission of voice and data information.

local area network (LAN)

A local area network (LAN) is generally understood to describe a network, within a single building or a single campus of buildings, which connect data processing devices and terminals--especially networks which support the interconnection of devices from more than one vendor. Increasingly, voice and video capabilities are being incorporated into local area offerings.

magnetic bubble storage

Magnetic bubble storage consists of a thin layer of garnet material containing magnetic domains. When an external magnetic field is applied, the domains look and behave like bubbles which are manipulated to represent information bits.

mainframe

Mainframe is a term used to designate a medium and large scale CPU.

management information system (MIS)

A computer based information system having applications in support of management activities.

mbps (megabits per second)

Megabits per second (mbps) is a data transmission speed equal to one million bps (bits per second).

message switching network

A message switching network is a communications network in which a message from one station to another is forwarded and stored at intermediate switching points, en route from the sending station to the receiving station (e.g., the telegram and teletype networks). Contrasts with a circuit switching network and packet switching network.

MICR (magnetic ink character recognition)

MICR (magnetic ink character recognition) is a system developed for the automatic handling of checks through the banking system, which is supported by increasingly large and sophisticated data communications systems. Checks are imprinted, using special ink which contains particles of magnetic substances, with characters of a typeface and dimensions specified in a standard developed by the American Banking Association. The fourteen specified characters (ten digits and four special symbols) are used to provide amount, bank identification, and control information. The inked letters are charged with small amounts of electricity and then read and sorted by devices which transmit the MICR data as input to bank computers for processing. A related process is OCR (optical character recognition).

microcode

Microcode directly controls the sequencing of computer circuits at the detailed level of a single instruction. The code is stored in dedicated high speed memory. It can be used for emulation. See emulator.

microcomputer

A microcomputer is one of a large variety of general purpose computers manufactured utilizing one or more microprocessors. Microcomputers can range from computers with relatively small amounts of memory to computers with large amounts of random - access memory and several peripheral devices. Typically an end-user microcomputer is of desk-top size and requires no special environmental site preparation.

micrographics
Micrographics is that branch of science and technology concerned with methods and techniques for converting any medium that contains images too small to read without magnification. The medium is generally useful for long-term storage of data.

microprocessor
A microprocessor is the portion of a microcomputer that provides the arithmetic, logic, and control capability and sometimes, main memory manufactured on a single, large or very large scale integrated circuit chip.

microwave
Microwave communication is a form of radio transmission constituting a narrow beam which can be separated in space by frequency-division multiplexing (FDM) to form several channels. Microwave transmission is limited in the distance signals can travel before requiring retransmission through a repeater station. Thus repeater stations are typically placed approximately thirty miles apart on towers, the tops of tall buildings, or hilltops to provide line-of-sight paths. The microwave radio beams usually have a width of five degrees and operate with low-power levels (about 12 watts) to prevent interference on the beams.

minicomputer
A minicomputer is a computer somewhere in size between a microcomputer and a mainframe. These units are characterized by higher performance than microcomputers, richer instruction sets, higher price and a proliferation of high-level languages, operating systems, and networking methodologies.

MIPS/MFLOPS
This is a convenient measure of the speed of computers - speed is usually defined in terms of MIPS - millions of instructions per second or MFLOPS - millions of floating operations per second.

modem
A modem is a device that accepts a stream of digital bits as input and produces a modulated analog carrier as output (and vice versa). The term modem is a contraction of modulator-demodulator. The modem is inserted between the digital computer and the analog telephone system.

modular
Modular defines a design feature and capability of computer/communications systems in which components can be added and deleted in a relatively easy manner to permit a variety of configurations.

modulation

Modulation is the process of changing some parameters of a carrier wave in relation to the value of information to be transmitted. Types of modulation include amplitude, frequency, phase, phase-adaptable, pulse code, and others.

multiple instruction - multiple data processor (MIMD)

A MIMD is a parallel processor which obtains concurrency by executing asynchronously with different processes utilizing the problem data simultaneously. See asynchronous processor.

multiplexer

A multiplexer is a device that accepts input from a collection of lines and inputs the data onto a single line. This may be accomplished by time division multiplexing, frequency division multiplexing, or statistical multiplexing.

