Chapter 3

Technology Links: Choices for Distance Learning Systems

Photo credit: AT&T Archives

Microwave radio relay tower, Albany, TX

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Technology Links: Choices for Distance Learning Systems

INTRODUCTION

Ten years ago the technological options for delivering education over a distance were limited. Today, they are numerous and growing. **Advances in information and telecommunications technology are rapidly expanding learning opportunities and access to educational resources beyond those immediately or traditionally available.** These technologies, both new and old, allow users to transmit, receive, create, and combine information in many new ways. Such advances are a major force in the explosive growth experienced by distance learning in business, higher education, and now K-12 schools in the last several years.

Today's technologies are faster. more powerful, and more flexible than comparable technologies of only a few years ago.[1] The technologies of telecommunications and information processing are also increasingly integrated; technological systems are more intelligent and are more capable of being interconnected with other technologies. The use of digital technology is rapidly changing the nature of telecommunications and information processing, allowing more types of information to be sent, stored, and manipulated more easily and quickly. Finally, easily customized services and hardware allow users to choose and combine technologies in ways that best suit their needs. These developments give educators and students a new set of capabilities and opportunities for teaching and learning.

Schools trying to match technological options to educational needs have a wide range of choices. A number of technologies and technology systems can be used, either separately or in combination. Many of these actual systems were described in chapter 2. Technical choices are best defined by the specific demands of each distance learning situation. A broad examination of the current technologies show what applications the technologies allow and what restrictions they place on teaching and learning. This chapter discusses the technologies for distance learning; analyzes their capabilities and limitations; and discusses relevant regulatory concerns, issues, and implications for the future.

FINDINGS

- **Many technologies are being used to provide education over a distance.** Transmission systems include: satellite, fiber optics, Instructional Television Fixed Service (ITFS), microwave, the public telephone system, and coaxial cable. Any of these technologies can be interconnected to form "hybrid" systems. No **one technology is best for-all situations and applications.** Different technologies have different capabilities and

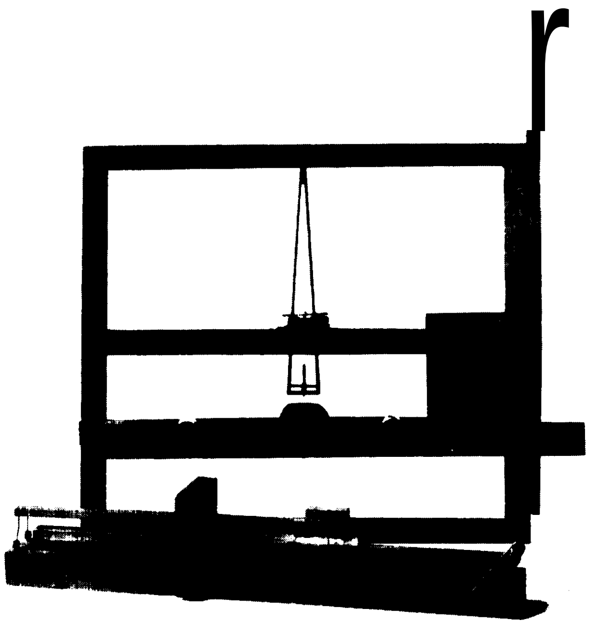


Photo credit: Smithsonian Institution

'Its mighty triumphs are but half revealed, and the vast extent of its extraordinary power but half understood." —an 1851 assessment of the potential of the telegraph.

[1] For a complete review of the forces driving technological change, see U.S. Congress, Office of Technology Assessment, *Critical Connections Communications for the Future*, OTA-CIT-407 (Washington, DC: U.S Government Printing Office, in press).

limitations, and effective implementation will depend on matching technological capabilities to educational needs.

- **The technologies for accessing, storing, and manipulating information have more impact on the distance education experience than the technologies for transmitting signals.** Personal computers, display technologies, optical memory systems, facsimile (fax) machines, and graphics scanners expand the use of information and resources at distant locations.

- **Future developments in transmission, processing, and storage technologies promise even greater capabilities and benefits for education at the same or lower cost.** Advances in digital compression technology, for example, may greatly expand the number of channels that can be sent over any transmission medium, doubling or even tripling channel capacity. **Educational telecommunications systems may also enable new and different uses beyond the traditional school setting. K-12** distance education systems can serve the needs of adult learners, continuing education at home or in the workplace, and the community.

- **The base of telecommunications infrastructure available for distance education is wide and expanding, giving schools an opportunity to utilize existing local resources and forge innovative partnerships. Local,** regional, and even State distance education efforts can be linked with telecommunications networks operated by colleges and universities, local businesses, public broadcasting stations, and State governments. Increasingly, the private sector, including the telephone and cable companies, are becoming active in helping schools expand their teaching and learning opportunities.

- Telecommunications policymaking and regulation is spread across several agencies and levels of government. There is no single focus of or direction to telecommunications policy that can help educators identify the problems and opportunities for educational telecommunications. **Regulatory uncertainties in the telecommunications field make planning for distance education difficult. Public policy changes in the regulation of the public telephone network, for example, will affect how distance education can be provided and how much it will cost.**

- Funding for distance education will compete with other education needs. Although technological capabilities continue to increase even as hardware costs decline, **the overall costs for distance education systems vary widely. The** cost of educational telecommunications systems will be determined in part by the number of sites, instructional demands, technical complexity, and distances involved. Initial equipment costs, while most visible, do not reflect the full costs of the system. Operational and programming costs may require substantial long-term financial commitments.

TECHNOLOGIES FOR DISTANCE EDUCATION

In the most fundamental sense, what distance learning systems try to do is to connect the teacher with the student when physical face-to-face interaction is not possible. **Just as highways move vehicles or pipes carry water, telecommunications systems carry instruction, moving information instead of people.** How these systems affect the educational setting/instructional process depends on the types of technology used and their design. The technology at distant locations, including computers, videocassette recorders **(VCRs), fax machines, television monitors and cameras, and even the telephone, are critically important.** Together, these technologies affect how interaction takes place, what information resources are used, and how effective a distance learning system is likely to be. Some systems allow simultaneous, two-way audio and visual interaction plus an exchange of print materials. Other systems limit interaction to the one-way communication of voice, images, or data. Still others permit only delayed (asynchronous) interaction.

Audio

Live delivery of one-way audio programming is possible through the telephone system or a broadcast radio format.[2] In this format, the teacher speaks to the students, but they cannot respond directly. This lack of direct interaction is compensated for in some

[2] Some developing countries using radio-based distance learning systems also deliver programming by mailing audiocassette tapes to schools that arc too remote or geographically isolated to be reached by radio.

Photo credit: TI-IV

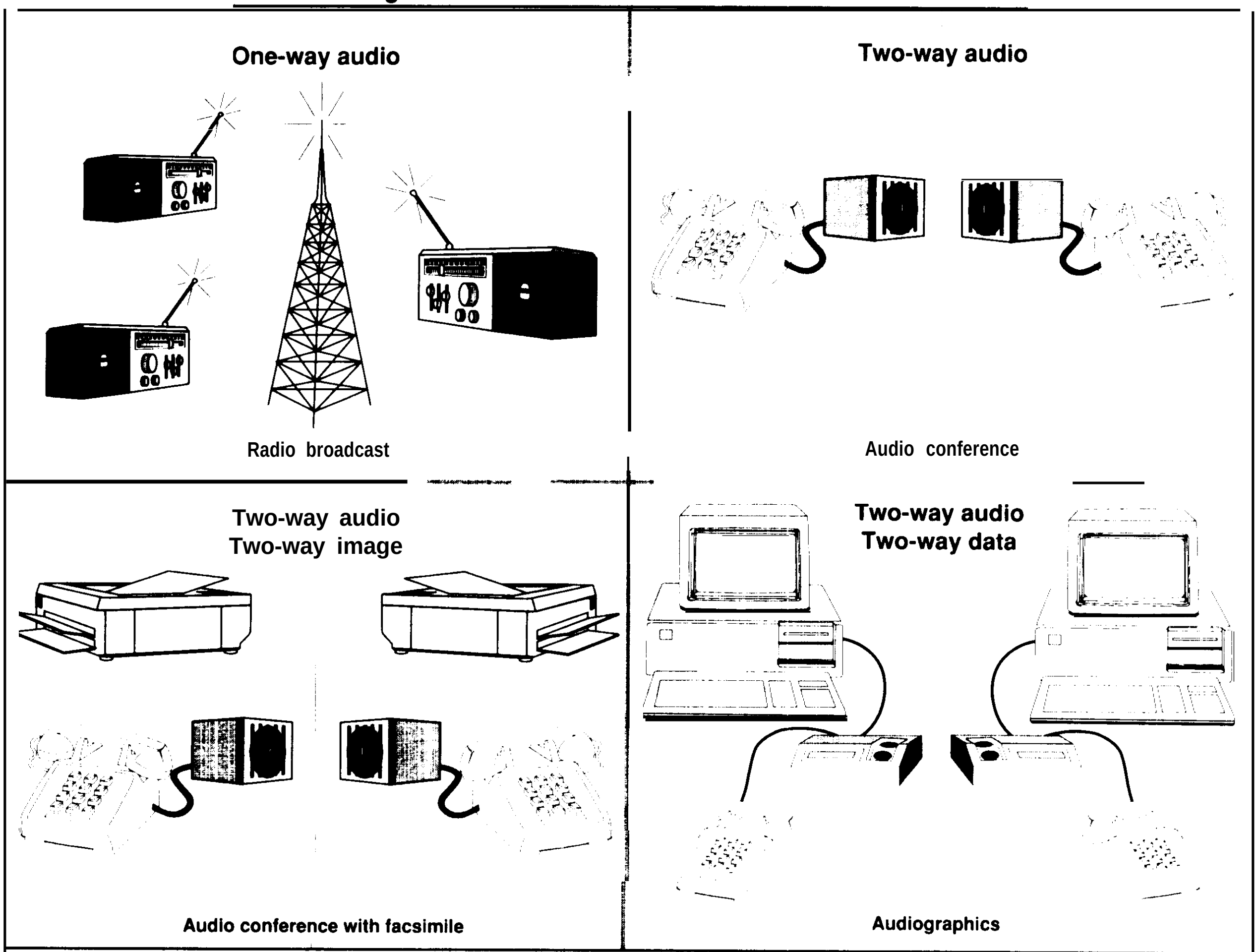
At the push of a button and the twist of a dial, students reach their distant teacher.

radio broadcast formats by a course design that requires students to "talk back" to the radio itself. Broadcast audio has been used extensively for student learning and teacher training in several developing countries, but, despite its extremely low cost, use in the United States has been very limited.[3]

Two-way audio allows both parties to talk and respond. (See figure 3-1.) This may be a simple two-way telephone link between a teacher and a homebound 'student or a "homework hotline," which students dial up to get special tutoring in specific subjects. The use of speaker phones at multiple sites connected by an audio bridging system allows a teacher and students to be connected and talk simultaneously—an extended "party line.'" Two-way communication can also take place asynchronously (not in "real time"). Voice mail systems

[3] For a discussion of various radio instruction projects in the developing countries, see U.S. Agency for International Development, Bureau for Science and Technology, *Development Communication Report, 1988/Special* Issue.

