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(NASA-CR-182749) NASA AND THE CHALLENGE OF ISDN: THE ROLE OF SATELLITES IN AN ISDN WORLD Final Report (Colorado Univ.) 67 p CSCL 12B

N88-22676

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G3/66 0140236

Center for Space and Geosciences Policy

Boulder, Colorado

FINAL REPORT

NASA AND THE CHALLENGE OF ISDN:
THE ROLE OF SATELLITES IN AN ISDN WORLD

Prepared for:

The National Aeronautics and Space Administration,
Office of Space Science and Applications,
Communications and Information Systems Division (EC)

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NASA Grant NAGW 1105
May 25, 1988

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EXECUTIVE SUMMARY

To understand what role satellites may play in Integrated Services Digital Networks or ISDN, it is necessary to understand the concept of ISDN, including key organizations involved, the current status of key standards recommendations, and domestic and international progress towards implementation of ISDN. This report covers each of these areas.

The report also contains a summary of the technical performance criteria for ISDN, current standards for satellites in ISDN, key players in the ISDN environment, and what steps can be taken to encourage application of satellites in ISDN.

ISDN is a developing concept of how telecommunications networks should evolve in the future. At the most basic level, ISDN is an integrated services network that provides digital connections between user-network interfaces. The fact that ISDN means "different things to different people" is significant, for it indicates that evolution of the concept, and thus the role satellites may play, is still ongoing. Therefore, the evolution of ISDN and the role that satellites can play in ISDN should be seen as parallel developments.

At the same time, standards are being set, which means that roles are being defined. In setting standards the major international players are the CCITT and the CCIR, both part of the ITU. Domestically, ANSI, ECSA, and the COS and the (independent) "T1" standards committee are key players. Ensuring a role for satellites in ISDN will require knowledge of, and participation in, each of these key groups.

Considerable work has been done in identifying the basic elements of ISDN. These are contained in the so-called "I-Series" Recommendations from the CCITT. These Recommendations cover general aspects of ISDN, service capabilities, overall network aspects, user interfaces, internetwork interfaces, and maintenance principles. The CCITT I-Series Recommendations compose the initial "boundary conditions" of ISDN, and thus an understanding of their requirements and any constraints they may pose for satellites in ISDN is important.

Other new aspects of the ISDN environment are important: First, interest seems to be shifting towards emphasis on broadband ISDN, which could have far-reaching implications for networks in the future. Second, methods of pricing ISDN are beginning to emerge as companies begin experimenting with different tariff structures. Third, there is an emerging consensus that market acceptance of ISDN will not pose a barrier to implementation.

Progress towards implementation of ISDN is occurring at domestic and international levels. Within the U.S., Ameritech, US West, Nynex, Pacific Telesis and others have initiated or are planning field trials. Internationally, Germany, Japan, Sweden, and the UK are actively involved in implementation of ISDN.

Current efforts to include satellites in ISDN have not been widespread. INTELSAT has played a active role in encouraging the formation of an "ISDN and Satellites Coalition." The coalition has held several meetings and could serve as a focal point for future efforts on behalf of satellites. The CCIR's Study Group 4 has examined the role of satellites in ISDN, suggesting that the major role for satellites will be in long distance, high grade, international segments.

The CCIR and CCITT have issued several Recommendation and reports that will impact satellites in ISDN which are covered in detail in Chapter VI, "Technical Challenges". The important point to note here is that these Recommendation and reports set out specific performance standards for satellites in ISDN, some of which could, either in their current form or as a result of a modification, pose a problem for satellites. Without a thorough understanding and continuous evaluation of the implications of these technical performance objectives for satellites in ISDN, there is a potential for standards to evolve that are detrimental to satellite involvement in ISDN.

Thus, it is important to clearly understand and be able to operate within the CCITT and CCIR committees and subcommittees involved in ISDN as well as the domestic commmittees that develop U.S. consensus positions. The interrelationships between different committees are as complex as they are important, making complete knowledge of the process a prerequisite to effective participation.

If satellites are to play an important role in ISDN, there are several steps that can be taken now. These can be broadly grouped into four categories: 1) obtaining the necessary space resources; 2) meeting the technical challenges posed by ISDN; 3) impacting the standards process; and, 4) promoting the technical and operational advantages of satellites to users.

NASA can serve as a facilitator and source of support in a manner consistent with the statutory authority granted the Agency under the 1958 National Space and Aeronautics Act and in a manner consistent with the President's February 1988 National Space Policy. Such a role could be pursued under a general strategy of technical, supporting, and liaison activities. In particular, NASA could work with other national space agencies to ensure a coherent posture with regard to the role of satellites in ISDN.

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INTRODUCTION

In the past few years the tone of discussion surrounding the role of satellites in world communications has undergone an interesting metamorphosis. The first stage was disbelief that satellite applications could be affected by fiber optics. The second stage was marked by a fear that a fiber optic vs satellite "showdown" was imminent and that the future of satellites was uncertain. The third and current stage recognizes that transitions will occur, but that each medium has its own ideal applications.[1]

There may be yet a fourth stage, a stage marked by total end-to-end digital interconnectivity across virtually all forms of user interfaces at extremely high data rates. This concept -- integrated services digital networks or ISDN -- is becoming synonymous with the future direction of telecommunications. At the industry level, interest and participation in field trials has been high. Similarly, some foreign governments have already made a substantial commitment to testing ISDN technologies. Internationally, the ITU, CCITT and CCIR are beginning to set standards for ISDN, some of which could impact the role of satellites in ISDN. It is this last issue, the role of satellites in ISDN, that is the focus of this study. In particular, this study seeks to identify the role that satellites could play in ISDN and to assist NASA's Communications and Information Systems Division in understanding what kinds of efforts can help make that potential role into a reality.

ORGANIZATION OF THE STUDY

To understand what role satellites can play in ISDN, it is first necessary to understand ISDN.

Chapters I through IV describe the concept of ISDN, organizations involved in defining ISDN, the current status of key recommendations for standardization, and domestic and international progress towards ISDN implementation. These Chapters serve as backdrop against which the role of satellites is discussed.

Chapters V and VI focus on current efforts to include satellites in ISDN and some of the technical issues involved. This section isolates some of the performance criteria that are key to including satellites in ISDN, summarizing the importance of the major CCITT and CCIR recommendations with respect to satellites.

Chapter VII examines the importance of the standards process for satellites in ISDN, outlining the key players, the relative influence of their roles and how the process of standardization works.

Chapter VIII examines what steps need to be taken in order to ensure a role for satellites in ISDN. These steps are discussed in terms of necessary space resources, future technical challenges, the standards process, and the comparative advantages offered by satellites.

Chapter IX summarizes the importance of the study's findings for NASA's Communications and Information Systems Division. Within the context of the study, this Chapter is almost a "stand-alone" contribution, as it seeks to meet the specific needs of NASA's Code EC in the area of satellites and ISDN.

I. THE CONCEPT OF ISDN

ISDN is a developing concept related to how existing telecommunications networks should evolve in the future. Thus it is not now a tangible product or system. ISDN pre-supposes the existence of a digital telecommunication network, envisioning a variety of services which are accessible to users via a small set of multipurpose interfaces. Figure 1 shows schematically how users would access such a variety of different telecommunications services, presently, and in an ISDN. ISDNs will be characterized by the types of services they provide to users, rather than by the internal network technology or architecture which permit those services to be provided.

The formal International Consultative Committee on Telephone and Telegraph (CCITT) definition of ISDN, adopted in October 1984, reads:

> Integrated Services Digital Network (ISDN), an integrated services network that provides digital connections between user-network interfaces.[2]

This succinct definition specifically mentions the interfaces between users and the network, a key component of ISDN. A 1981 draft definition stated essentially the same thing in a slightly longer and more descriptive way:

> Integrated Services Digital Network (ISDN), a network evolved from the telephony IDN [Integrated Digital Network] that provides end-to-end digital connectivity to support a wide range of services, including voice and non-voice services, to which users have access by a limited set of standard multipurpose customer interfaces.[3]

"ISDN" is actually a very descriptive acronym, and understanding each of the words that make up ISDN will help one understand its essence.

A. Integrated

There are two ways to look at "integrated", or "integration." First, there is integration of services, which implies a network that provides or supports a variety of different telecommunication services, such as telephony, data, and telex, and the associated terminal equipment which allows the user access to those services. Second, there is integration of access, which implies a single connection to obtain access to the network(s) which provide the services.

B. Services

In ISDN, the word "service" can have several meanings. For example, in the CCITT I-Series recommendations defining ISDN, there are "bearer services," "supplementary services," and "teleservices," each with its own specific definition. In this report "service" is defined as that which is provided by the network to the user (also called a customer or subscriber) in order to satisfy a specific telecommunication requirement.[4]

C. Digital

Within the past ten to fifteen years, the transition from analog to digital technology has been very evident in the field of telecommunications; first for transmission, followed more recently by digital switching, and now digital user terminals. Using digital technology makes possible both storage of messages in the network and conversion of the speed, format, protocol or medium of the signal, allowing users with different kinds of terminals to communicate with each other. Details of the many technological and cost advantages of digital technology applied to telecommunications are discussed at length in many other sources.[5] This transition to digital technology is quite advanced in many telecommunication networks. According to Mr. Richard Hansen of AT&T, for example:

> Now, in mid 1987, we are well on our way to establishing a completely digital network. We stopped adding any new analog transmission systems to our network in 1983 and have accelerated our deployment of digital systems to meet exploding customer demand. The technology that we have right now, and are developing, will enable us to build a total digital network. We don't need significant technological breakthroughs or dramatic cost improvements.[6]

AT&T, with the largest network in the world, is leading this trend, and other U.S. network providers, both public and private, are following suit. The situation throughout Europe, Japan, and in many other countries, is quite similar. This transition is primarily motivated by cost and by the ability to provide new services to users (i.e., to generate new revenues).

Although AT&T and other network providers may soon have totally digital networks, this does not mean digital end-to-end connectivity for all users. Except for larger business users, "the last mile" local loop connection to the network is still analog, and will remain so for the near future. This will influence the feasibility, timing, and costs of providing new services to small business and residential users.

D. Network

The CCITT defines "network" as a set of nodes and links that provides connections between two or more defined points to facilitate telecommunication between them. New telecommunication services will be made available by means of networks. Ideally, these services would be available from one totally integrated network, although initially this will not be possible; public networks, private networks and value-added networks will all have their roles.

II. ORGANIZATIONS INVOLVED IN DEFINING ISDN

There are several domestic and international organizations involved in defining standards for ISDN. Without a "road map" of sorts, the process of developing standards for ISDN can be confusing. This section provides a brief picture of the "major players"; information on the many other players in this process can be found in several other sources.[7]

The two primary international organizations developing digital communications standards are the International Telecommunication Union (ITU) and the International Organization for Standardization (ISO). Within the ITU, the development of standards (called Recommendations) is managed by the International Telegraph and Telephone Consultative Committee (CCITT) and the International Radio Consultative Committee (CCIR). Most of the work on digital communications networks is confined to CCITT. The CCIR is primarily concerned with the technical aspects of radio spectrum use. CCITT Study Group XVIII is the focal point of international activities related to ISDN, and CCIR Study Group IV is responsible for recommendations related to fixed satellite service. These two organizations (CCITT and CCIR) and their sub-groups (Study Group XVIII and Study Group IV) are important to note for they appear throughout the study.