narrowband

In data communications, narrowband refers to a bandwidth or circuit capable of handling digital signals up to 2400 bps. A narrowband circuit in telephone communications refers to a channel capable of transmitting an analog signal with a bandwidth of 3 KHz or less. Ordinary telephone lines generally utilize narrowband circuits over twisted pair copper wire.

network

A telecommunications network is an interconnected set of locations or devices linked by communications facilities, including telephone lines and microwave and satellite connections.

network architecture

To reduce complexity in both discussion and design of data communications networks, it is valuable to consider LAYERS or LEVELS of a network, where each level has a distinct function. In general, the purpose of each level is to offer certain services to the higher levels. Between each pair of adjacent levels there is an interface. The set of levels or layers and the set of protocols (rules governing their intention) is collectively called the network architecture.

node

A node of data communications networks is a device at a physical location which performs a control function and influences the flow of data in the network. Node can also refer to the points of connection in the links of a network.

non-volatile memory

Non-volatile memory is memory whose contents is retained when power is removed.

OCC (other common carrier)

Other common carriers (OCCs), also referred to as specialized common carriers (SCCs), are common carriers providing transmission capabilities beyond point-to-point transmission of unaltered data streams. A specialized common carrier may provide value-added network services or basic transmission facilities for voice and data services at rates competitive with the telephone companies.

OCR (optical character recognition)
OCR (optical character recognition) describes the process of machine recognition (i.e., direct interpretation) of printed or written characters through scanning and sensing by photoelectric transducers. OCR machines recognize the pattern of the characters. OCR techniques are increasingly being used to support the input of information to data communications systems because they have the potential to eliminate expensive and error-prone manual input. A related process is MICR (magnetic ink character recognition).

office automation
Office automation is the technology of automating the office functions such as text processing, electronic mail, information storage and retrieval, personal assistance features and task management.

operating system
An operating system is software that controls the execution of computer programs. An operating system may provide services such as resource allocation scheduling, input/output control, and data management. Although operating systems are predominantly software, partial or complete hardware implementations are possible.

OSI Layer 1 (physical layer)
In the ISO reference model of Open Systems Interconnection (OSI), the physical layer is the lowest of the seven defined layers of the generalized network architecture. The physical layer defines the transmission of bits over a communication channel, ensuring that 1s and 0s are recognized as such. Physical layer protocols specify the time in micro seconds a bit occupies, the number and definition of individual pins in a connector, and so on. The physical layer merely accepts and transmits a stream of bits without recognizing or defining any structure or meaning.

OSI Layer 2 (data link layer)
In the ISO reference model of Open Systems Interconnection (OSI), the data link layer is the second (working from the lowest) of the seven defined layers. The data link layer provides methodologies for transforming the new physical layer link into a channel that appears free of errors to the network layer (the next higher layer). The data link layer accomplishes this by splitting the input or data stream provided in the physical layer into data frames which are transmitted sequentially as messages and by processing the acknowledgement (ACK) frames sent back over the channel by the receiver.

OSI Layer 3 (network layer)

In the ISO reference model of Open Systems Interconnection (OSI), the network layer is the third (working from the lowest level) of seven defined layers. The network layer accepts messages of data frames from the transmitting host, converts the messages to packets, and routes the packets to their destination.

OSI Layer 4 (transport layer)

In the ISO reference model of Open Systems Interconnection (OSI), the transport layer is the fourth layer (working from the lowest) of seven defined layers. The transport layer accepts data from the session layer (the next layer up, which is the human user's interface to the network), splits this data into smaller units, passes these units down to the network layer, and ensures that all the pieces arrive at the destination in the correct order. The transport layer is a true end-to-end process; i.e., a program on the source transmitter carries on a conversation with a similar program at the end receiver. This end-to-end consideration in layers 4 to 7 is different from the protocols in layers 1 to 3, which regulates subnetworks at intermediate stages of a true end-to-end transmission. While the principles of data flow are the same in the network layer 3 and the transport layer 4, the transport layer protocols are communicated from the host to the ultimate receiver while the network layer protocols are communicated within the intermediate subnetworks and not "end-to-end."