Figure 3-1—Audio Links for Distance Education



SOURCE: Office of Technology Assessment, 1989.

allow students to call-in questions that are recorded in their instructor's voice mailbox. The instructor can respond via voice mail or talk to the student personally. These voice mail systems often supplement other distance learning systems. If more immediate interaction is desired, materials can be sent by fax or other electronic means.

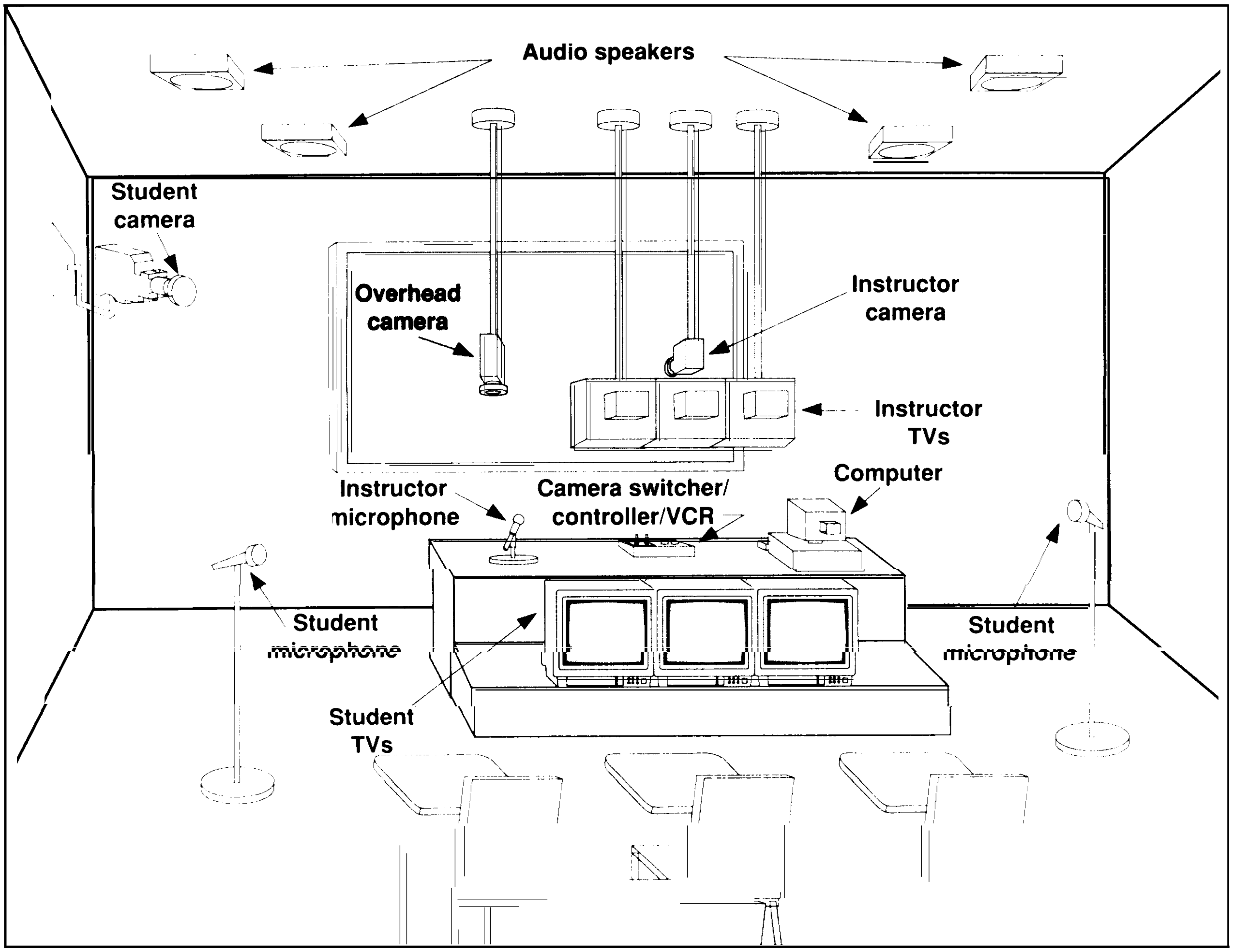
Video

The use of video communications, both one and two way, has increased dramatically in recent years. Factors behind this increase include: the growing availability of high bandwidth transmission paths over satellites and fiber optic links, the decreasing cost of such transmission, and the increasing ability to compress video signals.[4]

There are several formats for transmitting video. Full-motion video signals can be transmitted on television broadcast frequencies, on satellite circuits, over coaxial cable, and over fiber optic lines. Limited-motion or compressed video uses digital technology to reduce the amount of information it takes to send a video signal, making the programming cheaper to send. These signals may appear "smeared" or blurred, but quality is generally good enough for applications where motion is limited.

[4] Advances in compression technology are being made very rapidly. Rates as low as 56 kilobits per second (kbps) are being developed that will transmit video signals. The improvement in quality at lower speeds is also noticeable; images transmitted at 1.544 Mbps are much clearer than those of only 1 or 2 years ago. Rob Stoddard, "Compression's Catching On," *Satellite Communications*, vol. 13, No. 4, April 1989, pp. 31-33. The downside to compression is that the equipment necessary for digital-analog conversion can be expensive, costing up to $60,000. With one codec needed at each end of a transmission line, like a computer modem, total costs can rise quickly in a digital video system with many sites.

Figure 3-2—Two-way Interactive Instructional Classroom



This two-way interactive classroom can function as either a sending or receiving site.
SOURCE: Tele-Systems Associates, Inc., 1989

Compressed video signals can be used on all types of transmission systems except basic telephone lines. For digital video transmission over the public telephone network, special digital lines may be required. The only type of video standard telephone lines can transmit presently is a slow scan or freeze frame image, such as those used in videophone applications, in which a still image is sent approximately every 30 seconds. In the future, high definition television (HDTV) may be used in education. However, standards for HDTV transmission and production are not set, and the development of HDTV remains uncertain.

One-way educational programming is broadcast (point-to-multipoint) via satellite, ITFS, cable television, or public broadcasting systems. In interactive telecourses, one-way video is supplemented by two-way audio, allowing students to ask questions or respond to the teacher in real time. In some systems, a one-way data/text transmission is broadcast along with the video, allowing the student to receive printed material such as homework assignments, handouts, and quizzes.

The VCR extends the use of live instruction by allowing students and teachers to record materials for later use. Teachers can record programming for use in their own lesson plans. Students can record classes, allowing them to "attend class" when it is convenient for them. This capability also allows students to replay sections they did not understand the first time through-in essence asking the teacher to repeat a missed point.

Two-way video allows full audio and visual communication between teacher and student. Because two-way video systems take so much bandwidth to transmit, they generally operate as closed-circuit systems using fiber optic, coaxial cable, or microwave links. These systems are usually local, and involve a limited number of sites. Students at the remote sites can see the teacher, and depending on system configuration, the teacher can see all the students either simultaneously, or sequentially, by switching among sites. (See figure 3-2.)

Computer

Computers in today% classrooms can also be used for distance learning. Personal computers (PCs) can communicate and share information with other PCs or mainframe computers in real time or with some delay (asynchronously) using modems and the public telephone networks

Computer-based applications in distance education can serve as a stand-alone system, e.g., audiographics or computer conferencing, or as a supplement to another system, such as videoconferencing. Computers can also be used by students before and after class either to prepare lesson materials for their distance learning class, or to engage in other learning activities (such as computer-assisted instruction).

Computers linked to remote databases or bulletin board services (BBS) provide students and teachers with access to a wide variety of information and resources. Through a BBS, teachers can keep in touch with colleagues or take professional development classes. Students can "talk" to each other, share data, or receive instruction. On-line courses allow students at home or in computer centers to access coursework day or night. Students work on group projects collaboratively over time (asynchronously) and leave messages in personal electronic mailboxes. Messages can be left 24 hours a day, 365 days a year; users can "go to school" at their own convenience.

With special communications software, teacher and students can communicate in real time using their computers. More advanced software allows the teacher's computer to control the students' computers, allowing the group to see and work on the same screen (text or graphics) at the same time. This function, known as "electronic blackboarding," allows a teacher to reach a homebound student, for example. If more than two sites are to participate in the lesson, a telecommunications bridge linking all users simultaneously would be required,

Computer-based distance learning delivery systems can be expanded in several ways. To enhance input capabilities, scanners and graphics tablets can be added. A scanner allows the teacher to send graphics or drawings prepared on paper. The image can also be stored in the computer until needed. A graphics tablet allows teacher and students to write or draw electronically-on a special digitized pad with a special pen—just as on a piece of paper. The computer screens in both locations become electronic blackboards. Adding a printer enables the teacher to send handouts or homework assignments. With special software, a fax machine can provide input to the PC as well as allow the PC to originate fax transmissions.