ISO, the largest standards organization in the world, is responsible for the development of the Open Systems Interconnection (OSI) Reference Model. The OSI Model is a seven-layer model* which defines a framework for the establishment of protocols so that separate systems complying with the model will be "open" to one another and thus will be able to communicate. The model was developed to: 1) accelerate the development of computer technology; 2) decrease the cost of computers and computer services, 3) address the problems of computer-to-computer communications; and, 4) meet the steady increase of data communications for an ever-increasing number of applications.[8]

Layer 1, the physical layer, defines the electrical characteristics needed to transmit data across the transmission medium such as a transmission wire, microwave, fiber optic or satellite link.

Layer 2, the data link layer, frames the data into packets that make up the messages and manages error checking. The next layer up, the network layer (3) sets up and manages the routing

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* The "layers" start with the physical hardware at layer (1) and progress through (2) data link, (3) network, (4) transport, (5) session, (6) presentation, and (7) application layers.

of data packets to travel across the networks. The standards for layers 1-3 also apply to local area network products which are primarily made by independent software companies and computer companies. Another U.S. standards organization, IEEE, has played a principal role in developing specific local area network standards.

The transport and session layers (layers 4 and 5) manage the end-to-end connection between machines, multiplexing of messages and synchronization of data exchange. These are of particular interest to communications companies although they can not be considered out of context of the entire model.

Layer 6, the presentation layer, provides negotiation of a common syntax for the transfer of data between programs on different computers. It manages the transfer syntax for character sets, text strings, data display formats, file organization, graphics syntax, videotex, financial information, etc. This standard effects any segment of the information industry which may be developing information products and services for delivery over a computer network.

At the top, layer 7 is the applications layer which directly interfaces to the end user activity. It selects the appropriate services for the user application processing and also manages the interfacing of user applications with other OSI layers. It provides both generic services such as file transfer and remote job control, as well as industry specific protocols such as for banking, library, business transactions and others. The OSI Model has had a direct impact on the development of certain standards for protocols and interfaces in ISDN.

Within the U.S., the American National Standards Institute (ANSI) is the national clearinghouse for voluntary standards. ANSI not a standards-developing organization <u>per se</u>, but rather establishes and promulgates full consensus standards (developed by other organizations) as American National Standards (ANSs). The Exchange Carriers Standards Association (ECSA), formed as a result of the breakup of AT&T, develops standards which preserve the integrity of nationwide telecommunications and facilitate the interconnection and inter-operability of carrier services.[9]

ANSI has promulgated two particularly relevant data communication performance standards. These are the American National Standard for Information Systems, Data Communication Systems and Services; User-oriented Performance Parameters, ANS X3.102, and the American National Standard for Information Systems, Data Communication Systems and Services; Measurement Methods for User-oriented Performance Evaluation, ANS X3.141. These standards are being used for measurements serving to quantify ACTS system performance. Satellites like ACTS could be used as hubs in ISDN's.[16] ECSA is both a trade association and sponsor of an independent standards committee, "T1." Committee T1 is the focal committee for ISDN standards efforts in the U.S. and is recognized as such by ANSI.

Another important organization is the Corporation for Open Systems (COS). COS does not develop standards, but works in conjunction with the National Bureau of Standards (NBS) to encourage uniform national implementations of standards for open systems, such as those related to ISDN and the OSI Model. COS is also charged with developing test bed and certification procedures so that vendors can test compliance with standards against an agreed upon reference implementation.

III. THE CURRENT STATUS OF ISDN RECOMMENDATIONS

Since 1980, the development of the necessary standards (Recommendations) has taken place within the CCITT with Study Group XVIII playing a lead role. One of the Group's most significant outputs has been a series of ISDN Recommendations, known as the "I-Series Recommendations". These Recommendations were adopted at the VIIIth Plenary Assembly in October 1984.

A. The I-Series Recommendations

Considerable work has been done since the first recommendation describing the principles of ISDN was published in 1980. A total of 29 Recommendations were prepared and ratified at the CCITT Plenary Assembly in 1984, and work has continued at an even more rapid pace since then.[11] Table 1 provides a general summary of the I-Series Recommendations adopted in 1984.

A comprehensive overview of all of the specific recommendations contained in the I-Series is beyond the scope of this study. However, a brief discussion of each series serves to highlight some of the important aspects of these ISDN Recommendations, providing a context for the identification of key issues being discussed in the current study period.

(1) I.100 Series - General

This series outlines the basic principles of ISDN and the evolution of ISDNs. The main feature of the ISDN concept is the support of a wide range of voice and non-voice applications in the same network. A key element of service integration for an ISDN is the provision of a range of services using a limited set of connection types and multipurpose user-network interface arrangements.

(2) I.200 Series - Service Capabilities.

The I.200 Series is concerned with the identification and categorization of services to be offered in an ISDN. This topic received considerable attention during the 1981-1984 study period. Rather than define specific services, it was decided to establish categories of services based on their relationship to different levels of[12] the OSI Model. Three categories of services were established:

- Bearer services: those providing the capability for the transmission of signals between user-network interfaces.
- Teleservices: those providing the complete capability for communication between users of specified user terminals.
- Supplementary services: those supplementing or modifying a basic telecommunication service.

TABLE 1

General Structure of I-Series Recommendations Adopted by CCITT at the 1984 Plenary Assembly.[13]

I.100 SERIES - GENERAL

- Frame of I-Series Recommendations; Terminology
- Description of ISDNs
- General Modelling Methods
- Evolution

I.200 SERIES - SERVICE CAPABILITIES

- Service aspects of ISDNs (Bearer Services and Teleservices)

I.300 SERIES - OVERALL NETWORK ASPECTS AND FUNCTIONS

- Network Functional Principles
- Reference Models (Protocol and Functional Architecture Models; Hypothetical Reference Connections)
- Numbering, Addressing and Routing Principles
- Connection Types
- Performance Objectives (Circuit and Packet Switched Connections)

I.400 SERIES - USER-NETWORK INTERFACES

- General Aspects of User-Network Interfaces (Reference Configurations, Channel Structures and Access Capabilities)
- Applications of User-Network Interfaces (Basic and Primary Rate Interfaces)
- Layer 1 Recommendations (Basic and Primary Rate Interfaces)
- Layer 2 Recommendations (LAP D)
- Layer 3 Recommendations
- Multiplexing, Rate Adaptation and Support of Existing Recommendations X.21, X.21 bis, X.25, V-Series, 56 kbit/s

I.500 SERIES - INTERNETWORK INTERFACES

I.600 SERIES - MAINTENANCE PRINCIPLES

- General Maintenance Principles
- User Related Testing and Maintenance Principles

(3) I.300 Series - Overall Network Aspects and Functions.

The I.300 Series of Recommendations deal with the network itself and how it will provide the services that are part of the ISDN. The primary topics related to network aspects include architecture, protocols,[14] connection types, numbering, routing, and performance.

(4) I.400 Series - User-Network Interfaces.

At the beginning of the 1981-1984 Study Period, issues were prioritized within Study Group XVIII, and high priority was given to the I.400 Series area -- user-network interfaces. Sixteen of the 29 I-Series Recommendations approved in 1984 were in the I.400 Series related to user-network interfaces. Of particular importance was the definition of a limited set of channel types for access to ISDNs through user-network interfaces, and the establishment of reference configurations for ISDN user-network interfaces.

Several different channel types have been defined, including the "B" and "D" channels which will be used in the initial implementations of ISDN. The "B" channel is a 64 kbit/s channel intended to carry a wide variety of user information, either voice, data, or image. The "B" channel does not carry any signaling information, which will be handled by the "D" channel at either 16 kbit/s for the Basic Rate Interface or 64 kbit/s for the Primary Rate Interface. The "D" channel can also accommodate low speed packet data.

A Basic Rate Interface consisting of "2B+D", 144 kbit/s, and a Primary Rate Interface (nominally "23B+D" (1.544 Mbit/s) or "30B+D" (2.048 Mbit/s)) have been specified as the fundamental arrangements for access into ISDN.

(5) I.500 Series - Internetwork Interfaces.

The I.500 Series deals with the network-to-network interfaces that will be needed to connect separate ISDNs together, as well as connecting ISDNs to existing non-ISDN networks. This issue will become more important once actual ISDNs are established, and it is receiving more attention in the current study period.

(6) I.600 Series - Maintenance Principles.

The I.600 Series focuses on maintenance principles, a relatively low priority area of study during the 1981-1984 study period. This topic is also expected to receive more attention in the coming years.

(7) Summary of I-Series Recommendations

Some of the basic foundations for ISDN have been established in the I-Series Recommendations which set out basic principles and specific technical requirements for ISDN. The adoption of the I-Series Recommendations is, however, only the beginning of an evolving process of standardization. The next step is to establish stable standards for first implementations (discussed in Chapters III and IV).[15]

B. Increased Emphasis on Broadband ISDN Issues

The study of broadband ISDN has assumed an important position during the 1985-1988 study period. The completion of certain I-Series Recommendations may provide for compatible implementations of narrowband ISDN by the end of the 1980's. Broadband ISDN topics, however, have far-reaching implications for the direction of networks of the future.

A Broadband Task Group (BBTG) was formed at the beginning of the current study period to examine "broadband aspects of ISDN." Since then, the topic has come to dominate the work of Study Group XVIII. The focus of the broadband study has shifted from distributive services (such as television), to encompass fast-packetburst-switching techniques. The work on broadband ISDN is divided into three parts: services, user-network interfaces and channels, and transfer modes. A recommendation containing the basic principles of ISDN broadband aspects and associated evolutionary strategy, and a detailed list of specific broadband issues will be prepared for formal adoption at the 1988 CCITT Plenary Assembly.[16]

C. Emerging ISDN Tariff Principles

The CCITT has recently been involved in the establishment of tariff principles and accounting procedures to guide ISDN service providers. Though the CCITT will play an important role in the development of ISDN pricing and tariff structures, the organization cannot actually set tariffs. As the CCITT's director, Theodore Irmer said during an interview with Business Communications Review in November, 1986:

> The CCITT does not establish tariffs; that is a national matter. What we are doing is establishing principles for the tariffs and procedures for sharing revenue among network providers for an ISDN call. Although there are some nations that adopt these principles as their national tariff structure, doing so is their choice; it is not mandated.[17]

One ISDN tariff principle emerging from the CCITT is that ISDN should provide a reasonable return for network operators and that the tariffs must be simple to understand.