OSI Layer 5 (session layer)

In the ISO reference model of Open Systems Interconnection (OSI), the session layer is the fifth (working from the lowest) of seven defined layers. The session layer is the human user's interface into the network through which the user establishes a connection with a process on another distant machine. Once the connection is established, the session layer manages the end-to-end dialog in an orderly manner, supplementing the application-oriented user functions to the data units provided by the transport layer. Establishing the session layer connection is typically a multistep operation, involving addressing the host, authenticating password access, stating communications options to be used (such as communications speeds and full or half duplex transmission), and billing arrangements. Once the session is underway, the session layer manages the interaction.

OSI Layer 6 (presentation level)

In the ISO reference model of Open Systems Interconnection (OSI), the presentation layer is the sixth (working from the lowest) of seven defined layers. The presentation layer protocols format the data to meet the needs of different computers, terminals, or presentation media in the user's end-to-end communications. The protocols at this layer may also provide data encryption for security purposes in transmission over public networks or data compression for efficiency and economy.

OSI Layer 7 (application layer)
In the ISO reference model of Open Systems Interconnection (OSI), the applications layer is the seventh (working from the lowest) of seven defined layers. The application layer specifies the protocols for the human user's intended interaction with the distant computer, including such applications as data base access, document interchange, or financial transactions. Certain industry-specific end-to-end application protocols, such as in banking or airline reservations, enable computers and terminals of different manufacturers to provide essentially the same user application interfaces.

packet assembler/disassembler (PAD)
The CCITT X.25 standard defines a specific format for packets in a packet switching network. So that ordinary asynchronous terminals can communicate on the network, a device is needed to collect individual characters from a group of terminals and to output properly formatted packets. Similarly at the receiving end, the inverse operation is required to split up the packet into individual characters. The device performing character-to-packet and packet-to-character transformations is called packet assembler/disassembler (PAD).

packet switching network
A packet switching network is a communication network which, in order to transmit a message from one station to another station, breaks the message into small units called packets. Each packet contains destination (header) information and a part of the message. The packets are routed from the sending station to the receiving station through switching points, where each of the switches is itself a computer capable of recognizing the address information and of routing the packet to its destination. The packet switching nodes can dynamically select the best route for each packet, so that later packets may in fact arrive prior to earlier packets. The switch at the receiving end reassembles the packets in the proper order. Packet switching networks do not establish a real connection between transmitter and receiver, but instead create a virtual circuit that emulates the connection created by a physical link. Packet-installed networks are highly efficient and can improve real-time transmission.

paging
Paging is a procedure for transmitting pages of information between main storage and auxiliary storage, especially when done for the purpose of assisting the allocation of a limited amount of main storage among a number of concurrently executing programs.

parallel processor

Parallel processors obtain concurrency in one of two ways: they perform identical operations in lock step on different portions of the data or execute asynchronously with different processes utilizing the problem data simultaneously. See asynchronous processor.

parallel transmission

Parallel transmission of data describes simultaneous transfer of bits containing a single character, so that each bit has a unique channel dedicated to it. Because of the multichannel requirement, parallel transmission is generally more expensive than serial transmission. Parallel transmission is typically used for short links, such as between a computer and its peripheral devices. In parallel transmission, the bits of a character are transmitted in parallel, but the characters themselves are transmitted serially.

PBX/PABX

A private branch exchange (PBX), or private automatic branch exchange (PABX), is a telecommunications switching mechanism--now generally based on a stored program digital computer--located on the site of a particular organization. The PBX and associated network of telephones and other devices may be obtained from the operating telephone company, or may be purchased or leased from an interconnect company.

personal computers

A personal computer is often defined as being low cost, based on microcomputer technology, movable, personally controllable, and easily used. Examples of personal computer usage are: home, hobbyist, professional, small business. See microcomputer.

pixel

In computer graphics, a pixel is the smallest element of a display surface that can be independently assigned color or intensity (picture element).

polling

Polling is a centrally directed technique of enforcing line discipline and eliminating contention among transmitting terminals. All terminals remain quiet until the central controller requests each to transmit.

processor

The word is used in several contexts, these include: 1. the arithmetic, logic, and control units; 2. the arithmetic unit; 3. the arithmetic, logic, and control units and the main storage.