The most advanced form of computer networking, audiographics, augments computer interaction with real-time audio communication. Not only can the participants communicate with each other via their computers, they can also talk to each other at the same time. Audiographics systems have traditionally required the use of two telephone lines, one for the audio connection and another for the computer/data connection. Systems now in use can combine the two lines onto one phone line.[6]

[5] There are currently more than 6,()(1(1 schools (7 percent) with modcms, U.S. Congress, Office Of Technology Assessment, *Power On! New Tools for Teaching and Learning, OTA-SET-379* (Washington, DC: U.S. Government Printing Office, September 1988), p. 192, footnote 11.

[6] A special modem combines the two signals so that they can be sent over the same line, thus cutting line costs in half. The most advanced systems also have a "screen grabber" capability, allowing color video images such as photographs to be electronically captured, transmitted, and annotated. An instructor teaching electronics, for example, could scan in an image of a circuit board which could then be annotated by the teacher to point out the various components.

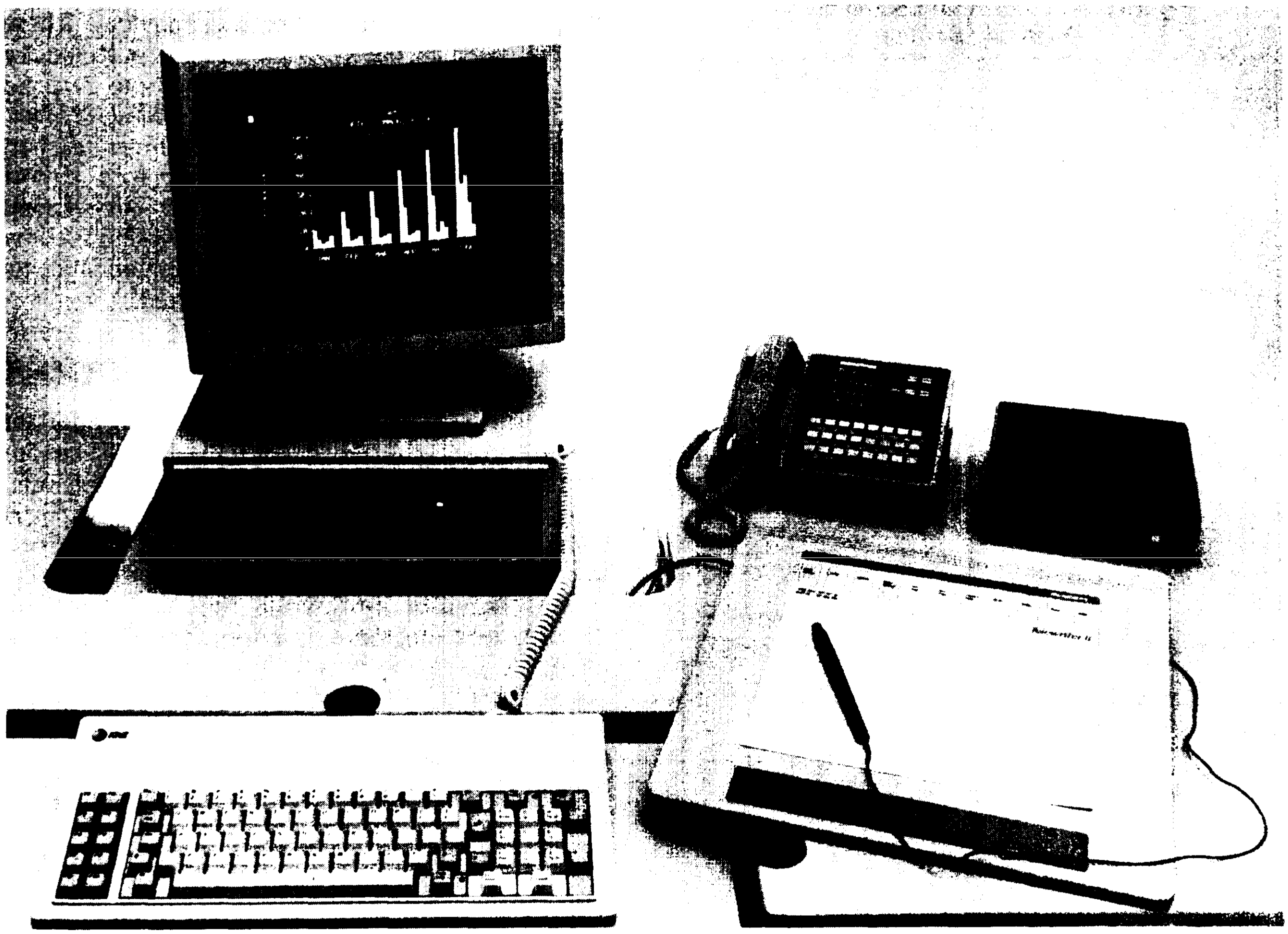


Photo credit: Optel Communications, Inc.

Audiographics systems combine the power of the computer with the personal touch of a telephone conversation.

In the future, more powerful computers, an improved public telephone network, and a wider array of peripherals promise to bring even more capabilities and features to computer users and distant learners alike. Advances in graphics manipulation and storage are one area of rapid advance.[7] Technologies such as digital video-interactive (DV-1) and compact disc-read only memory (CD-ROM) are bringing full motion video display and editing capability to desktop computers, while advances in HDTV promise even clearer images and graphics.

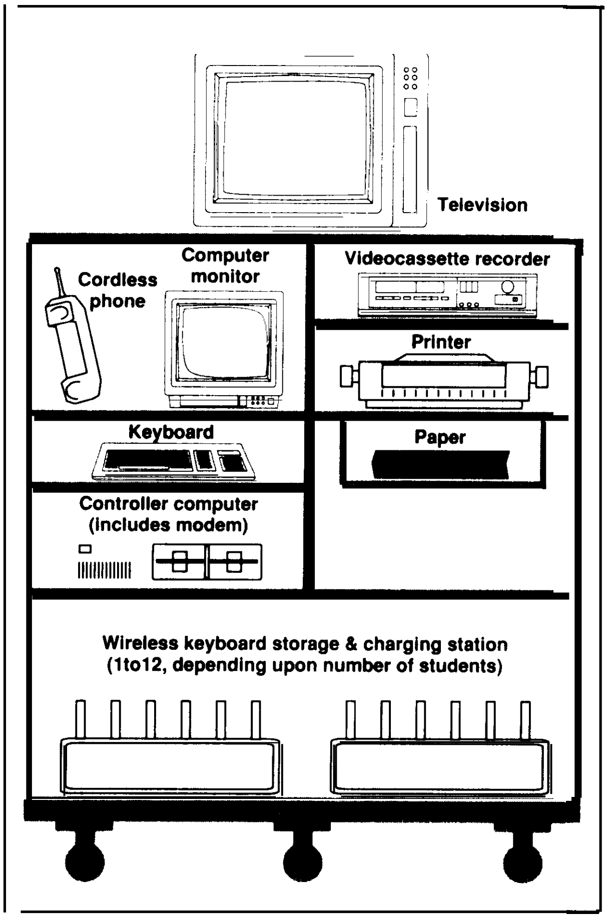
Supplemental Technologies

Almost any of the systems described previously can be supplemented by other technologies to provide more features and capabilities. Figure 3-3 shows some of these technologies used in the Kentucky Educational Television system.

Generally, the exchange of hardcopy is the "weak link" in any distance learning system. Many districts use courier services or the U.S. Postal Service, but these can be slow and/or expensive as well as unreliable. Other methods of delivering hard copy include: transmission of data in satellite sidebands or in the Vertical Blanking Interval (VBI) of the television signal, by fax, or by converting data to standard television signals. In these cases, special equipment such as data controllers maybe needed to receive and print out the material.

[7] John W. Veritz and Corie Brown, "The Graphics Revolution: A Special Report," *Business Week, No.* 3081, Nov. 28, 1988, pp. 142-153.

Figure 3-3-Classroom Equipment for Distance Learning



Many different technologies are used in the distance learning classroom. Often, equipment is placed together on a movable cart that can be rolled from class to class as needed.
SOURCE: Kentucky Educational Television, 1989.

Storage and other information technologies enhance educational material delivered electronically. The VCR allows students and teachers to tape live or prerecorded educational programming for later use. Optical discs combine audio, full-motion and still video, and data on one disc. They are known by various names including: CD-ROM, DV-1, and compact disc-interactive (CD-1).[8] Consumer applications of such technology already allow disc players to read both computer CD-ROMs and compact audio discs.

To increase the amount of interaction between student and teacher, many satellite-delivered programs now use student feedback devices. These devices, such as the keypads piloted by Kentucky Educational Television, allow students to respond directly to questions posed by the remote teacher. Responses are transmitted to the remote teacher, tabulated by a computer, and displayed almost immediately, allowing the teacher to respond quickly to student feedback. Such systems allow teachers to better judge how well remote students understand the material being presented.

TRANSMISSION TECHNOLOGIES

Transmission technologies also play an important role in the delivery of distance education. There are many ways to transmit a signal between two points, and users may not know (or care) how a signal is being transmitted-by copper wire, optical fiber, satellite, or microwave. **Each technology has capabilities and limitations that constrain the distance learning system, shaping the educational product. (See table 3-l.)** Satellite systems and other broadcast technologies, for example, do not generally allow the teacher to see the students, a critical concern for many educators. Other concerns facing educators as they contemplate distance learning delivery systems include regulatory requirements, availability of local infrastructure resources, and possible technical and economic trends that may affect these transmission technologies. The following section addresses these areas as they affect each delivery system. Sample costs for the technologies can be found in appendix B.