The CCITT's Irmer feels that the network providers are entitled to a reasonable return but has declined to quantify what is a "reasonable return." He pointed to the West German ISDN basic access tariff of DM$56 ($28 in the U.S.) per month which is double the monthly access charge for basic single line telephone service. Irmer said, "...the philosophy is to charge double even though the basic (ISDN) access can do much more than two telephone lines in an analog world."

Aside from the CCITT, the Bell operating companies have been exploring tariff options. In the initial commercial ISDN offerings from the Bell operating companies, the general tariff approach is to negotiate single-customer specialized rates for the present, and develop generic tariff structures later when more data is available and demand is sufficient.[18]

A second emerging principle is a service-independent tariff structure which Irmer described as follows: "The network provider gives the customer these 64 kbps channels, and what the customer does with them - their content - should not affect the price of service, provided that the equipment needed to provide the service does not change....This tariff should be related to the telephone tariff because ISDN derives from the digital telephone network....Telephone traffic will be the bulk of the traffic and so it is logical that the tariff is oriented to telephony traffic".[19]

In the U.S., there is some early evidence to suggest that the price of an ISDN basic rate access line will be about 1.5 times the price of basic single line telephone service. The rationale follows that a single ISDN line, which supports simultaneous voice and data communication, should offer users some degree of savings over the cost of two separate, conventional lines needed to support voice and data communications in non-integrated systems.[20]

D. Views on Market Acceptance of ISDN

At the ISDN '85 conference, participants explored whether sufficient revenue can be generated to support any ISDN concept prior to 1990. Participants included representatives from telephone company service providers, manufacturers, and carriers from around the world: the United States, Canada, UK, France, Germany, Sweden, Japan, Spain, Italy, Switzerland, Holland, Finland, and Norway. During the workshops a number of varying viewpoints were expressed and some consensus was reached on a number of points.[21]

The first common theme to emerge was that voice and data markets are growing -- voice at 3 to 10 percent per year and data at 15 to 20 percent per year.

Second, the ISDN market was recognized as being non-uniform. More market research is needed to help determine customer acceptance of, and willingness to pay for, the type of services available through ISDN. The business sector appears to be the market most ready for immediate acceptance of ISDN. In the residence sector, cost-effective pricing and easy access to services on an integrated basis will determine the degree of customer acceptance of ISDN.

A third area of agreement was that new services and low costs will determine the degree of market penetration around the world. Many services will meet with wide user acceptance. Yet other services may fail if the market willingness to pay is not in line with the cost of delivering the service.

Lastly, a significant conclusion reached by the group was that by 1990, the ISDN infrastructure will be the dominant deployment architecture worldwide.

E. Summary of Current Status of ISDN

Some network providers and equipment manufacturers have already made a strong commitment to ISDN, and are actively participating in the creation and adoption of international standards to make ISDN a reality. Efforts are occurring simultaneously to 1) convert existing analog networks to digital technology, 2) complete key standards for narrowband ISDN to permit uniform implementations, and 3) define issues and principles for future networks and services in broadband ISDN. Few actual standards have been completed and adopted, but it is hoped that significant progress will be made so that key issues will be resolved in time for the 1988 Plenary Assembly, when revisions and additions to the existing I-Series Recommendations will be considered for adoption.

IV. DOMESTIC AND INTERNATIONAL PROGRESS TOWARD IMPLEMENTATION

Several companies and countries are either conducting ISDN field trials or have scheduled field trials for 1988. These field trials or "tests" are generally seen as an important first step towards widespread ISDN deployment. In addition to giving vendors and network service providers an opportunity to gain valuable experience with ISDN technology, the field trials serve as a vehicle to test market acceptance.

A. U.S. Field Trials

In the U.S., all seven regional Bell holding companies are proceeding with ISDN trials to evaluate the various capabilities of the architecture and test the compatibility of network equipment supplied by different vendors. Some residential trials have also taken place. The five field trials summarized below[22] are representative of the efforts being undertaken by the major (Bell) network service providers in the United States.

(1) US West

US West (through the Mountain Bell telephone company) conducted a 200-line test that began in November, 1986 in Phoenix involving two Arizona state agencies, the Department of Administration and the Department of Game and Fish. Mountain Bell is engaged in three additional ISDN trials in the Phoenix area, two of which include Honeywell Information Systems and Intel Corp. as customers. These trials used switching equipment manufactured by AT&T, GTE, and Northern Telecom.

In December, 1986, Mountain Bell began an internal ISDN trial using an ISDN switch manufactured by NEC (Japan) to provide service between an analog AT&T central office switch and US West locations in downtown Denver. Some 96 basic rate ISDN lines are involved in this trial which will also test high-speed facsimile, integrated voice and data, and local area network applications.

Initiated in March, 1987, a field trial conducted by Pacific Northwest Bell will test the feasibility of providing ISDN service through a digital Centrex system, which dedicates a portion of a central office switch to a customer and acts as a private exchange. This test will use a Northern Telecom central office switch to provide 200 basic rate (2B+D) access lines to the U.S. National Bank of Oregon.

(2) Ameritech

Ameritech has disclosed one ISDN trial and one demonstration to date. Illinois Bell began providing Centrex service to

McDonald's corporate headquarters in Oak Brook, Illinois in December, 1986. An AT&T digital exchange serves the company with 120 ISDN lines. In addition to testing digital Centrex, this trial also includes high-speed facsimile and asynchronous word processing. The trial is scheduled to run through July, 1988.

(3) Nynex

Nynex Corp. is conducting or planning ISDN trials in New York and Boston. The company is presently evaluating switching equipment from both Northern Telecom and Siemens (Germany). Nynex hopes to announce commercial ISDN customers in 1988.

New England Telephone began an internal ISDN trial in July of 1987. The eight month trial will use an AT&T digital switch to connect four of the telephone company's downtown Boston locations. Applications to be tested include voice and data integration, local area networking and PC-to-PC communications.

(4) Pacific Telesis

Pacific Telesis Group is conducting a 16 month ISDN trial that starts in Sunnyvale, Cal. and will eventually encompass San Francisco and San Ramon. The Sunnyvale test, which began in September, 1987, provides ISDN service to Lockheed Missile and Space Co., Inc., Hayes Microcomputer Products, Inc., and AT&T Network Systems through an AT&T switch equipped with an ISDN switching module.

Lockheed will use 37 lines in developing applications for computer-aided design, engineering and business computing, an integrated local area network, video, and telemetry. In early 1988 the test will be temporarily interrupted to install the full ISDN feature set on the AT&T switch.

Hayes Microcomputer Products will use two ISDN lines for engineering development, accounting administration and electronic mail transmission. An interface circuit card developed by Hayes will be used to connect personal computers at Hayes' facility in San Francisco to the telephone company's ISDN network.

AT&T Network Systems' regional headquarters in Sunnyvale will begin using three ISDN lines for office administration functions, with additional links to remote locations in San Francisco, San Ramon and Palo Alto.

The combined access lines of these three tests will eventually number 250 and involve seven customers. All three tests will provide basic rate service with primary rate (23B+D) ISDN service scheduled for mid-1988.

(5) Residential Trials

The demand for ISDN services from residential subscribers is seen as secondary to much larger business markets for ISDN. As such, residential ISDN trials have been limited. It is worthwhile to note that at least three Bell operating companies have installed or are planning to install in the very near future fiber optic cables that will extend from the local exchange to the subscriber's home. Demonstrations of wideband services (such as video) to customers may be a precursor to the residential market's acceptance of ISDN.

In one noteworthy residential offering, Southern Bell has plans to offer ISDN services over fiber optic cables to 500 homes in the Heathrow housing development near Orlando, Florida. Foregoing trials, Southern Bell is offering ISDN on a commercial basis from the start, confident that customers will respond positively. Homeowners have a choice of sticking with POTS (plain old telephone service) or opting for ISDN, which will be priced about 1.5 times higher than POTS.[23]

B. International

There have been numerous field trials and other advances outside the U.S. Some of the more notable examples are listed below with a brief synopsis of their activities.

(1) Germany

The Federal Republic of Germany PTT, the Deutsche Bundespost, has set the following schedule for ISDN implementation:[24]

1986: ISDN trials.
1988: Start of serial ISDN introduction with services including voice, circuit-switched data, teletex, telefax, and videotex.
1989: All digital exchanges prepared for ISDN.
1990: 100 digital trunk exchanges and 200 local exchanges installed with access to 50% of the potential ISDN subscribers. Also, beginning of introduction of broadband ISDN.
1992: Integration of broadband ISDN.
1993: Nationwide ISDN coverage.

(2) Sweden

Sweden began an extensive network digitalization program in 1985. At current levels of investment in the telecommunications network (about 4.5 - 5 billion SEK (500 - 600 million US$) per year), about 40% goes into new digital systems. The proportion of digital connections in the inter-exchange network passed the 50% mark in 1985. At the same time, about 18% of all telephone subscribers were connected to digital exchanges. About 250,000 new lines, or about 5% of the present total, are being connected to digital systems every year. A fully digital, synchronized long-distance network with common channel signaling* and interconnecting about 75 digital exchanges is expected to be in place in 1987.

In Sweden, the ISDN is expected to evolve within the framework of the general digitalization of the telecommunications network. Within this framework, the first step towards ISDN will be a nationwide capability for 64 kbps digital connectivity, available in 1987. Technical and commercial ISDN service trials are planned during 1987-89. Commercial offerings are expected to commence in 1989 leading to nationwide availability to virtually any customer by the mid 1990's.[25]

(3) United Kingdom

In 1985, British Telecom launched its IDA (Integrated Digital Access) service as a first step towards a full ISDN. Initial service was provided from a single exchange in London with remote multiplexers used to serve more distant customers. Three additional exchanges were added to the pilot system, each with the capability of providing service to 250 single line IDA customers.

In the next few years there will be a rapid increase in the number of digital local exchanges in service in Britain, each of which will be equipped to provide ISDN service. By the end of 1987 there should be about 180 systems in place. In addition, a fully digital trunk network is planned sometime prior to the end of the decade.[26]

(4) Japan

Over the last two decades Japan has pushed steadily forward in network digitalization. The completion of the nationwide

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* Common channel signaling is a method of signaling between two switching centers that uses a connection separate from the voice and data channels.

digitalization of the telephone network is scheduled for 1995. The recent annual growth rate of telephone traffic among some 64 million subscribers has been about 3%. Non-telephone traffic is estimated to be growing at a much higher rate. The number of facsimile terminals, for instance, is increasing by about 50% a year.

In the past five years NTT, the major provider of domestic telecommunication service in Japan, has implemented specialized networks dedicated to either circuit switched or packet switched data, or to facsimile communication. Both data networks and private line services operate at up to 6.3 Mbps on an end-to-end digital basis. Other specialized network services, such as videotex and video conferencing, are also being widely used in large cities.