protocol

A protocol is a set of agreed upon rules and conventions governing the formats and processes used in data communications. Protocol functions include establishing procedures for beginning and terminating connections, identifying stations, and ensuring compatibility between devices. Examples of protocols include the CCITT-recommended X.25, and the IBM SDLC and BISYNCH.

radio frequency (RF)

A radio frequency (RF) is a message transmission frequency in the range from approximately 10k Mz to 300g Mz (i.e., 10,000 Hz to 300,000,000,000 Hz).

resale carriers

Resale carriers are companies that offer reduced-rate voice communications, data communications, and/or video services. In 1981, under order of the Federal Communications Commission (FCC), the AT&T System allowed its WATS and MTS (message telephone service) to be resold. This allowed a new group of firms, known as resale carriers, to offer discount private line and switched voice-grade services to their customers on a nationwide basis. (The FCC had previously permitted resale of private line services.) Resellers purchased leased lines from AT&T or other carriers, switched voice services from the specialized carriers, or WATS from AT&T. Customers reach a reseller in the same manner as they would a specialized carrier such as MCI, using a local number and an identification code. The reseller's switching equipment then selects the most economical routing. Although resellers offer nationwide coverage at significant discounts from AT&T, subscribers generally are limited to accessing them in the cities where they operate switches. The FCC has determined that resellers do not have to be regulated because of their number and because their underlying carriers are subject to regulation.

ring topology

Ring topology describes the configuration of a data network which is a continually connect chain of links, generally implemented with repeaters to relay messages around the ring from source to destination. There can be different kinds of arbitration schemes to control data transmission.

RS449 interface

The RS449 interface identifies a specification defined by the Electronic Industries Association (EIA), detailing the physical configuration of the connector to interface between data terminal equipment (DTEs) and data communication equipment (DCEs). RS449 was defined subsequently to RS232C, and specifies a 37-pin connector (and for devices using a second channel, an additional 9-pin connector). The RS449 interface also provides additional control and signaling capabilities beyond the RS232C.

RS232C interface
The RS232C interface identifies a specification defined by the Electronic Industries Association (EIA) detailing the physical configuration of the connector to interface between data terminal equipment (DTEs) and data communication equipment (DCEs). RS232C specifies the use of a 25-pin connector and the signal assigned to the end of the 25 pins.

SDLC (Synchronous Data Link Control)
SDLC (Synchronous Data Link Control) is an IBM transmission protocol similar to the binary synchronous (BISYNC). In both data are gathered into blocks; however, SDLC uses data bits to signal control functions instead of the full characters used by BISYNC. SDLC is the protocol used in IBM's Systems Network Architecture (SNA), which is close to the HDLC (High-level Data-Link Control) in the OSI (Open Systems Interconnection) protocol-level model promulgated by the International Standards Organization (ISO). More information on the OSI standard can be found in the entry for ISO reference model.

semiconductor technology
Semiconductor technology uses two types of silicon, one a good insulator and the other a good conductor, hence semiconductor, in conjunction with photolithography to manufacture an integrated circuit.

serial transmission
Serial transmission of data describes the sequential transfer of the bits constituting a character, one bit at a time. Serial transmission is contrasted with a parallel transmission.

signaling
Signaling in a telephone syistem refers to any of a number of methods used to alert users or operators.

simplex
Simplex describes a telecommunications transmission mode which is one way only with no capability of responding. Home reception of a television signal broadcast by the station is an example of simplex communication (analogous to a one-way street). Contrasted with half duplex and full duplex.

software
Software is computer programs, procedures, rules, and possibly associated documentation concerned with the operation of the system.

star topology
Star topology is a network configuration offering point-to-point communications through a centralized network controller (or node) to which all other devices are connected. The central node may also provide gateways to other networks. All communications between the various devices, such as computers and terminals, takes place through the central controller.

supercomputers

Supercomputers have high-powered processors with numerical processing throughput significantly greater than that of the largest general-purpose computer.

switched network

The switched network generally refers to the publicly available network of lines and switching equipment used for dialed telephone calls or dial-up data transmission. The term can also apply to private or otherwise limited networks of lines and switching equipment.

synchronous processor

A synchronous processor is one in which the performance of all operations is controlled by equally spaced signals from a master clock as opposed to a signal that the previous operation has been completed. Contrast with asynchronous processor.

synchronous transmission (synch)

Synchronous transmission (synch) transmits blocks of data characters together without any pause between the characters. Synchronization between source and receiver terminals is established at the beginning of each block of data. The synchronization is generally accomplished by having the source terminal send, preceding each block of data, at least two synchronizing characters (SYN characters). The receiver is designed to recognize the SYN characters, and when two SYN characters appear in a row, then by definition, the next group of bits will be a data character (if not another SYN character). Synchronous transmission is generally done with buffers in which the blocks are held until sent, and is more efficient than asynchronous transmission.