Broadcast Technologies

Broadcast television signals consist of audio and video channels transmitted from a central point that can be received by anyone within range of the transmitter. Television broadcasting requires expensive transmission equipment as well as a large tower from which to transmit the signal. Viewers, however, need only a standard television set to receive the signal; no special conversion is required. Geography is a barrier in mountainous regions where reception may be poor, but line of sight is generally not required. Most educational programming broadcast over television does not allow real-time interaction with the television teacher, but interactivity can be designed into live or recorded telecourses in a

[8] DV-I and CD-I are similar in concept, but DV-I operates through a personal computer, while CD-1 works through a videodisc player connected to a standard television set.

Table 3-l—Transmission Technologies for Learning at a Distance

Technology[a]	Configuration	Advantages	Disadvantages	Trends
Terrestrial broadcast	One-way broadcast of audio, video, and possibly data; possible audio return	No special receiving equipment or converters; reaches most schools and homes	Limited channels and air time; reception limited by geography; high transmission equipment and production costs	Increased use of data/text transmission
Fiber optic	Two-way audio, data and video	High capacity/speed; channel capacity easily expandable; high-quality signal	High installation cost; rights-of-way may be required to lay new cable	Costs are declining rapidly; fiber deployment is expanding rapidly
Microwave	Two-way point-to-point audio, data, and video	Low-cost transmission time; no rights-of-way needed	Must be FCC-licensed; tower space or location may be difficult to get; difficult and costly to expand channels; crowded frequencies; line of sight required	Use of higher frequencies is expanding
Instructional Television Fixed Service (ITFS)	One-way broadcast or point-to-point audio, data, and video; possibility of audio return	Low-cost delivery of video	Crowded frequencies, especially in cities; FCC licensing required; limited transmission range; line of sight required	Digitalization may triple channel capacity; wider coverage areas using repeaters; rebroadcast of satellite-delivered programming
Public Switched Telephone Network (PSTN)	Two-way voice; limited data and video	Wide coverage; low initial cost; high quality and capacity of fiber optic links; others handle repair and upgrades	Quality is spotty; limited transmission of data and video; cost is distance-sensitive	Expanding fiber installation; digitization of net-work increasing; increasing intelligence in the network
Satellite	One-way broadcast of voice, data, and video; possibility of audio and data return	Wide coverage transmission cost is distance insensitive	Expensive uplinks; high transmission costs; FCC licensing of uplinks; receive site microwave interference (C-band) or rain fade (Ku-band)	More use of Ku-band; possible transponder shortage; increased use of data; increased interactive capabilities
Audiographics	Two-way computer conferencing with audio interaction	Low cost; easy exchange of graphics; uses PSTN	Visual interaction limited to graphic/sktill video	More powerful computers; better software and peripherals increase capabilities
Cable television systems	One-way broadcast or two-way point-to-point audio, data, and video	Wide availability; low delivery costs	Limited capacity; can be difficult to interconnect; not usually designed for interactivity	Capacity increases using fiber; more addressability and two-way capability

[a]Technology systems do not have to operate independently; they are Often combined in "hybrid" systems.

SOURCE: Office of Technology Assessment, 1989.

variety of ways, including using the telephone to link students to teachers or aides or using the VCR interactively.

In addition to the video signal, television broadcast signals can send text and data simultaneously. The Public Broadcasting Service (PBS) recently demonstrated potential uses of the VBI, the unused portion of the television channel (the black band in the television picture), as part of its Educational Pipeline project. PBS plans to use the VBI to deliver student and teacher guides and support materials, program information, and computer software, including complete interactive computer-based courses. Another system allows data to be transmitted as a standard broadcast signal. The system could be likened to a viideo modem.[9] Data can be sent either before or after a telecourse has been delivered, but cannot be sent simultaneously. This system is useful for transmitting teacher's guides or any other print-based materials.

Low power television (LPTV) may also have a role to play in the delivery of distance education. These stations operate on normal television frequencies, but at a much lower power level. This limits their effective range to 20 miles at most. The advantage of LPTV over conventional broadcast is the much reduced cost of operation,

Radio broadcasting has been used extensively in other countries to deliver education and inservice training, but its use has been very limited in the United States.[10]

Instructional Television Fixed Service

ITFS refers to a band of microwave frequencies originally set aside by the Federal Communications Commission (FCC) in 1963 exclusively for the transmission of educational and cultural programming. There are 20 channels assigned to ITFS, down from the 31 originally allocated in 1963. These channels are usually grouped in blocks of four per licensee. In 1983, there were 88 ITFS systems operating 644 channels;[11] in 1989, that figure rose to 745 licenses to operate 2,358 channels.[12] In the last year, applications have increased dramatically, with more and more applications coming from rural areas.[13] Twenty-two of the Nation's 338 public television stations use ITFS to deliver instructional programming.

ITFS uses omnidirectional microwave signals in the 2.5 GHz band to transmit standard 6 MHz video signals to remote locations. (See figure 3-4.) In addition to the main video channel, there are two subchannels per main channel capable of carrying audio, data, and still pictures. ITFS usually functions as a broadcast (point-to-multipoint) television system, except that a special downconverter is needed to convert the microwave signal to a standard television signal. The normal range of ITFS transmissions is approximately 20 miles, although range can be increased by using signal repeaters, by increasing the height of transmitting and/or receiving antennas, by increasing receiver sensitivity, or by increasing transmitter power.[14] These options may add substantially to initial system costs. Like point-to-point microwave, ITFS requires direct line-of-sight to operate; receiving antennas must be precisely aligned to receive the signal. Areas subject to high winds or intense storms, for example, may require sturdy, and more costly, towers.

An ITFS network can serve as a stand-alone distance education delivery system, transmitting locally originated programming directly to local schools or cable companies for redistribution through their network. ITFS may also function as an intermediate link, taking a signal from a satellite feed, for example, and rebroadcasting it to local subscribers. Most commonly, ITFS is used to deliver one-way video to schools with telephone hookups for two-way audio. Two-way video is possible using

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[9] Computer data is fed into the modem, which converts it to standard video. The signal is then transmitted as any ordinary television signal. The information received is converted by the modem back into digital data and routed into a computer, where it is then available for viewing and printing. The data signal rides in the primary video channel of the broadcast signal (not in the vertical blanking interval or on a sideband), and appears as a series of boxes on the television screen.

[10] See, for example, U.S. Agency for International Development, 0P. cit., footnote 3.

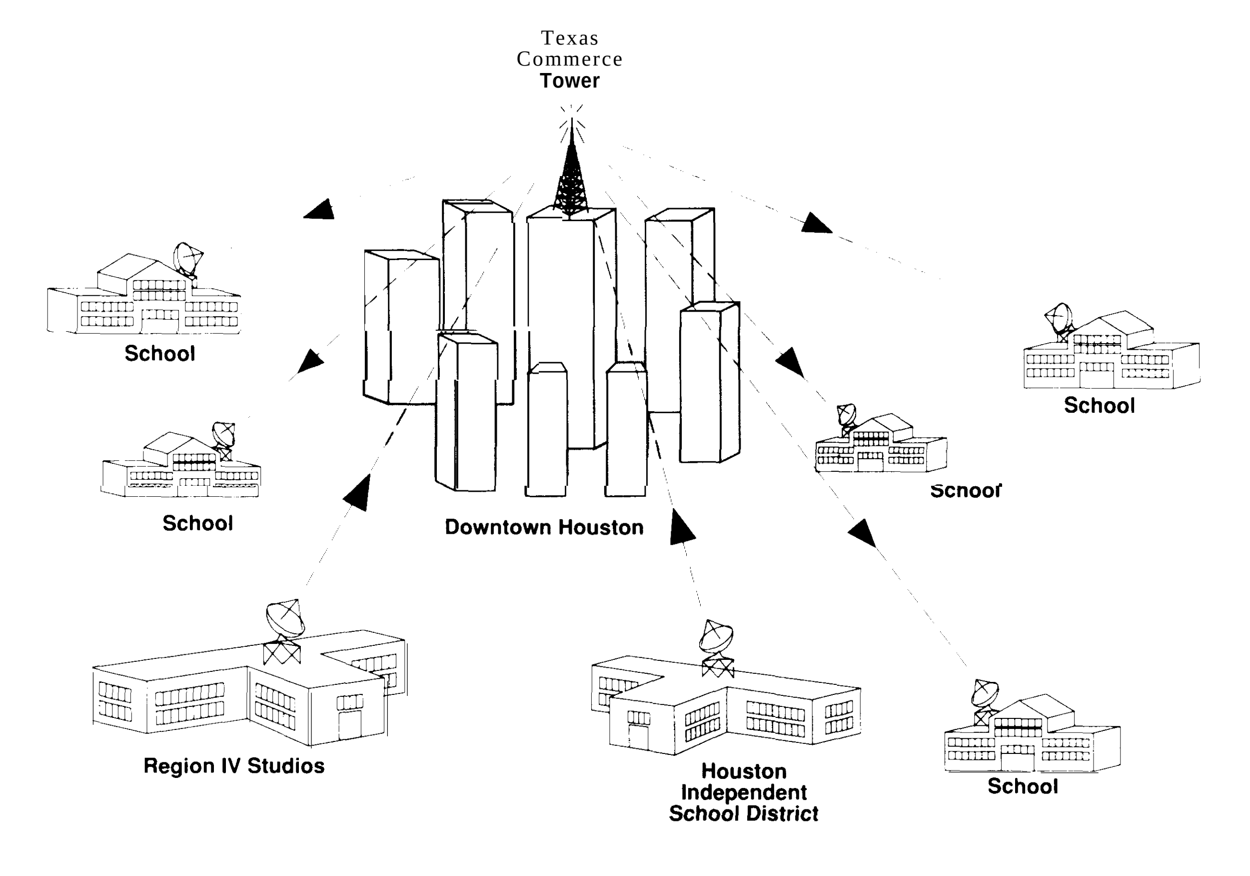
[11] Sally L. Bond, *Telecommunications-Based Distance Learning: A Guide for Local Educators* (Research Triangle Park, NC: Southeastern Educational Improvement Laboratory, spring 1987), p. 30.

[12] George Fehlner, FCC ITFS division, personal communication, Apr. 4, 1989.

[13] Ibid.