NTT hopes to integrate these separate networks into a single ISDN. But NTT has a bigger plan in mind than ISDN, which it calls INS (Information Network System). The INS concept will combine ISDN with communication processing nodes performing higher-level function so that a wide range of information and communication modes can be accommodated in a single network system.

An INS pilot is now being operated between Mitaka, a suburb of Tokyo, and part of central Tokyo. The pilot offers both 64 kbps digital communications combined with communication processors and wide-band visual services. By 1988, NTT expects that it will be able to meet the digital access demands for almost all substantial areas in Japan, and when CCITT Recommendations are completed, it will provide INS access on the internationally accepted 2B+D standard.[27]

V. CURRENT EFFORTS TO INCLUDE SATELLITES IN ISDN

The foregoing discussion has focussed on introducing the general nature of ISDN and some of the basic principles, recommendations and themes that have or are currently emerging. This Chapter focuses on how satellites are being perceived within the general concept of ISDN.

A. Efforts by Intelsat and the Satellite Industry.

Intelsat has been active in a number of areas, aiming at securing a role for satellites in ISDN, hoping not only to protect its interest but also to widen the competitive prospects for satellites in the future. In early 1986, Intelsat established a task force with the goal of ensuring compatibility between all aspects of Intelsat digital services and ISDN. Intelsat claims to be the only service provider that today can offer ISDN capabilities on a global network basis. In addition, their IDR (Intermediate Data Rate), IBS (Intelsat Business Service) and TDMA (Time Division Multiple Access) services are advertised as being fully ISDN compatible. (Of course this depends on the future direction of ISDN.)

Intelsat has also been an active participant in ITU meetings focused on the definition of standards for the ISDN, submitting contributions to, and hosting a meeting of, the CCITT Study Group on ISDN and satellites.[28]

On an industry-wide level, Intelsat and a number of satellite system manufacturers and service providers have formed the "Satellite Coalition for ISDN."

Speaking before the 1987 Satellite VI Conference Dr. Joseph Pelton, the Director of Policy at Intelsat, described a situation which seems to call for a group to promote satellites:

> For a number of reasons, the satellite case for ISDN has not really been made. What has been missing is a unified collective attempt by the satellite industry not only to rebut negative perceptions about satellites, but also to extol the many advantages of satellites in general, and especially for ISDN-compatible satellite services.[29]

The Coalition has since addressed a number of issues, including standards-making, compatibility between satellites and terrestrial-based systems, satellite/ISDN tests and demonstrations, image building, and economic studies of satellite versus fiber optic systems.

The Coalition has recognized the importance of active participation in the national and international standards making bodies responsible for establishing standards for ISDN. Active involvement in these organizations is particularly important in light of the Coalition's view that "...the participants (in these standards making parties) are almost exclusively comprised of operators of national networks and manufactures of equipment (central office switches, PBX's, user terminals, etc.) ... and we have often found that they are consequently indifferent to the peculiarities of satellite systems."[30]

At the Coalition's February 1987 meeting, representatives from Comsat assured the group that Comsat has been active in the appropriate CCITT forums and that, for the time being, there was no grave danger of standards being set resulting in the possible exclusion of satellites from the ISDN. Standards making is an ongoing issue, they added, and additional support would be helpful.[31]

At the coalition's second meeting in May 1987, a member from Intelsat commented that the CCITT recommendation on performance criteria, namely G.821 (Error Performance on an International Digital Connection Forming Part of an Integrated Services Digital Network) was quite acceptable for satellite transmission links. He also indicated that efforts to revise Recommendation G.114 on propagation delay appeared to be proceeding well, and that a draft revised recommendation taking into account more recent data could be expected in the coming months. (Both of these recommendations will be discussed subsequently in detail.)

An important area of concern appears to be switching protocols, with the feeling that more emphasis needs to be placed on ensuring that signalling and switching standards take satellite requirements into account.[32]

Another recent development taking place within CCITT Study Group XVIII and discussed by the Coalition concerns standardization for broadband ISDN. The standardization of the transmission rate is likely to be set in the range of 150 to 155 Mbps, rather than the previously discussed 140 Mbps. A data rate of 150 Mbps is just out of the reach of present satellite technology, therefore such a standard would require new planning approaches and/or hardware to be developed and implemented to allow Intelsat to transmit data at these high rates, and would probably affect other satellite systems as well.[33]

The Coalition's meeting in May 1987 included a discussion on the problem of compatibility between satellites and certain terrestrial-based facilities. Several members of the Coalition suggested that telecommunications equipment and switching facilities were frequently incompatible with satellite transmissions. One member added that the switching systems of certain PBX manufacturers were even incompatible with their own units if operated over a satellite circuit.

To address this situation, it was agreed that a working group would be created to:

a) participate in and contribute to the working parties and study groups involved with setting standards affecting satellite communications;

b) prepare a letter to send to manufacturers of digital PBXs and other digital communications equipment stressing the critical importance of compatibility with satellites;

c) monitor the developments taking place within the definition of Signaling System Number 7 to ensure its full compatibility with satellites. Signaling System Number 7 (SS No. 7), is a method of common channel signaling and is an essential component of the evolving international digital networks.

The use of satellites in ISDN has been demonstrated through efforts sponsored jointly by Comsat and British Telecom (BTI) and carried by Intelsat. Successful ISDN demonstrations also were conducted between London and Washington, D.C., and between London and New Orleans in early 1987. It was agreed that detailed articles on these demonstrations should be placed in the media and that targeted letters referring to the success of the demonstrations be sent to key telecommunications planners.[34]

It was further agreed that follow-up ISDN demonstrations should be pursued. Intelsat promotes the continuation of these demonstrations by offering free use of its space segment to its signatories for the purpose of demonstrating the feasibility of satellites in the ISDN.[35]

B. Recommendations from the CCIR on Satellites in the ISDN

International standards development for ISDN largely takes place within various study groups of the CCITT. Recommendations dealing with system performance and standards for radio communications, however, are the responsibility of the International Radio Consultative Committee (CCIR). Study Group 4 of the CCIR is responsible for all matters relating to operation and performance criteria of fixed-satellite service.* Within Study

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* The fixed-satellite service relays telephone, data, and radio signals from one point to another (point-to-point) or to many other ground stations (point-to-multipoint).

Group 4, Interim Working Party 4/2 ("IWP 4/2") on Satellites in the digital network has addressed several issues critical to performance objectives affecting satellites in the ISDN.

The IWP 4/2 held its fourth meeting from April 6-10, 1987 in Tokyo, Japan. The Working Party addressed a number of issues central to the development of standards and performance criteria necessary for the inclusion of satellites in the ISDN. The reports and recommendations produced at this meeting may have an important impact on the extent to which satellites are incorporated into the ISDN.

The efforts of the working party produced a new report entitled "The Integrated Services Digital Network and the Fixed Satellite Service."[38] The objective of this report is to provide for a broader understanding of ISDN throughout the satellite community and to identify the more important aspects that impact satellite system design.

The report sums up the importance of satellites in the ISDN, stating that:

> The major role expected for satellites in the ISDN is as part of the long distance, high grade, international segment. In fact, it can be expected that for international connections, satellites will be the primary transmission medium except for the areas where undersea cables are reasonable to install. These are also the highest density traffic routes so even in this case there will be a significant role to be played by satellite systems.

This is clearly the type of language preferred by the satellite community; however, it is no guarantee that satellites are assured an important role in ISDN. Doing that will require that 1) technical challenges are identified and effectively addressed; and, 2) the standards process is well understood and effectively utilized. Chapters VI and VII focus on these two areas.

VI. TECHNICAL CHALLENGES AHEAD

This section provides an overview of the most important CCIR and CCITT recommendations and reports that will impact satellites in ISDN. In general, these are CCITT Recommendation G.821 on satellite transmission qualityy objectives; CCIR Recommendation 614 on allowable error performance; CCIR Report 997 which contains detailed information on the characteristics of satellite service in ISDN; and CCITT Recommendation G.114 concerning limitations on propagation delay and the appropriate use of echo control devices for satellites in ISDN. This section ends with a list of technical issues that continue to face satellites in ISDN.

A. CCITT Recommendation G.821: International ISDN Transmission Quality Objectives.

The performance objectives that apply to satellites in the ISDN are derived from the overall performance objectives set forth in CCITT Recommendation G.821.[37] This recommendation, entitled "Error Performance of an International Digital Connection Forming Part of an Integrated Services Digital Network," forms the basis upon which performance standards are derived for communication links in an end-to-end ISDN connection.

Based on the perceived needs of end users, G.821 defines the performance objectives for each direction of a 64 kbit/s circuit-switched connection used for voice traffic or as a "Bearer Channel" for data-type services. This 64 kbit/s circuit-switched connection is an all digital Hypothetical Reference Connection (HRX) with a total length of 27,500 km and is a derivative of the CCITT's Standard Hypothetical Reference Connection. A digital HRX is a model with which studies relating to overall performance can be made, thereby facilitating the development of objectives and standards.[38]

The performance objectives of G.821 are given for three different performance classifications. International ISDN connections -- where satellites are expected play a role -- must meet all of these requirements concurrently to be in compliance with the objectives. The objectives are:

(1) Degraded Minutes: Fewer than 10% of one-minute intervals to have a bit error ratio worse than 1×10^{-6} (this is equivalent to 4 errors or less for 90% of 1-minute intervals for a 64 kbit/s HRX)

(2) Severely Errorred Seconds: Fewer than 0.2% of one-second intervals to have a bit error ratio worse than 1×10^{-3} (this is equivalent to 64 errors or less for 99.8% of 1-second intervals for a 64 kbit/s HRX)

(3) **Errorred seconds:** Fewer than 8% of one-second intervals to have any errors (equivalent to 92% error-free seconds).

Since these objectives relate to an overall connection it is necessary to subdivide these into the constituent parts of the HRX. In G.821, the CCITT identifies three different components of an end-to-end international connection and classifies them as local grade (between the end user and local switching center), medium grade (between the local exchange and the international switching center), and high grade (the long-distance connection).

G.821 then describes the strategy used in allocating the overall objectives among the constituent parts. The apportionment of degraded minutes and errorred seconds is given as:

a) Local grade: 15% block allowance to each of two ends;
b) Medium grade: 15% block allowance to each of two ends;
c) High grade: 40% (this is a distance-sensitive allocation equivalent to a conceptual quality of 0.0016% per km for 25,000 km).

Realizing that the error performance of satellites is largely independent of distance, the CCIR, in cooperation with the CCITT, has undertaken studies to determine the performance allocation appropriate for satellites in the HRX. To facilitate these studies, the CCIR has developed a model called the Hypothetical Reference Digital Path (HRDP), which includes one earth-space-earth link and may be used to form part of an HRX.