T-1 carrier

T-1 carrier identifies the all-digital communications links now becoming available from telephone companies and other common carriers capable of supporting 1.5 mbps communications.

tariff

A tariff is a schedule published by a communication carrier; in the United States it must be filed with a state public service commission for intrastate services or the Federal Communications Commission (FCC) if interstate. A tariff describes the particular services provided, the charging rates, and the conditions under which the services are available.

telecommunications

Telecommunications refers to the transmission and/or reception of information by telephone, telegraph, radio or other methods of communication over a distance. The information may be in the form of voice, pictures, text, and/or encoded data.

teleconferencing

Teleconferencing describes the use of telecommunications links to support interaction by a number of conference participants at two or more physical locations. The telecommunications links may include one or more of the following: multiple connection voice telephone (audio teleconferencing); audio teleconferencing with audio-graphic capabilities; or one-way or multilocational video communication in addition to the audio, through which text and images may be read and augmented by authorized participants at their convenience. (Computer conferencing, in which participants converse with each other from remote locations via intelligent terminals or micro-computers, is also frequently referred to as teleconferencing). Video teleconferencing includes full-motion video, equivalent to the quality of a standard television broadcast; slow-scan, which involves transmitting a video image, via telephone lines, that slowly but constantly changes when displayed; and freeze-frame or still video, in which a still picture is held on the screen for approximately a half minute and then disolved.

telex

Telex is a teletypewriter (TTY) service introduced by Western Union in the 1950s. Telex teletypewriters have a printout speed of 66 words per minute and use Baudot five-level code. Telex messages can be sent worldwide through the facilities of international record carriers (IRCs). New telex-oriented message transmission and reception capabilities are being introduced which allow such devices as personal computers, electronic memory typewriters, and communicating word processors to communicate with each other.

tie line

A tie line is a leased communication channel linking two PBX systems.

time division multiple access (TDMA)

Time division multiple access (TDMA) is a multiple satellite access system. In TDMA, each ground station transmits to the satellite on a common frequency, occupying the totality of a transponder's capacity. In practice, each station transmits a burst of digital data in turn and for a given time, permitting blocks of data from the different stations to reach the satellite in sequence. The TDMA frame defines the transmission order for the stations. Transmission by each station is therefore repetitive and not continuous. Compare to frequency division multiple access.

time-division multiplexing (TDM)

Time-division multiplexing (TDM) is a multiplexing or channel-sharing technique in which each station has access to transmit at certain times, under rules enforced by a network controller or the interface protocols. TDM methodologies include polling, CSMA/CD, and token passing.

token passing
Token passing is a form of line discipline or contention resolution which operates without a central control. Each terminal on a network is permitted to transmit when, and only when, it possess the single "token." When it is finished, or after a given period of time, or if it has no transmission, the terminal passes the token to the next terminal in order (not necessarily the adjoining terminal).

topology
The topology of a communication network describes the physical or logical interconnection of terminal nodes on the network. The topology can be described as a bus, ring, star, tree, or a combination of these.

transaction processing
In transaction processing, a transaction triggers a full processing cycle such as a record retrieval, a record update, a record creation or record deletion.

transponder
A transponder is a device on a satellite that receives and amplifies radio frequency (RF) uplink signals from an earth station, and then redirects the signal back toward its destination earth station within the particular satellite's footprint. Modern satellites generally have 24 transponders.

trunk
A trunk is a telephone line or channel between two telephone company central offices or between two switching devices, which is used to provide voice or data connections between two locations.