[14] For example, with a high-powered (50 watts) transmitter, distances of 50+ miles are achievable. At 20 miles, a 2-foot parabolic dish can be used for reception. For longer distances, larger receiving dishes are needed (the limit without regeneration appears to be 50 miles with a lo-foot receiving dish)`. Some fading can occur if the signal travels over large bodies of water,

Figure 34-The InterAct Instructional Television Network



Seven channels of programming originate from the Region IV studios; one channel comes from Houston Independent School District. Thirty-seven districts subscribe to the network and 300 schools receive programming.

SOURCE InterAct Instructional Television Network, Region IV Education Service Center, Houston, TX

ITFS (or point-to-point microwave) to transmit back from the remote schools. However, this greatly increases the cost of the system, and requires double the number of channels for a given number of sites. Along with the 20 audio/video channels, there are also 20 corresponding audio channels located together at the high end of the ITFS frequency band that can provide audio feedback from receiving sites. These channels are not used by most systems because regular telephone lines can be used for the same purpose. If telephone connections are long distance, ITFS talk-back maybe more cost-effective in the long term. Two-way audio capability requires additional electronics (transmitter, multiplexer, and possibly a new antenna) at each receive site.

Data or text can be sent over an ITFS system in many ways. Data/text sent simultaneously with video programming is possible using the VBI or subchannels. The "video modem" allows data/text to be sent either before or after a broadcast.[15] Any of these methods require the use of additional equipment to convert data for transmission as well as equipment to decode the data once it is received. This equipment enhances system capabilities, but also increases system costs.

Digital technology and compression techniques may increase ITFS channel capacity so that three compressed video signals could be transmitted on each ITFS channel. However, the equipment needed

[15] See footnote 9.

to compress and decompress these digital video signals is still very expensive, and the technology has not yet been demonstrated. ’b

Regulation

FCC and sometimes Federal Aviation Administration (FAA) approval and licensing are required to operate an ITFS system.[17] FCC approval can take as long as 2 years. FCC requires and reviews an engineering analysis of each proposed system. One problem identified by FCC has been the varying quality of the applications.[18] In some cases, FCC must do its own analysis; adding even more time to the process. FCC review of how the system will actually be used has become more stringent as competition for ITFS frequencies has increased.

Siting and zoning requirements in local communities may conflict with tower placement or height. Schools may find that towers cannot be situated on school grounds or that the height required for adequate reception is too high for local regulations.

Issues and Future Implications

ITFS channels are saturated in many locations, especially metropolitan areas. Educators considering an ITFS system, especially at the K-12 level, may find that channels have already been licensed to higher education institutions or PBS stations. Many ITFS channels are not used by educational institutions, but have been leased to Multipoint Distribution Services (MDS) operators, who use the channels to offer premium entertainment channels (such as HBO) and data transmission services. FCC does not monitor how many channels are leased, but has established safeguards to ensure that channels are used for education (at least 20 hours per channel per week) and that time can be “recaptured” from commercial operators if educational needs increase. The amount of time recaptured by original educational licensees is also unknown, but is thought to be very small.[19]

Because the range of ITFS is limited to 20 miles and requires line-of-sight, ITFS is best suited to local or regional applications. However, the scope and range of an ITFS system can be extended through connection(s) to such long distance transmission systems as fiber optic backbones or satellite.

Satellite

Satellites function as relay stations in the sky. A communication signal is sent from an Earth station (called an uplink) to the satellite, which then retransmits the signal back to Earth, where it is received by a satellite receiver (downlink).[20] Satellites are normally used to transmit audio, data, and video programming in a point-to-multipoint configuration.[21] (See figure 3-5.) Like other broadcast technologies, the signal from a satellite can be received by any dish in the satellite’s coverage area pointed at that satellite and tuned to the appropriate channel (transponder) .22 Some channels, however, are scrambled, requiring a descrambler to receive the signal.

Two types of satellites orbit the Earth, Geosynchronous satellites maintain a constant relative position in the sky, meaning that they can always be “seen” by receiving dishes. Other satellites called low-altitude satellites orbit the Earth at lower altitudes than the geosynchronous satellites, and cannot maintain a constant position above the Earth. This means that they are only accessible when they come into view of the receiving dish, two or three times a day, and then only for a few minutes at a time. These low-altitude satellites are generally smaller and cheaper than geosynchronous satellites,

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16Federal Communications Commission regulations governing Instructional Television Fixed Service (ITFS) are currently based on analog technology. These regulations would probably have to be rewritten to accommodate digital transmission on ITFS channels.

17FAA approval may be required for tall towers that may interfere with low flying planes.

18Fehlner, op. cit., footnote 12.

19Ibid.

20There are many terns for satellite receive devices, including dish, antenna, television receive only (TVRO), terminal and downlink.

21In addition to the main (wideband) video channels sent, there are also narrow bandwidth subcarriers that can be used to send audio or data signals to remote sites. Missouri’s Educational Satellite Network system plans to use subcarrier transmission of data to printers at each school, while TI-IN uses the Horizontal Blanking Interval of the video signal for data transmission. Other methods for transmitting data and text include using the Vertical Blanking Interval in standard video transmissions and the video modem system described in the Broadcasting section. Such systems allow the program originator to send teachers guides, written homework assignments, and questionnaires to all receive sites.

22The area in which a particular satellite can be received is called that satellite’s “footprint. ” Satellites, which can be received all over the continental United States, provide full “conus” coverage. Receive sites located at the very edges of the footprint require much larger dishes than those in the middle of the coverage area because the signal gets weaker towards the edges of coverage.