In Recommendation G.821 a block allowance of 20% of the permitted degraded minutes and errorred seconds objectives is allocated to a single satellite HRDP employed in the high-grade portion of the HRX. Given this allocation, the satellite HRDP objectives required for compliance with the overall objectives of G.821 can be stated as:

a) Degraded minutes: Fewer than 2% of 1-minute intervals to have a bit error ratio worse than 1×10^{-3};

b) Severely errorred seconds: Fewer than 1×10^{-3};

c) Errorred seconds: Fewer than 1.6% of 1-sec intervals to have any errors (equivalent to 98.4% error-free seconds).

B. CCIR Recommendation 614: Allowable Error Performance

This recommendation, drafted by IWP 4/2 of Study Group 4 of the CCIR and accepted by the CCIR at the XVIth Plenary Assembly in 1986, specifies the allowable error performance for a HRDP in the fixed satellite service forming part of an international connection in an ISDN.[39] It states that the bit error ratio at the output of a satellite HRDP operating below 15 GHz and forming part of a 64 kbit/s connection should not exceed:

a) 1×10^{-7} for more than 10% of any month;
b) 1×10^{-6} for more than 2% of any month;
c) 1×10^{-3} for more than 0.03% of any month.

The above objectives were established utilizing the method outlined in CCIR Report 997 (Characteristics of a FSS HRDP forming part of an ISDN) and are sufficient to meet the required FSS HRDP performance objectives given above in Recommendation G.821.[40] The Recommendation applies only when the system is considered available as defined in Recommendation 579.[41]

In order to provide guidance to the CCITT in determining the appropriate performance allocation for a satellite HRDP, the CCIR studied the performance requirements of a number of connections covering a diverse range of network configurations. In these studies it was noted that satellite error performance is generally distance-independent, with a maximum single hop covering an equivalent terrestrial distance of approximately 16,000 km.

Several different HRX configurations were studied and it now appears reasonable that up to 40% of the total performance degradation may be allocated to a FSS HRDP when forming part of a Hypothetical Reference Connection (this is compared to the 20% block allowance for a satellite element now employed in the high-grade portion of the HRX allowed by Recommendation G.821). Although a distance related approach did not appear to be applicable to satellites, the need to allocate a portion of the overall performance objectives gave rise to the concept of a "satellite equivalent distance" (SED) that could be assigned to the satellite HRDP.

The value of this hypothetical distance was determined from a study of real situations and HRXs. These studies resulted in a distance of 10,000 km for a "traffic weighted" SED and 13,000 km based on examinations of actual international busy hour traffic. Both of these values are close to the 12,500 km figure currently allocated to a FSS HRDP in CCITT Recommendation G.821.

Models involving two satellite hops were also studied. The use of dual satellite hops may lead to problems in user acceptance due to propagation delay and network synchronization due to variations in delay. Connections of this type should therefore only be used in exceptional cases were alternatives are not practical. The number of satellite hops, including those involving inter-satellite links, continues to be studied by the CCIR.

The study of satellite HRDPs continues to be important because of the rapid evolution in the design and application of satellite networks. Trends towards the use of smaller earth stations have resulted in decreasing terrestrial distances from the earth station to the end user. Consequently, different performance allocations may need to be considered in these cases.

C. CCIR Report 997: Satellite Characteristics in ISDN

Providing the basis for and supporting Recommendation 614 (above), this report, "Characteristics of a Fixed-Satellite Service Hypothetical Reference Digital Path Forming Part of an Integrated Services Digital Network," first appeared in the CCIR 1986 "Green Book". A draft revision of the report, including new material on various topics which bear on the development of ISDN performance criteria, was prepared by IWP 4/2 of the CCIR and presented at their meeting in Tokyo in April of 1987.

The report provides some insight into the ISDN HRX requirements as specified in Recommendation G.821. Report 997 translates the performance requirements in G.821 into terms useful to a satellite system designer and provides the necessary background information. In addition, it describes the method that has been used for converting from the CCITT specification to the form of performance objective used for satellite systems, and gives the satellite HRDP performance requirements that result from applying this method to the values quoted in Recommendation G.821. Report 997 notes that, "...the performance of a satellite digital transmission channel can be designed to meet virtually any performance specification. However, the use of forward error correction, power control and site diversity which can significantly improve system performance has penalties of decreased capacity and/or increased cost. The use of such techniques therefore requires suitable justification."[42]

Report 997 then goes on to discuss other technical aspects affecting the performance of satellites in the ISDN.

1. Availability

The performance objectives of G.821 apply only when a link is considered to be available. Availability can be affected by atmospheric conditions (e.g. heavy rain) causing high bit error rates. The generally accepted definition of unavailable time, as stated in Report 997, is:

> A period of unavailable time begins when the bit error rate (BER) in each second is worse than 1×10^{-3} for a period of 10 consecutive seconds. These 10 seconds are

considered to be unavailable time. The period of unavailable time terminates when the BER in each second is better than 1×10^{-3} for a period of 10 consecutive seconds. These 10 seconds are considered to be available time and would contribute to the severely errorred second performance objective. Excessive BER is only one of the factors contributing towards the total unavailable time. Definitions concerning availability can be found in CCITT Recommendation G.106.[43]

2. Error Causing Mechanisms

Propagation and interference effects are major causes of error in digital satellite systems. The NASA Propagation Program has played a fundamental role in understanding such adverse effects.[44] The wide bandwidths available at higher frequencies make them attractive for high-capacity digital systems, but rain, clouds, and atmospheric gases tend to degrade Earth-space transmissions severely with increasing frequency.

CCIR Report 997 provides information on error mechanisms other than propagation and interference. The following error causing mechanisms have been identified:

- signal path switching in earth-station IF and RF equipment;
- signal path switching in earth-station baseband equipment;
- power supply transients at earth stations;
- signal path switching in the satellite.

Estimates of the frequency and duration of error bursts due to the above mechanisms can be found in Annex III of Report 997.

3. Interference and Sharing Constraints

Prior to G.821, performance standards for systems in the fixed-satellite service were obtained from CCIR recommendations written for systems using pulse code modulation (PCM) for telephony (non-ISDN). Depending on the method used to improve performance (e.g. higher output power per channel), the improved performance levels required of ISDN satellite connections can cause higher levels of interference into other FSS networks and represent a higher percentage of total noise than anticipated for satellite circuits designed to meet CCIR recommendations. One study refered to in Report 997 indicates that the level of interference caused by radio-relay and fixed-satellite service systems will account for 34% of the total noise at the input to systems forming part of an ISDN. Further difficulty with the effects of interference is anticipated in that many systems are expected to be constrained by the severely errorred seconds performance standard.

The CCIR further believes that urgent and extensive study of the effect of interference on satellite ISDN connections is necessary and that new recommendations relating to allowable interference into ISDN satellite circuits may need to be developed. Propagation plays an important role in interference. Tropospheric ducts and scatter from precipitation are the two most important propagation phenomena contributing to interference.

4. Error Performance at Higher Transmission Bit Rates

The error performance objectives currently specified by the CCITT and CCIR are based on a communications channel operating at the standard 64 kbit/s rate. It is necessary to consider how these objectives can be applied to higher transmission rates. A method for translating the BER criteria to transmission rates higher than 64 kbit/s is proposed in Annex IV of Report 997. This matter will be the subject of further study within the CCIR.

D. Echo and Delay in Satellite Communications

High altitude communication satellites, such as those in geostationary orbit, are often subject to criticisms directed at echo and delay associated with satellites.

It is well known that the effect of echoes in voice communications, when accompanied by a substantial transmission delay, can be detrimental to the quality of communications. In data communications as well, the propagation delays imposed by satellite connections may require special considerations. Yet there are techniques available today that effectively deal with the adverse effects of echo.

The results of subjective tests performed by AT&T[45] and the TransCanada Telephone System[46] provide substantial evidence that through the proper use of echo control devices, voice communications carried via satellite can be equivalent in quality to those carried by terrestrial-based radio and cable systems.

The problems associated with long transmission delays in certain data communication applications can be minimized through the use of protocols that effectively compensate for the delay.

The principal recommendations concerning limitations on propagation delay and the appropriate use of echo control devices are contained CCITT Recommendation G.114.

1. <u>CCITT Recommendation G.114: Limits on Propagation Delay and Use of Echo Control Devices</u>

G.114 states:

"The times in this Recommendation are the means of the propagation times in the two direction of transmission in a connection. When opposite directions of transmission are provided by different media (e.g. a satellite channel in one direction and a terrestrial channel in the other) the two times contributing to the mean may differ considerably."

1. <u>Limits for a connection</u>

   It is necessary in an international telephone connection to limit the propagation time between two subscribers. As the propagation time is increased, subscriber difficulties increase, and the rate of increase of difficulty rises. As a network performance objective, the CCITT therefore recommends the following limitation on mean one-way propagation times when echo sources exist and appropriate echo control devices, such as echo suppressors and echo cancelers, are used:

   a) 0 to 150 ms, acceptable;

   b) 150 to 400 ms, acceptable, provided that increasing care is exercised on connections when the mean one-way propagation time exceeds about 300 ms, and provided that echo control devices, such as echo suppressors and echo cancelers, designed for long-delay circuits, are used;

   c) above 400 ms, unacceptable. Connections with these delays should not be used except under the most exceptional circumstances.

The Recommendation continues:

2. Values for circuits

   2.3 International Circuits:
   The magnitude of the mean one-way propagation time for circuits on high altitude communication satellite systems makes it desirable to impose some routing restriction on their use. Details of these restrictions are given in Recommendation Q.13.

And, from the conclusion of Annex A to the Recommendation:

> In public telephone networks, only connections which do not contain more than one satellite hop should be permitted. Two hops can only be tolerated in special cases. Connections with more than two hops are totally unsuitable for telephony.

The fact that this Recommendation suggests limitations on the mean values for one-way propagation times is significant and implies certain limitations on the use satellites.

When used to carry transmissions for both directions of a connection, the use of satellites would be limited to one up-link, one down-link, and one intersatellite link. The use, for instance, of a satellite link to carry the international portion of a call, combined with another satellite in the domestic long-distance network, would be prohibited. This does not mean, however, that a double-hop satellite link is always prohibited. For example, if a double-hop satellite link is used for transmission in one direction, and a terrestrial channel in the other, the limitations on mean one-way propagation time can be met. This is effective because the total round-trip time is significant, not only the one-way delay.

2. Implications for Data Communications

Communication system designers must take the delay characteristics of satellites into account when establishing timing limits on acknowledgements, handshaking*, count-down timers, etc. These limits must not be less than some reasonable minimum amount of time required for the transmission of data via satellite. A reasonable value might consist of: a) the best case minimum propagation time possible with satellites (earth stations in close proximity); b) some time for additional transmission delay due to earth stations located far apart from each other; c) some small allowance for variations in transmission delay due to orbital perturbations; d) some allowance for an intersatellite link; e) some allowance for on-board switching or signal processing; and f) some allowance for the delay encountered in terrestrial-based switching and transmission facilities. Items b)

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*"Handshaking" describes a mode of communication between two electronic devices. One device sends a signal (extends its hand) to a second device in an effort to initiate communications. If the second device does not assert the appropriate response (extends its hand to the first device) within a specified amount of time, the communication is terminated.

through f) above will be relatively small compared with the 260ms single-hop one-way transmission delay and may not be applicable in all cases but must be taken into account.