TWX
TWX is a teletypewriter (TTY) service introduced by AT&T in 1963 and acquired by Western Union in 1971. TWX teletypewriters have a printout speed of 100 words per minute and use the ASCII eight-level code. TWX terminals and telex terminals, incompatible when first introduced, can communicate through code-translation via Western Union computers. Western Union's TWX service is now known at Telex II, reflecting the compatibility between the services. New message transmission and reception capabilities are being introduced that enable users to utilize their personal computers, communicating word processors, and electronic memory typewriters to send and receive telex-based messages.

user terminal
A user terminal is an input/output unit by which a user communicates with an automatic data processing system.

value-added network (VAN)
A value-added network (VAN) is a common carrier which provides services in addition to transmitting unaltered data streams. These services could include error detection and correction, temporary data storage, and speed or protocol conversion.

vector type architecture
In a vector type architecture, the instruction set is designed to operate on both vector e.g., a 1-dimensional array, and scalar operands.

videotex
Videotex is used to describe various electronic information and communications systems and services that are usually aimed at a general audience and that have two-way capabilities enabling the user to interact with the system. Typically, a videotex service makes available a data base of textual and graphic "pages" of information which can be accessed over telephone lines or cable television. Using small keypads, users retrieve information for display on television receivers equipped with an adapter. Some services are designed to be accessed by personal computers. In addition to information retrieval from a remotely held data base, videotex activities often offer transactional services through which consumers can purchase goods and services; messaging capabilities permitting users to contact each other; automatic alarm and meter reading; games; and other features. Videotex is also known as "viewdata," particularly in connection with the British Prestel system. One-way broadcast of information to television receivers is called teletext. While the above is the generally accepted terminology, there is considerable variation in the use of videotex, viewdata, and teletext.

video disk
A video disk is a device that contains data (audio/video) recorded on spiral or circular tracks with a lowpower laser.

virtual address space
The virtual address space is the form in which memory is presented to the software as opposed to the actual location addresses required by the hardware. With virtual addressing, programs can be assigned to noncontiguous areas of memory in relatively small blocks.

VLSI (very large scale integrated) circuits
VLSI (very large scale integrated) circuits are circuits, equivalent to former large electrical circuits, compressed on a single small silicon chip.

voice grade channel
A voice grade channel is a channel suitable for the transmission of speech, generally with a frequency range of about 300 to 3000Hz. Such a channel may also be used to transmit digital data, other analog signals, or facsimile.

voice mail
Voice mail involves the electronic storing and forwarding of voice messages. Messages are sent using a tone push-button telephone, digitized, and stored in a computerized message exchange system. To receive a message, a user accesses a private mailbox via a push-button telephone. The computer then relays an exact recording of the message. Voice mail systems are generally add-on devices for PABXs and are also available on a time-sharing basis.

volatile memory
Volatile memory is memory whose contents are lost when power is removed.

von Neumann type processor
A von Neumann type processor has a CPU which performs operations serially.

wideband:
Wideband transmission facilities is a term generally referring to transmission facilities which are capable of handling frequency bands greater than those required for voice communications; that is, greater than 3 to 4 KHz.

X.21
X.21 is a bit-oriented data communications protocol, promulgated by CCITT in 1976. X.21 defines a physical "plug" configuration for the physical connection of data communications devices, and also specifies the procedural (data link) interface (layers 1 and 2 of the IDS Reference Model for Networks). X.21 is a subset of protocol X.25.

X.25
X.25 is an international, three-level protocol for interfacing computers and terminals to public packet-switching networks worldwide. Developed by the CCITT with the participation of the United States, Canada, Great Britain, France, and Japan, X.25 includes electrical, link control, and network interface protocol layers. The physical/electrical interface follows the X.21 recommendation. The link control level is compatible with HDLC and can accommodate the BISYNC (binary synchronous) protocol developed by IBM. The network interface protocol defines the origination, termination, and use of virtual circuits which connect host computers and terminals across the network.

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This document, the second in a series, focuses on telecommunications technology and related areas in computer organizations. It contains four primary parts: the telecommunications forecast through 1999, three perspectives on the divestiture of AT&T, a discussion of the general impacts of technology on computer security, and the management implications of the trends in information technology. Additionally, it contains the summary of an industry workshop on this forecast, a brief update of the 1983 forecast, and a glossary of terms. This forecast is a companion to "Future Information Processing Technology - 1983" which contains fifteen year projections of computer hardware and software.

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