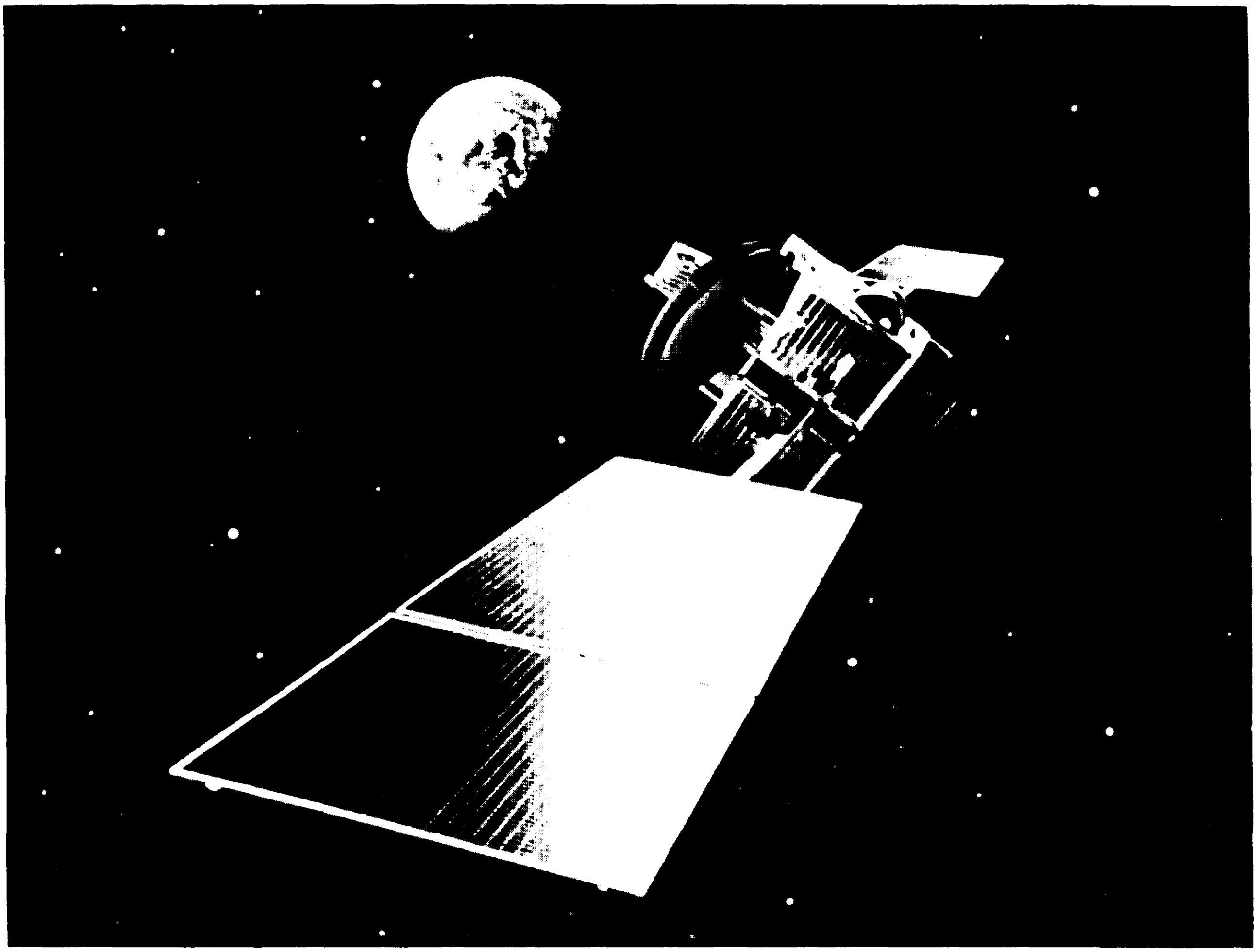


Photo credlt: GTE Spacenet

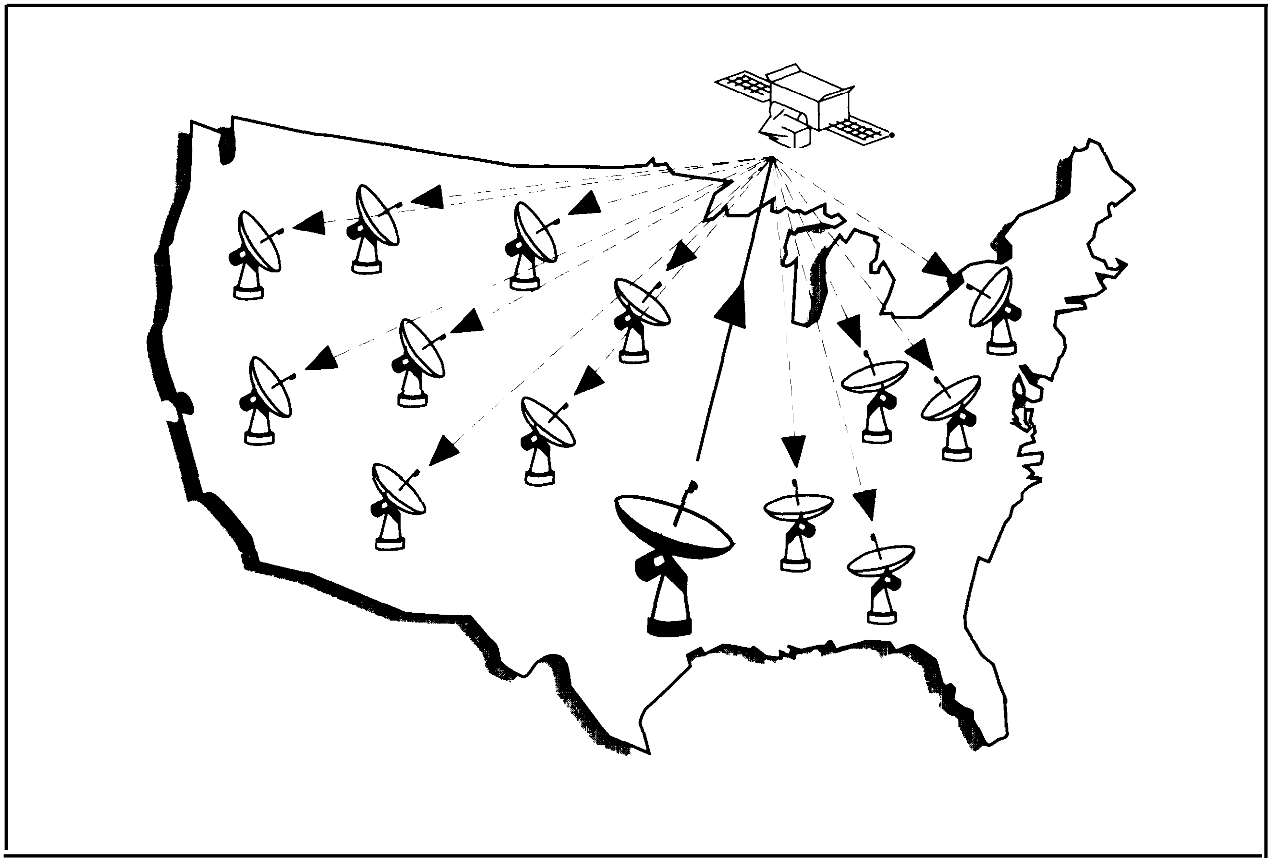
From 22,300 miles **above** the Earth, satellites can transmit phone conversations, video programming, and data communications around the would.

and may lend themselves well to "store and forward" applications such as computer conferencing or voice mail in which immediate interaction is not required.

Satellite transponders receive signals from the uplink and transmit them back to Earth. Satellites typically have between 12 and 24 transponders that operate in two frequency bands: C-band and Ku-band. C-band satellites are the oldest and most common type of system in use today. They use a signal operating at 6 GHz for the uplink and 4 GHz for the downlink (6/4). Receiving dishes are usually large (3.2 to 10 meters), making them somewhat expensive and difficult to install. C-band reception is subject to interference from terrestrial microwave facilities, but interference from rain is not a problem as with higher frequency (Ku-band) satellites.

Ku-band satellites operate at 14/12 GHz, and use smaller (3 meters or less) dishes that are cheaper and easier to install than C-band dishes. Ku-band frequencies are not shared with terrestrial microwave facilities as are C-band, reducing potential interference. Ku-band, however, is much more subject to transmission problems caused by precipitation. Because of its lower cost and smaller dish size, Ku has become the most popular band for many satellite

Figure 3-5-Satellite Communication System



Satellites can deliver educational programming and courses to schools across the country. Video programming and text materials are broadcast from a central origination site (uplink) to any school with a satellite receiver (downlink).
SOURCE: Office of Technology Assessment, 1989

program providers, especially in business, and an increasing percentage of future satellites will be Ku-band or Ku/C-band combinations.[23]

The deployment of Ku-band satellites has also led to the development of new receivers called Very Small Aperture Terminals (VSATs). VSATs are small (1.8 to 2.4 meters), easy to install, and basic models are relatively inexpensive. They are used primarily for data communication, but can be upgraded to provide interactive audio and video services. Adding such services, however, greatly increases cost. VSATs cannot usually communicate with each other directly; they can only send and receive signals to and from a central site (known as a "hub"). In order to connect remote sites, a signal must be transmitted to the hub, which then rebroadcasts it to the receiving site.

Direct broadcast satellites (DBS) are high-powered satellites that transmit programming directly to the general public. Receive dishes used in DBS systems are very small (1 meter). DBS could allow programmers to beam educational programming directly to homebound students, providing an alternative to over-the-air broadcasting or cable hookups, Although no such services are operating in

[23] There is, however, a large installed base of C-band transmitters and receivers, and C-band satellites are expected to be used extensively, especially by the cable television industry, for many years to come.

the United States,[24] a DBS education service serving European schools plans to begin operation in October 1989.[25]

Ka-band satellite technology is the most advanced satellite technology being developed, but no Ka satellites will be operational until the early to mid-1990s. Ka-band satellites will use frequencies in the 30/20 GHz band, allowing them to transmit much more information. Ka-band receive dishes are expected to be smaller (1 meter in diameter), cheaper, and easier to install than today's Ku dishes. The National Aeronautics and Space Administration's Advanced Communications Technology Satellite, scheduled for deployment in the early 1990s, will be Ka-band. Ka-band satellites, using on-board switching and narrower transmission beams, may eventually enable direct point-to-point (school-to-school) communication.

Regulation

FCC regulation of satellite communication most directly affects satellite uplink operation. Every C-band uplink must be licensed due to potential interference with adjacent satellites and terrestrial microwave sources. The licensing process requires careful frequency coordination, a sometimes lengthy process. It is much easier to license Ku-band uplinks because there are no terrestrial interference concerns. Regulations regarding satellite downlinks are not hard to satisfy. Downlinks need not be licensed at all for Ku-band receivers and for C-band receivers only when the user wants to protect against possible future interference.

Issues and Future Implications

The number of schools with satellite dishes is growing rapidly. The number of dishes installed in schools has doubled since last year. Data from the 1988-89 school year indicates that approximately 7 percent of school districts had satellite dishes: 68 percent of those districts have C-band dishes, 40 percent have Ku-band dishes, and 7 percent have dual-band dishes capable of receiving both C- and Ku-band; 84 percent of dishes owned by school districts are steerable.[26]

The amount and variety of programming a school can receive depend on many factors. Schools wanting to receive many different satellite programs must be able to access different satellites; use different frequency bands; decode different audio, video, and data formats; and adapt to different scheduling times. Schools have fewer programming choices if they have a fixed dish aimed at only one satellite as opposed to a steerable dish, which may be reaimed to receive other signals. While increased access is an advantage, the higher costs and sometimes lower performance of a steerable dish may prove to be substantial barriers. The type of dish (C or Ku) also limits programming possibilities. Satellite dishes can usually only receive one band of transmission. Dishes that can receive both C and Ku are more expensive than single band dishes. The trend in the satellite industry toward Ku-band satellites may also pose problems for schools;[27] it may be difficult or impossible to upgrade from C to Ku without buying a new dish.

Access to programming also depends on receiving electronics. Some receivers, especially at Ku-band, are preset to receive signals from a certain satellite (or certain transponders on a certain satellite); even if a school has a steerable dish, it may not be very useful in accessing other satellites.

A shortage of satellite capacity (both C- and Ku-band) may develop. Demand for satellite services has increased rapidly, especially in the business sector with the proliferation of VSAT networks.[28] The generation of satellites currently in orbit, however, is due to be retired in the early 1990s.[29]

[24] The Public Service Satellite Consortium (PSSC), in conjunction with Advanced Communications Corp., an FCC-licensed DBS operator, had planned to offer a dedicated educational channel called "Your Educational Service." It was to provide educational programming directly into schools, especially rural schools. Unfortunately, plans fell through due to a lack of funds. PSSC is continuing talks with satellite suppliers in the hope of using another satellite. Suzanne Douglas, Public Service Satellite Consortium, personal communication, Apr. 3, 1989.

[25] "Eurostep To Offer Europe-wide Classes," *Satellite Communications, vol. 13, No. 6,* June 1989, p. 15.

[26] PBS Elementary/Secondary Service, The *PBS School Satellite Survey* (Alexandria, VA: Public Broadcasting Service, July 1989). In addition, PBS estimates that more than 1,200 institutions of higher education have satellite downlinks.

[27] Much of the commercial programming now available to schools is on C-band, but many program providers, especially in the business arena, are switching to Ku-band because there is less terrestrial interference and because receive dishes are smaller and less expensive.

[28] Tom Kerver, "Good Ideas To pay Off in '89," *Satellite Communications*, vol. 13, No. 1, January 1989, p. 15.

[29] Ibid.

Nineteen satellites have been authorized by FCC (10 are replacements); these satellites are not expected to be operational for 4 to 5 years. In the meantime, demand may outstrip supply of satellite capacity, possibly forcing up the transponder fees satellite program providers pay. More seriously, if a shortage were to develop, occasional users could be bumped off the satellites in favor of full-time users willing to pay premium prices. Educational providers (universities, consortia, regional school districts) would have to lease their own transponders or cooperate with those who do have access.

Technical developments may ease any potential shortage. Ku-band transponders can be "split," doubling the number of channels that can be transmitted.[30] This allows a provider to add additional programming without buying extra transponder time.[31] Several educational programming providers, including the National Technological University and TI-IN, use split transponder techniques. Another technique for maximizing transponder capacity is to use digital compression. Systems under development may allow up to 18 full-motion video channels to be transmitted over one transponder.