In the ISDN, the communications protocols are currently being designed around the seven-layer Open Systems Interconnection (OSI) reference model. Complete specifications for the OSI model are currently undergoing development within the ISO. At this time, it appears that the protocols can be made to accommodate satellites in compliance with the OSI model. It is essential, however, that the interests of the satellite industry be represented, through continued participation in the appropriate standards making bodies, to ensure total compatibility with developing protocols and standards. Therefore, a thorough understanding of the standards making process (as discussed in Chapter VII) is essential in forming an ISDN environment receptive to a strong satellite presence.

E. Areas for Further Study

In setting an agenda for study, the CCIR has listed a number of areas. Contained in Question 29/4, for example, are three general areas for study:[47]

(1) What are the preferred satellite system characteristics significant for digital transmission networks?

(2) What are the implications of multiple satellite hops and inter-satellite links on various types of digital services?

(3) What are the optimum interface characteristics for the transmission of various kinds of digital traffic (e.g. telephony, television and data)?

The CCIR has further recommended that a number of additional more specific studies should be conducted in areas such as:

(1) determination of the impact that Low Rate Encoding and Digital Speech Interpolation might have on the characteristics of voice and data communications in digital satellite systems;

(2) identification of the various points at which digital satellite systems might interface with a digital network and determination of the characteristics of such interfaces;

(3) determination of availability and performance criteria (e.g. phase jitter, slips, bunched digital errors) at the relevant interfaces; and what coding/decoding techniques for error correction, if any, may be needed to meet the performance criteria;

(4) determination of how best to accommodate elastic buffering to compensate time delay variations due to satellite movement;

(5) determination of the impact, if any, of ISDN services on satellite system design;

(6) determination of satellite system characteristics which are of significance for data transmission and the similarities with, and differences from, terrestrial networks;

(7) the impact on current data networks or services of factors relating to satellite systems, in particular the transmission delay and its periodic daily variation;

(8) solutions which might offset the potential unfavorable effects of satellite systems on existing data services;

(9) error-correction systems better suited to data transmission by satellite (coordination with CCITT Study Group VII is required);

(10) the means of integrating satellite systems into international data networks;

(11) high-speed services that can be provided by satellite and are comparable with the facilities offered by terrestrial networks;

(12) the effect of multi-destination and multiple access satellite characteristics on data network topology; and

(13) determination of the extent to which satellite[48] system design may need to take account of OSI layered protocols.

F. Summary Technical Aspects

CCITT Recommendation G.821 sets performance standards for any international connection that is part of an ISDN whether or not satellites are involved. CCIR Recommendation 614 establishes the performance objectives for satellite systems forming part of an international connection in an ISDN necessary to comply with the overall quality standards required by CCITT Recommendation G.821. Report 997 provides supporting material to Recommendation 614. CCITT Recommendation G.114 sets generally applicable standards for echo and delay which satellites must meet and which present a challenge to satellite designers.

These recommendations have been formulated to serve as guidelines in the design and planning of satellite communication systems. The constraints on system design imposed by these recommendations do not appear to be overly stringent and could result in the realization of economical satellite systems ensuring the role of satellites in the ISDN as it develops in the future. At the same time, it is clear that there remain numerous technical issues to be addressed. In seeking the appropriate role for satellites in ISDN, it will be important for the satellite community to be actively involved in meeting the current technical objectives (as contained in the above Recommendations and Reports) as well as to anticipate future technical requirements (as suggested by areas for future study).

VII. UNDERSTANDING THE STANDARDS PROCESS

This section examines the ISDN standardization effort and the primary factors influencing its pace and direction.

Standards for ISDN will define the system, determine equipment that can be used, and set protocols for use of the system: thus they are a critical part of ISDN and important with respect to the inclusion of satellites. The process itself is dynamic and still taking shape. Standards that are too rigid may delay adoption of the system while standards that are too loose may preclude the needed degree of integration. Early standards may freeze immature technology while late ones may face too many existing systems. It is important, therefore, to have a clear understanding of the process of standardization since it has a direct bearing on the utility of satellites in ISDN.

A. CCITT as the Focal Point of International Activities

The CCITT has had the responsibility of providing standards and operating guidelines for international telephony networks since its inception. In the 1960's, as digital transmission technology began to be implemented in the national networks of member countries participating in CCITT, the transition of telephone networks from analog to digital technology was a natural area for further study. As early as 1972, CCITT had formulated two definitions describing this development: First, "An integrated digital network (IDN) is a network in which connections established by digital switching are used for the transmission of digital signals." The second definition read:

> An integrated services digital network (ISDN) is an integrated digital network (IDN) in which the same digital switches and digital paths are used to establish connections for different services.[89]*

With these initial definitions as a foundation, work continued throughout the 1970's, resulting in an expanded list of conceptual principles that were accepted at the 1980 Plenary Assembly. Study Group XVIII was created by the Plenary Assembly to carry this work forward, and to coordinate ISDN related work of other groups during the 1981-1984 Study Period. The other groups with a particular interest in ISDN are Study Groups VII, XI, and XVII. A complete list of CCITT Study Groups is shown in Table 2.

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* This definition has since been superceded by the definitions in Chapter I.

Table 2
CCITT Study Groups (SG), 1985-1988 Study Period[50]

SG-I:	Definition, operation and quality of service aspects of telegraph, data transmission and telematic services (facsimile, Teletex, Videotex, etc.)
SG-II:	Operation of telephone network and ISDN
SG-III:	General tariff principles including accounting
SG-IV:	Transmission maintenance of international lines, circuits and chains of circuits; maintenance of automatic and semi-automatic networks
SG-V:	Protection against dangers and disturbances of electromagnetic origin
SG-VI:	Outside plant
SG-VII:	Data communication networks
SG-VIII:	Terminal equipment for telematic services
SG-IX:	Telegraph networks and terminal equipment
SG-X:	Languages and methods for telecommunications applications
SG-XI:	ISDN and telephone network switching and signalling
SG-XII:	Transmission performance of telephone networks and terminals
SG-XV:	Transmission systems
SG-XVII:	Data transmission over the telephone network
SG-XVIII:	Digital networks including ISDN

As a result of intensive effort during the 1981-1984 Study Period, the I-Series Recommendations were created, establishing the general principles of ISDN, as well as detailed specifications of the user-network and internetwork interfaces (see pages 13-18). Building on the initial I-Series Recommendations, Study Group XVIII of the CCITT has continued to be the focal point for international ISDN standardization during the 1985-1988 Study Period. Work within the Study Group for the current study period has been divided among eight Working Parties listed in Table 3.

Table 3
Study Group XVIII Working Parties for the 1985-1988 Study Period[51]

XVIII/1	Service aspects
XVIII/2	Network aspects
XVIII/3	User-network interfaces, layer 1
XVIII/4	Architecture and models
XVIII/5	Maintenance and general aspects
XVIII/6	Performance aspects
XVIII/7	Transmission aspects
XVIII/8	Speech processing

During the current study period, many of the interim standards which carried over from the 1981-1984 period have been enhanced and expanded. There has also been a considerable amount of work done on standards for broadband ISDN. Many of the more important draft Recommendations that have been completed are being submitted to an accelerated procedure for provisional approval prior to the 1988 Plenary Assembly. CCITT instituted this accelerated procedure to accommodate the fast changing nature of the technology and to allow completed Recommendations to be approved and put into use as needed between Plenary Assemblies which occur at four year intervals.

In addition to participation by the more than 160 member countries of the ITU, CCITT enjoys participation from numerous recognized private operating carriers (RPOAs, e.g. AT&T), scientific and industrial organizations (SIOs, e.g., IBM) and international organizations (e.g.,Intelsat). As an incentive to participate, membership rates for these groups are only one-fifth those of member countries, resulting in the cooperation of practically the entire telecommunications industry. Presently, there are 147 manufacturers and 56 network operators participating.[52] This high level of industry participation is one of CCITT's greatest strengths, resulting in considerable influence in the international arena.

Given this broad international support, and the potential ramifications of international standards developed by CCITT, many countries have established national standards organizations designed to follow the progress of CCITT very closely. In the U.S., this is done through ECSA's T1 committee which has the technical expertise, and a group, the "U.S. CCITT", which coordinates various contributions from U.S. participants in an attempt to present unified U.S. positions at CCITT meetings.

Within the U.S., the T1 Committee enjoys the same level of industry support that CCITT has on an international level. T1 committee membership categories include: exchange carriers, inter-exchange carriers and re-sellers, manufacturers and vendors, and general interest, which includes government agencies, consultants, user groups and liaisons with other committees. The T1 committee currently has six technical subcommittees, listed in Table 4.

Table 4
T1 Technical Subcommittees*[53]

T1C1	Carrier-CPE Interfaces
T1D1	ISDN
T1M1	Internetwork Operations, Administration, Maintenance and Provisioning
T1Q1	Performance
T1X1	Carrier-Carrier Interfaces
T1Y1	Specialized Subjects

Subcommittee T1D1 is concerned with all aspects of ISDN, and prepares positions on ISDN matters for submission to the U.S. CCITT and other standards organizations. T1D1 has three Working Groups:

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* The T1 technical subcommittees have since been restructured. T1C1 and T1D1.3 have been merged to form T1E1. Similarly, T1X1, T1D1.1, and T1D1.2 now form T1S1. The net result has been to integrate ISDN across the subcommittee structure, indicating a further degree of growth in ISDN.

T1D1.1 - ISDN Architecture and Services
T1D1.2 - Switching and Signalling Protocols
T1D1.3 - Physical Layer

Although the T1 committee is less than four years old, it has already assumed the position of the most important U.S. standards committee related to ISDN, with subcommittee T1D1 leading this effort.

B. The Influence of Other Standards Organizations on ISDN

Given the large scope of ISDN standards development, the CCITT cannot and has not worked in isolation from other standards organizations that are either directly or indirectly impacted by ISDN standards. The input of these other standards organizations has had an influence on the evolution of ISDN standards development. CCIR's expertise in fixed satellite services and ISO's input regarding compliance with the Open Systems Interconnection Model (OSI Model) are two examples of this influence.

As a result of cooperation between the CCITT and CCIR several recommendations have been changed to document explicitly the recognition of satellites as a possible component in the implementation of ISDN. This cooperation has been formalized by the creation of CCIR's Interim Working Party 4/2, and by liaison representation from CCITT. Good progress has been made, although not all of the issues have been resolved (see pages 54-57), and this working relationship is likely to be maintained as ISDN standards continue to evolve.