Cable Systems

Cable television systems use coaxial and fiber optic cable to distribute entertainment and other services to local subscribers. (See figure 3-6.) Programming is received from local broadcast stations and national programming services, such as HBO, at the cable "headend" and is sent out over the cable in a tree configuration. A cable headend can receive many types of signals, such as satellite or microwave transmissions, which can then be retransmitted to the schools over the normal cable system. The reach or scope of the system depends on the size of the franchise area and interconnections with other companies. A cable franchise area does not necessarily follow the same boundaries as local school districts, and in some areas, different schools or districts may be served by different cable companies. Cable systems vary greatly in size, often depending on the age of the system.[32] In addition to the actual cable, the equipment required includes: modulators, demodulators, addressable convertors (for certain programs such as pay-per-view), and amplifiers. The life expectancy of this equipment is approximately 10 years.

Cable television systems are primarily one-way, broadcast (point-to-multipoint) type systems. Many systems also have a limited number of reverse channels that can give some measure of two-way interactivity to the system. The number of reverse channels depends on the design of the system. They are most commonly used for data transmission or ordering pay-per-view services, but are capable of transmitting video signals.[33] A school could be assigned its own reverse channel to allow it to transmit information back "upstream"' to the cable headend. Most cable systems make only limited use of this two-way capability, because additional (reverse flow) amplifiers are needed to move signals upstream, as well as special filters to keep upstream and downstream signals separate. Additional equipment also requires increased maintenance.

Most (two-way) cable systems have limited switching ability; that is, they cannot directly connect point-to-point. Instead, signals from the schools are sent back to the headend via reverse channels, and then retransmitted over a standard (perhaps scrambled) downstream channel. Anyone on the system can receive the signal (in addition to the intended site) by simply tuning in that channel. Some newer cable systems use addressable decoders connected to the television set that restrict nonpaying television subscribers, and allow specific programming, such as pay-per-view services, to be received. Some systems, such as the University of Lowell cable system (see figure 3-7), do have some switching ability, but this system is a dedicated institutional network separate from the public cable system.

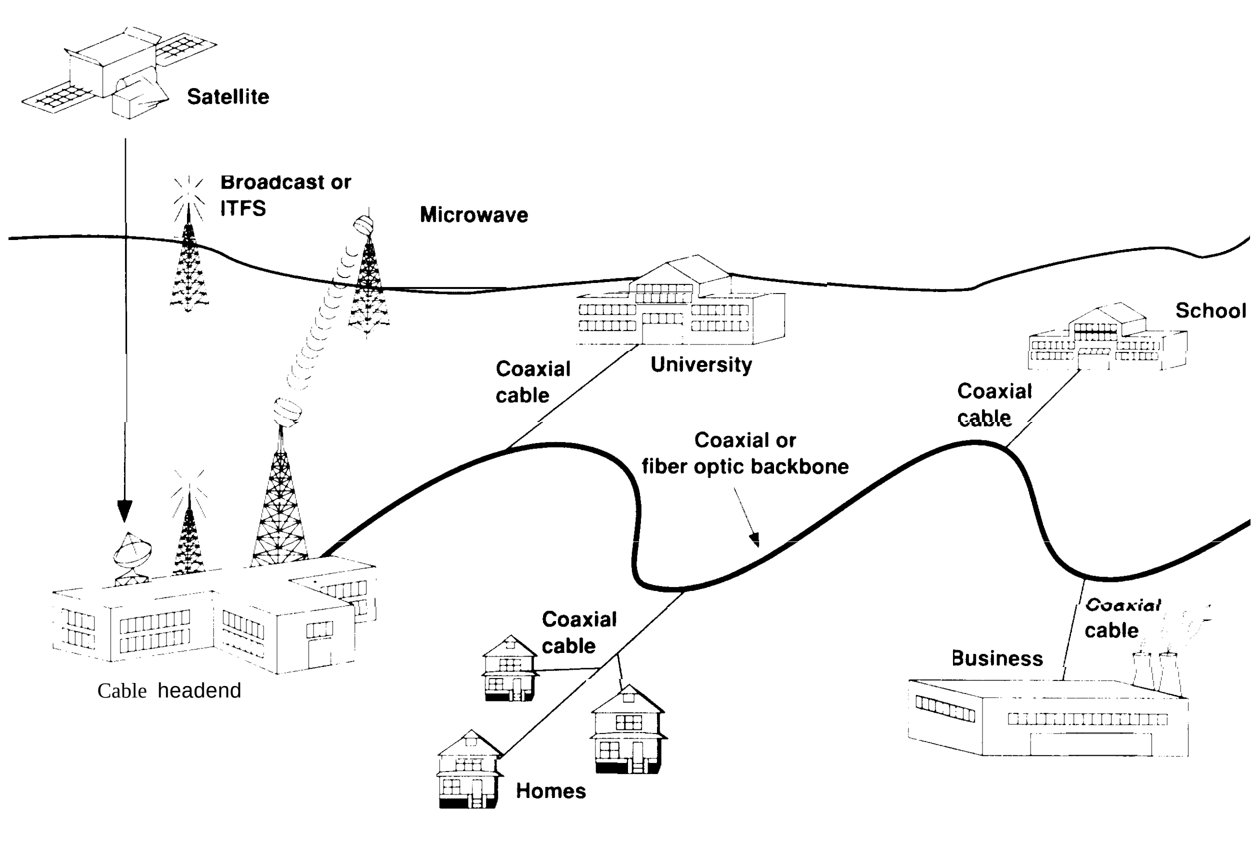
30 Because most C-band transponders do not have enough bandwidth (36 MHz), this technique is not available to them.

31 There is a trade-off between dish size and cost. If the signals interfere with each other, power can be reduced to lessen the interference, but larger and more expensive dishes may then be needed to receive the signal.

32 Cable systems are limited by the number of times a signal must be amplified to reach a subscriber. Each time the Signal is amplified, more noise is introduced into the signal, and after 20 to 30 amplifications, picture quality becomes unacceptable. New developments in fiber optic technology arc extending distances between amplifiers and improving signal quality.

33 An innovative Project in Sibley County, MN, found another way to increase interaction by connecting fax machines over the cable television lines. The benefits realized include greater speed, no telephone charges (new dedicated lines and long distance charges), and simultaneous broadcast capability (most fax is broadcast sequentially). David Czech, "Fax, TV and the Remote Classroom," *T.H.E. Journal, vol.* 16, No. 8, April 1989, pp. 69-72.

Figure 3-6--Cable Television Distribution System



Programming from many sources can be redistributed through a cable television distribution system. Schools can receive educational **programming through the local cable company and some systems can also be used for two-way communication between schools.**

SOURCE Off Ice of Technology Assessment, 1989

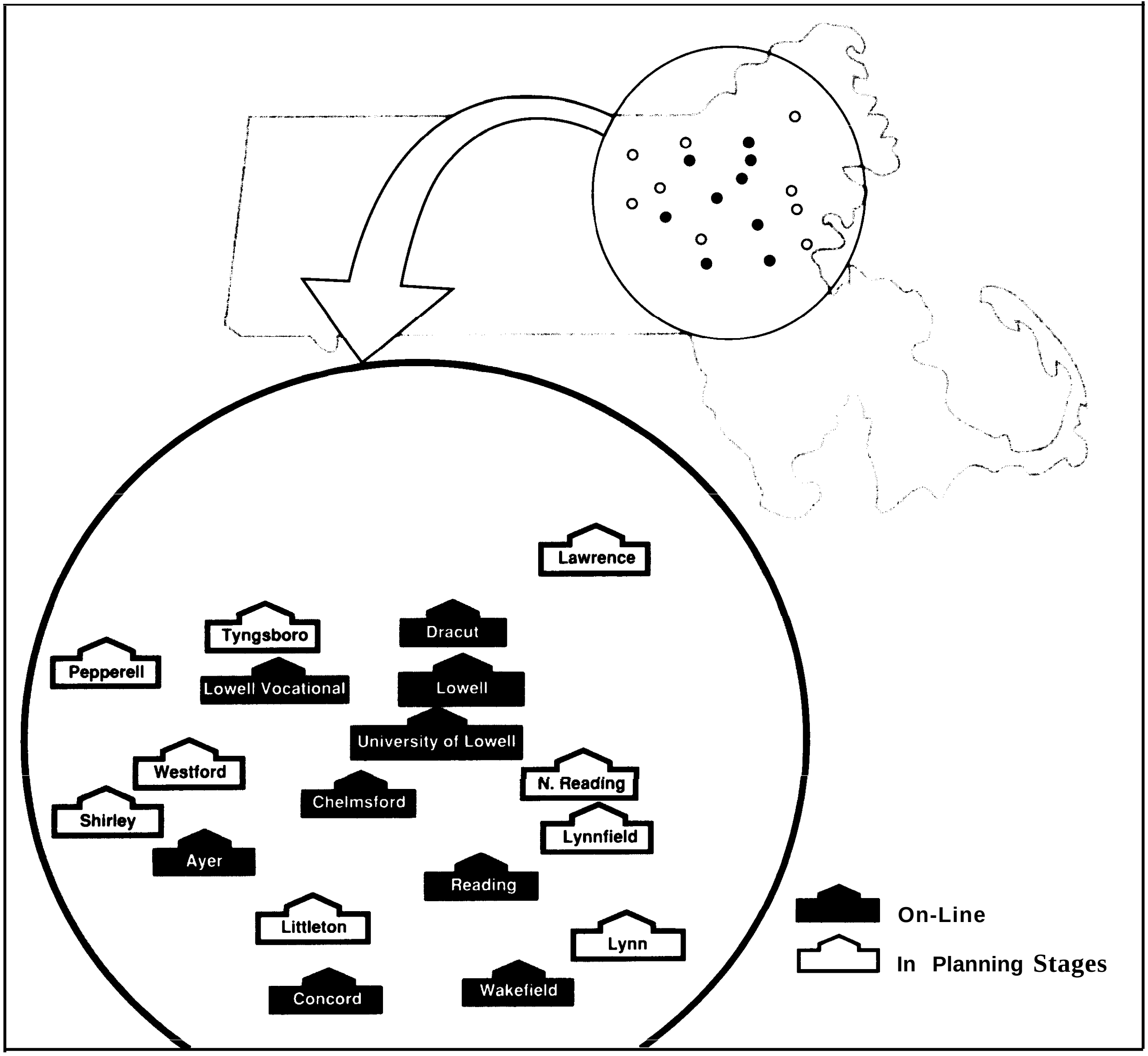
Converting a one-way system to two-way operation may require extensive redesign and upgrading, depending on the age and condition of the system. Two-way capability can be accomplished by running an additional dedicated cable from the school to the cable headend to allow signals to be sent back, but this can be very expensive. (See appendix B.)