In the case of the OSI Model (which is in the domain of ISO) the CCITT has taken several steps to ensure that ISDN standards are developed in accordance with the concepts of the model. Most importantly, CCITT has taken ISO's International Standard #7498, which describes the OSI Reference Model, redrafted it using its own terminology, and adopted it as standard of its own, known as Recommendation X.200. Aside from minor differences in terminology, these two standards are virtually identical. Consequently, CCITT is giving due consideration to how the OSI Model affects ISDN, since CCITT tries to coordinate all of its own standards so as to minimize contradictions or areas of conflict.

Beyond procedural considerations, the ISDN standards themselves reflect an effort to fit ISDN into the OSI Model wherever it makes sense to do so. For example, definition of user-network interfaces in ISDN comprise the first three layers of the OSI Model. Specific protocols, such as the LAP-D protocol for ISDN signaling on the D channel, conform closely to the

HDLC* protocol of the OSI Model.

The OSI Model is evolving in much the same way that ISDN standards are evolving, and there will be a continued mutual ---- influence between the two efforts in the future. Formal liaison agreements now in place should facilitate the necessary exchange of planning and technical information so that this parallel evolution could take place in a smooth and efficient manner, and so that the evolution for both systems would be complementary.

C. The Debate over Dominant Vendors

Dominant vendors (i.e., AT&T, IBM) obviously have an interest in the standards process. There is however, some debate over the degree of influence they may have vis-a-vis small vendors.

One the one hand, there has been some concern that large companies with dominant positions in the marketplace may exert undue influence because they are able to send more people to more meetings, thus ensuring that the company's interests are expressed and protected. In addition, the larger, established companies may enjoy an advantage due to the *de facto* standard which their product already may have set in the market place.

On the other hand, the potential for undue influence appears to be largely neutralized through the voting structure of committees like CCITT and T1, which allow only one vote per vendor. In some cases, such as AT&T and GTE, two votes are allowed; one as a network provider and one as an equipment manufacturer. However, there is no weighted voting process built into the system and thus a small vendor's vote counts the same as a large vendor.

D. The Role of the ITU

Once a particular question or project comes to the ITU for study, a determination must be made as to which Consultative Committee and which Study Group or groups should be involved. In determining which organization should be responsible for which areas of standardization, differences are resolved at a high level between the administrations of the standards organizations, presumably with a certain amount of negotiation and compromise. Although all of the organizations involved in this activity have an international scope, the ITU is the only

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* HDLC-- High Level Data Link Control. A bit-oriented synchronous transmission protocol defined at the data link layer of OSI model. See page 9 for layers of the OSI Model.

organization established by formal government-to-government treaty; both ISO and IEC may defer to the decision of the ITU in areas where national governments are directly involved.

Within both CCITT and CCIR, questions and projects are assigned to study groups at the Plenary Assembly which takes place every four years. At the study group level, working parties follow ITU procedures for the submittal of "contributions" to the full study group. Consensus must be achieved among the working group doing the work before draft recommendations can be passed up for approval by the Study Group and ultimately by the Plenary Assembly.

E. Interpretation and Implementation of Standards

Ambiguity in the language or various options written into a standard can lead to problems of interpretation and implementation. Reconciliation at this stage often occurs outside the context of the standards-making body that produced the standard.

The problem of interpretation and implementation is being addressed in the U.S. and in Europe. The Corporation for Open Systems (COS), in conjunction with NBS, is working to establish common interpretations of standards so that their full benefit can be realized by users, carriers and equipment manufacturers. In Europe, the common market has passed a "recommendation" (not to be confused with CCITT Recommendations) which defines deadlines and specifications of what services will be offered throughout the 12 countries that comprise the European Community, to encourage the introduction of a single version of ISDN.[54] Prior to the Parliamentary recommendation, each European PTT would comply with international standards for connecting networks, while implementing country-specific user interfaces and services not specified by the standards. This was done intentionally to maintain relationships with preferred equipment suppliers. Although the PTTs favored the old approach, multinational users in Europe found the practice very frustrating and expensive.

The European shift towards standardized user interfaces is in marked contrast to the ongoing struggle to include a specification for the "U" reference point interface into the CCITT Recommendations for ISDN. The essence of the problem is shown in Figure 2.

FIGURE 2

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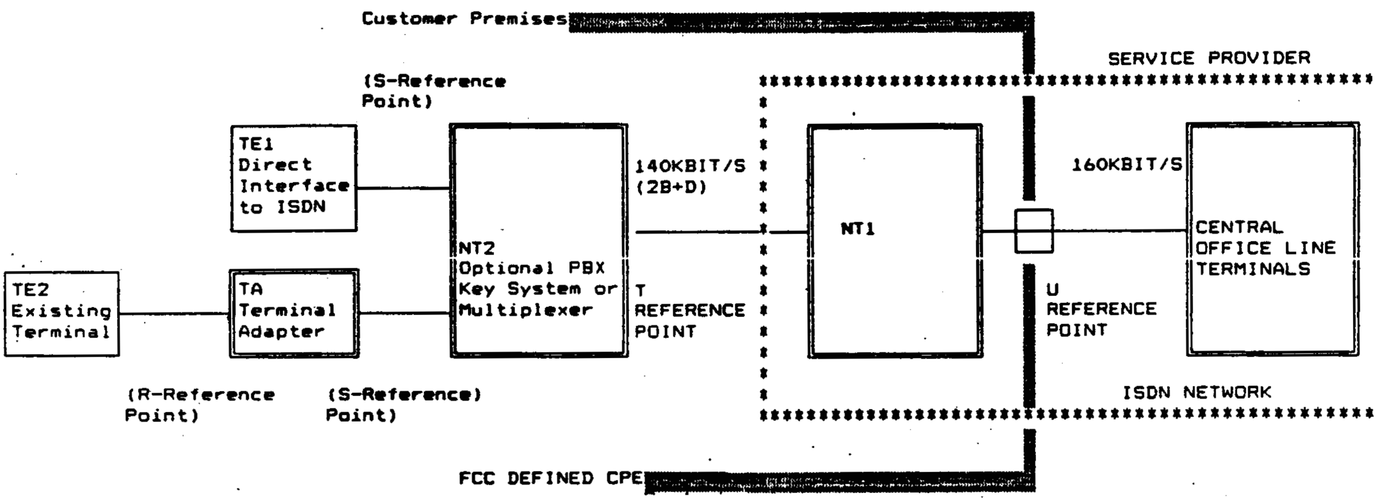

ISDN User-Network Interface Reference Model showing the location of the U Reference point. Asterisk line denotes ISDN network boundary as interpreted by most countries. Solid line denotes FCC-defined Customer Premises Equipment boundary.

As a result of an FCC ruling, in the U.S. competitive telecommunications marketplace the network termination equipment (NT1) is considered to be customer premises equipment and not part of the network. Consequently, there is a need to standardize the U interface on the network side of the NT1 for the U.S. market. In virtually every other country in the world, the NT1 is considered part of the network and is owned by the service provider, not by the customer. The interface between the central office and the NT1 is therefore not subject to ISDN Recommendations.[55]

The U reference point interface is a good example of the importance that a particular standard can have and how, subject to interpretation, a part or parts of a network can be considered either subject or not subject to applicable Recommendations.

VIII. ENSURING A ROLE FOR SATELLITES

If satellites are to play an important role in ISDN, there are several steps that can be taken now. These can be broadly grouped into four categories: 1) obtaining the necessary space resources; 2) meeting the technical challenges; 3) impacting the standards process; and 4) promoting the technical and operational advantages of satellites to users.

A. Obtaining the Necessary Space Resources

Space resources, in this context, includes primarily both the appropriate bands of radio frequencies that permit the transmitting signals to satellites and re-transmitting the signals to ground receivers and the appropriate geostationary orbital positions in which to station communication satellites. Making certain that the necessary radio frequencies are allocated to the various satellite communication services is only one part of the challenge facing satellites. Obtaining the right to use frequencies in the allocated bands, and the accompanying geostationary orbital position, without suffering harmful interference from other satellite communication systems is another area of importance concerning resources.

For governmental or private entities that intend to provide a satellite communication system, the process of obtaining resources has two parts, both of which are important to understand.

First, the right to use the space resources in question must be recognized and approved by an agency of the user's own government. Second, the use of the space resource must be recognized by an agency of the International Telecommunication Union, the International Frequency Registration Board (IFRB).

Two different procedures for obtaining this right to use certain frequencies and the associated geostationary satellite orbital position have evolved: the first-come, first-served procedure and the *a priori* procedure. The first-come, first-served approach is based on national telecommunication administrations notifying the ITU's International Frequency Board of frequencies to be used by domestic radio stations if: 1) the frequencies in question are capable of causing harmful interference to any other radio service; 2) the frequencies are to be used for international communication; or 3) the administration desires "to obtain international recognition of the use of the frequency."[58] This process is still the prevailing rule though there has been continuing pressure from the developing world for an *a priori* assignment process. Such an approach, if adopted by the ITU, would involve the allotment of space resources to countries according to a pre-arranged formula, perhaps through the medium of a formal treaty.

Assured access to necessary space resources is an obvious prerequisite if satellites are to play a role in ISDN. The next ITU World Administrative Radio Conference at which the allotment process will be discussed and possibly altered, will be held in 1988. With respect to satellites in ISDN, this is the forum within which the "raw resources" for satellite operations will be determined. Thus, the importance of the process of allocation cannot be over-emphasized for without these base resources, satellites will have no firm foundation for a future within ISDN.

Two additional resource areas are worth noting. First, satellite operators must be able to launch and correctly orbit their satellites. Availability of launch services and related support (including insurance) cannot be ignored as a resource issue. Second, operators will be faced with the increasing potential for damage by space debris. These two real problems are outside the scope of the present report but neither can be overlooked as an issue.

B. Meeting the Technical Challenge

A vitally important part of encouraging a role for satellites in ISDN will be the ability to meet the technical challenges that evolving standards may pose. As a point of departure, the list of CCIR "Areas for Further Study" presented earlier in this report (see pages 37-38) should be fully studied. Though this initial list may not be comprehensive, it does illustrate the scope of technological efforts needed to ensure a role for satellites in ISDN.

C. Impacting the Standards Process

It is important for representatives of the satellite industry to expand and strengthen current efforts aimed at participating directly in the development of standards for ISDN. Impacting the standards process however, will require more than just organizational representation.

The "Satellite Coalition & ISDN" has already identified areas that need to be addressed if satellites are to impact the standards process more effectively. The coalition has identified the prominent standards-making bodies and agreed that their efforts should be focused on participation in the key national and international groups; in particular subcommittee T1D1 and CCITT Study Group XVIII.[57]

To be effective, the strategy of participation must be driven or guided by clear objectives, each aimed at enhancing the perceived value of satellites in ISDN. Part of the problem may stem from the lack of visibility of the satellite community in the definition of the network architecture and models of the ISDN. In an effort to enhance the recognition of satellite capabilities in the ISDN a number of contributions were submitted to the CCITT meeting in July, 1987 suggesting modifications to appropriate ISDN-related recommendations in order to more adequately reflect the advantages of satellites in the ISDN (e.g., their natural point-to-multipoint ability, and the possibility of non-hierarchical networks with distributed earth stations extending to locations relatively close to the end user). The contributions were considered to be relatively successful but more are needed.[58]

Two other standardization efforts paralleling the development of ISDN that require particular attention are the OSI reference model and Signaling System No. 7.

The OSI reference model is an architecture that describes how data communications protocols should be structured. The OSI model is well on its way to becoming an internationally accepted standard, along with the HDLC protocol. It was noted by the coalition that while presently, both the OSI reference model and Signalling System No. 7 can be made to be essentially satellite compatible, attention must be given to assure that they continue to remain so. For example, only the first three of the OSI model's seven layers are well defined. As the other layers are defined, principally under the direction of users, care should be taken to ensure their compatibility with satellites.[59]

Signaling System No. 7 is the common channel signaling system that will be an integral part of ISDN. The system as designed should work well with both land-based and satellite links, provided that the delay characteristic of satellites is taken into account when the transport protocols are established. A member of the satellite coalition commented that in the video-conferencing area, a move towards certain standards, including standards for delay, could discriminate against satellites. The coalition has agreed to monitor these developments in an effort to ensure full compatibility between satellites and Signaling System No. 7.[60]

An important underlying issue that the satellite and ISDN coalition has identified is that satellite communications suffers from a poor public image - primarily in regards to echo and delay, security, and overall transmission quality. Though the use of echo cancelers and other advances in technology can be successful in solving the fundamental problems of echo and noise, this is generally not perceived as such by users. This "image problem" has been seen by many members of the satellites and ISDN coalition as the most serious obstacle facing satellites in their attempt to assume a full role in ISDN.[61]

The coalition has taken some specific steps towards meeting the challenge of ISDN. They have, for example, agreed that the collection of additional data on satellite echo and delay would be helpful and that further studies on "pure" delay (without echo) may be required. They further agreed that a public relations campaign emphasizing the positive aspects of satellites, including their flexibility and digital transmission capabilities, would be beneficial in strengthening the image of satellites held by users and systems planners. In addition, the need for better studies of the relative strengths of fiber optic vs. satellite has been recognized.

D. Promoting the Use of Satellites

In order for satellites to enjoy widespread acceptance and application in an ISDN world, they must do more than merely achieve technical compatibility with ISDN standards. The satellite industry should strengthen efforts aimed at promoting the inherent operational, technical, and economic strengths that satellites have over fiber optic and other terrestrial-based communication systems. A strategy of promoting the use of satellites can be built around areas where satellites are competitive or have a distinct comparative advantage. These would include, but may not be limited to:

-- point-to-multipoint communications.

-- high quality, high capacity international point-to-point communications.

-- thin-route applications for low volumes of traffic.

-- mobile-satellite communications and related applications such as RDSS (Radio Determination Satellite System)*.

-- inherent flexibility that can be used to adjust network configurations dynamically or to accommodate sudden increases in demand for transmission capacity.

-- the fact that satellite networks are easily and quickly implemented. If the proper satellite is in operation and available a system can be brought on line almost immediately after installing the necessary earth station user equipment.

-- the ability, through VSATs, to bypass local telephone company access charges.

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* RDSS allows the tracking of, and message dispatch to, mobile fleets that may be air, land, or sea-based.

-- satellites are only system today that can offer a capability for global connectivity in ISDN.

-- broadcast

IX. SUMMARY AND IMPLICATIONS FOR NASA

The National Space Act of 1958 gives NASA broad statutory authority to engage in space applications research and development. Section 102(c)(5) of the Act calls for NASA to preserve "the role of the United States as a leader in aeronautical and space science and technology and in the application thereof to the conduct of peaceful activities within and outside the atmosphere."[62] In addition, The President's February 1988 National Space Policy clearly supports NASA's institutional role in assisting commercial efforts in space as long as direct subsidies are not involved. These two instruments give NASA the authority to do space applications related to ISDN. How that authority can be used to define an effective role for NASA in ISDN is addressed here.

Efforts aimed at an Integrated Services Digital Network global telecommunication system are currently underway on various national and international levels. To some extent, ISDN is still a concept though some significant pilot projects have been initiated, plans are being made, and detailed discussions on the expected standards have already taken place. Within this setting, the future role of satellites in ISDN is being determined.

ISDN *per se* is not a threat to the satellite communications industry; optical fiber is the technology that could take much of the business. However, ISDN -- apparently a neutral concept -- could be the tool used to give traffic to optical fiber at the expense of satellites. As part of its statutory role to support the application of space technology, NASA should work towards ensuring that satellites evolve in parallel with ISDN and that appropriate standards are developed.

NASA has a history of successful flight projects, and is moving to add the Advanced Communications Technology Satellite (ACTS) to that record. However, NASA may be entering a new era in which (i) funds for major flight projects will be hard to find; and (ii) the communications program is being given a new mission -- helping science and applications programs. It is thus important that a new selective strategy be developed -- a focused effort -- through which the agency may best achieve its various goals synergistically.

The "Satellites and ISDN Coalition" is potentially a key actor for its existence gives NASA a place to interact strongly and effectively with industry while remaining within the proper role for a government agency. The coalition and NASA can have independent but complementary, mutually reinforcing programs to ensure that satellites have their proper place.

Three kinds of activities seem appropriate in a program to support satellite communications: They could be called technical, supporting, and liaison. All of these will interact, e.g., the results of technical activities might determine which supporting activities are carried out, and be disseminated through liaison activities.

Technical activities would include attacking the problems listed on pages 33-34 of this study, perhaps by putting experiment packages on NOAA or DoD satellites. There is also a need to review the situation to see if other technical problems have become more pressing. Experiments need to be conducted to test the feasibility of proposed standards. In addition, field trials involving satellites and ISDN must be supported. Such research may reveal that new technology needs to be developed. In all these activities (i) ground equipment should be considered, perhaps even more strongly than satellites; and (ii) the use of ACTS should be considered.

Supporting activities encompass those activities needed to make the standard setting process work <u>for</u> satellites instead of being negative or neutral. This must involve active, strategic support of the whole process. For example, it is necessary first to know in detail the players and the timetable. Often the U.S. position taken to an international standard meeting is coordinated only at the last minute. In this situation it is easy for specific considerations -- for example, the need to account for satellite characteristics -- to be overlooked. Thus there is a need to convene meetings at the appropriate time to exchange information and develop consensus. There is also a need to attend and support meetings. The National Bureau of Standards for years has encouraged its staff to support voluntary standards organizations, for example by becoming the secretary to a committee; they have found this to be an effective way to advance their goals. Overall, in these supporting activities there is need for consultation and coordination with industry.

Liaison activities can ensure a broadly coordinated effort in support of satellites. Some coordination with industry can be achieved through the ISDN coalition, if its membership remains broad, but more is needed. Specifically: (i) There is a need to coordinate with foreign space agencies. They should have an influence on their national PTTs which should in turn facilitate the adoption of international standards friendly to satellites; (ii) There is a need to work with other agencies interested in satellite communications, e.g., DoD and NOAA, and with other parts of NASA (Code T). It may be possible to use TDRSS for some technical activities. The DoD may be able to influence foreign defense ministries to support satellite-friendly standards.

Overall, the goal is to selectively promote satellites where they are strongest, and if necessary to do the work to prove their strength and improve their image. There are two inherent advantages to a NASA-ISDN strategy based on technical, supporting, and liaison efforts.

First, the strategy is relatively low cost, e.g., no new flight projects are required in order to make significant near-term progress on technical ISDN/satellite questions. Similarly, supporting and liaison are comparatively low-cost and low risk investments on NASA's part.

The second advantage concerns NASA's traditional role in serving the communications satellite industry. The rapid pace of changes in the ISDN environment and the complexity of participants in the standards process has created a need for a focused source of information and support for satellites in ISDN. Fulfilling that role through technical, support, and liaison activities affords NASA a timely opportunity to take the initiative and reach out to effectively support the needs of the communications satellite industry.

For NASA and the future of the communications satellite industry, ISDN can either be a problem or an opportunity. Failure to recognize and adapt to the changes of an ISDN world will clearly lead to problems for satellites. On the other hand, the question of ISDN and satellites creates a unique opportunity for NASA to effectively support the satellite communications industry and, from a broader perspective, assist in maintaining U.S. technological and economic preeminence in an emerging new field of communications.

GLOSSARY

B. Channel: 64 Kbps. The basic user channel used to carry digital data.

COS: Corporation for Open Systems. An American organization whose main objective is to promote compatible implementation of standards for open systems. COS is not a standards making organization and works closely with the National Bureau of Standards.

CCITT: International Consultative Committee on Telephone and Telegraph. An international committee established to promote standard for the development of telephone, telegraph systems and data networks, and to create the environment of interworking between the networks of the different countries of the world. This committee is set up under the International Telecommunication Union (ITU).

CCIR: International Consultative Committee on Radiocommunications. An international committee established to promote standards for the development of radio communication and set up under the International Telecommunication Union (ITU).

D Channel: 16 Kbps (basic access) and 64 Kbps (primary access). Carries signaling information to control circuit-switched calls and is also used for packet-switching or low speed telemetry.

ECSA: Exchange Carriers Standards Association. An American trade association and independent standards committee whose main objective is to develop and promulgate standards to enhance the existing nationwide telecommunications service and to encourage compatibility of carrier services.

ECS: European Fixed-Service Satellite System. A communication satellite system established by the Interim Eutelsat to provide service between fixed earth terminals.

FSS: Fixed-Satellite Services.

HRDP: Hypothetical Reference Digital Path. A CCIR digital model to assist in proper allocation of circuits.

HRX: Hypothetical Reference Connection. A CCITT digital circuit model which allows for extensive performance monitoring.

IDA: Integrated Digital Access. The first step towards full ISDN, IDA permits uniform connection to telecommunications services.

INS: Information Network System. INS combines ISDN with intelligent communication processing nodes, allowing a wide range of information and communication modes to be accommodated in a single network system.

ISO: International Standards Organization. An international committee whose main objective is to provide a standard for open systems architecture via a reference known as OSI (Open Systems Interconnect), first published in November 1978.

ITU: International Telecommunication Union. A special agency of the United Nations whose main objectives are:

1. The promotion of international cooperation for efficient use of telecommunication service;

2. Creation of the widest possible public access to communications facilities;

3. Coordination of activities between national interests in the telecommunication field.

ISDN: Integrated Services Digital Network. A planned worldwide telecommunication service that will use digital transmission and switching technology to support voice and digital data communication.

IWP 4/2: Interim Working Party. A group within the CCIR, under Study Group 4, dealing specifically with fixed-satellite services operations and performance criteria.

SS #7: Signaling System #7. A specification of the protocol and network for ISDN signaling, the SS #7 is a method of common channel signaling.

"U" interface: The notion that a transmission line from the local telephone company is essentially interfaced with the customer premise as bare wires.

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