Regulation

The main instruments of regulation of the cable companies are the Cable Act of 1984 and the local franchise process and agreement. These franchise agreements may provide opportunities for school systems to gain access to cable programming and capacity. For example, the local public agency signing the agreement could mandate public access or require educational channels. School connection to the local public or institutional cable network could be required. Many franchise agreements already specify that a number of channels be made available for public access or educational uses. Many schools, **however, have limited access or none at all. As cable franchises come up for renewal, local educators may increase pressure on the cable companies to connect unwired schools.**

The growing move to deregulate the cable industry because of alleged monopolistic practices could have major impacts on educational

Figure 3-7—University of Lowell Instructional Network



The University of Lowell Instructional Network is a two-way cable television/microwave system that local schools use to share live interactive classes. Each school can transmit and receive courses or other educational programming.

SOURCE: University of Lowell, 1989.

uses of cable television systems.[34] Possible changes in the Cable Act of 1984 could allow communities more direct control over cable operations, and could allow telephone companies to compete with the cable operators in the provision of video services.[35] Cable companies may be bought out by the telephone companies or form new relationships with them if existing cross-ownership rules are relaxed.

Issues and Future Implications

Cable television systems are an available telecommunications resource in many parts of the country. Cable penetration to the Nation's households is now 50 percent, with cable lines passing 83 percent of all American homes.[36] An estimated 55 to 60 percent of schools have cable hookups, and 80 percent of the Nation's schools are in cable franchise areas.[37] **However, even if a school has access to cable, it may be of limited value if classrooms are not wired to receive the signals.** In many cases, the cable connection only reaches one classroom or office. Few schools have all their classrooms wired to take advantage of cable-delivered programming.[38] Wiring al1 classrooms for cable is expensive, and communities negotiating franchises might require not only that the school be connected, but that all classrooms be wired as well.

Access to cable channels that could be used for distance learning is not assured. In many areas, commercial programming and other commitments fill existing capacity. Cable operators may resist reallocating channels for distance education programs or courses that have limited audiences.[39] Current cable system channel capacity is constrained by the limits of coaxial cable; channel capacity cannot be easily upgraded short of laying more cable. The deployment of fiber optic systems by cable companies may alleviate this problem. Fiber optic cable systems can transmit up to 150 channels. This new capacity combined with more advanced switching designs could allow cable companies to offer many advanced services such as two-way point-to-point video and computer networking.[40]

Cable company interest in distance education varies, but appears to be increasing. In Michigan, for example, of the 27 projects identified in the State's inventory of educational telecommunications, all involved local cable companies as participants, even if the system was not cable-based.[41] In some States, districts have had difficulty getting cable companies to participate in distance education projects; with the formation of the Alliance for Cable Education by several major cable company operators and programmers, opportunities to use cable systems for education are likely to increase.

Microwave Systems

Point-to-point microwave systems, as opposed to ITFS, operate in various frequency bands.[42] They can transmit audio, data, or video in either a one-way (simplex) or two-way (duplex) format. These systems require a clear line-of-sight between sender and receiver, making the signal sensitive to terrain and

[34] The issue was raised in testimony before the Senate Subcommittee on Antitrust, Monopolies, and Business Rights of the Committee on the Judiciary, Apr. 12, 1989.

[35] This issue is the focus of both congressional and FCC interest. Further Notice of Inquiry and Notice of Proposed Rulemaking in CC Docket No. 87-266, *In the Matter of Telephone Cable Television Cross Ownership Rules Sections 6354-63.58. The* issue also came up at various points in testimony before the Senate Subcommittee on Antitrust, Monopolies, and Business Rights of the Committee on the Judiciary, Apr. 12, 1989.

[36] U.S. Department of Commerce, National Telecommunications and Information Administration, *NTIA Telecom 2000* (Washington, DC: U.S. Government Printing Office, October 1988), note 1, p. 563.

[37] "Turner t. Launch 'CNN Newsroom' i. High Schools," *Broadcasting*, May 1, 1989, p. 116. A survey just completed by Jones Intercable indicates that approximately 1,100 of 1,500 schools passed by cable in their franchise areas have access. Gregory Liptak, Jones Intercable, personal communication, July 1989.

[38] The Dallas Independent School District is presently wiring all the classrooms in its school buildings, allowing students and teachers to access cable television, telephone, and computer services, at a total cost of $3.8 million. Diana Radspinner, director of media services, Dallas Independent School District, July 1989.

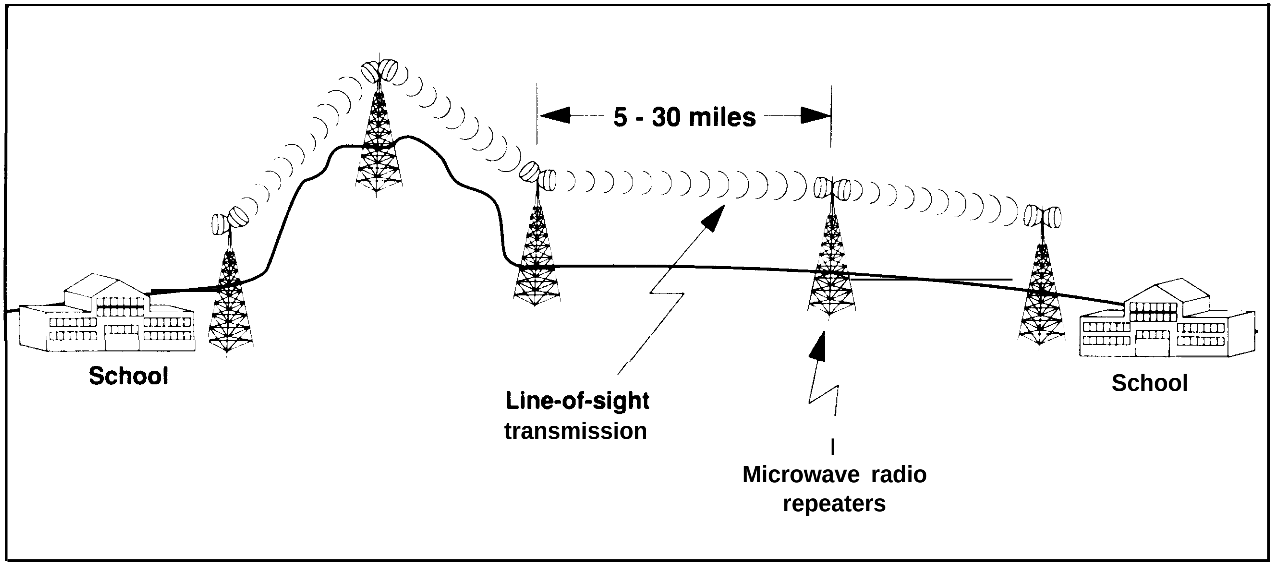
[39] One creative solution was found b, the South Berkshire Education Collaborative in Massachusetts. The cable company was in the process of upgrading the system, and instead of tearing down all the old trunk lines (a costly undertaking), they leased them to the schools for $1 per year.

[40] One such advanced system is now being installed in Augusta, GA, by Jones Intercable. The company is installing fiber optic trunk lines to support what it calls a Cable Area Network. The system will offer more channels more economically than the present all-coaxial cable network. Also, the company is laying more fiber cable than it currently needs, giving it a huge unused channel capacity, some of which may be used for educational applications. Liptak, op. cit., footnote 37.

[41] Michigan State Bored of Education, *Inventory of /m fractional Telecommunications Systems in Michigan* (Lansing, MI: March 1989).

[42] 900 MHz, 1.9 GHz, 2.1 GHz, 6.0 Ghz, 12.0 GHz, 18.0 GHz, and 23.0 GHz.

Figure Microwave Communication System



SOURCE: Office of Technology Assessment, 1989.

buildings. (See figure **3-8.)** At each transmit/receive site, microwave systems require towers, antennas, transmitters, and receivers.

There are two types of point-to-point microwave systems: short-haul and long-haul. Short-haul systems typically have a range of 5 to 15 miles, suitable for local communication between two schools, One university, for example uses a short-haul microwave link to reach a high school not served by the local cable company. These new short-haul systems ". . . are relatively simple to construct and operate, and require no State regulatory approval or right-of-way."[43] The cost of these systems has fallen significantly as the cost of the electronic components has declined. Development of digital microwave technologies has also improved performance for some signal types. All of these changes have resulted in a dramatic increase in the use of microwave technology for short-haul applications.[44]

Long-haul systems typically have a range of up to 30 miles between towers, depending on transmitter power, geography, dish size, and receiver sensitivity. In the recent past, multiple links of long-haul microwave were used extensively for the Nation's long distance services. At this point, fiber optic trunks have largely replaced these microwave facilities. Typical equipment lifetime is 7 to 10 years.[45]

Regulation

Microwave frequencies are regulated by FCC, and licensing is required for all transmitter sites because of interference concerns, and is necessary for receive sites desiring protection from possible new sources of interference. Local zoning ordinances may affect placement of towers. In some cases, towers cannot be built near the school, but instead must be located some distance away and connected to the school via coaxial or fiber cable.

Issues and Future Implications

The lower microwave frequencies are very crowded in high traffic areas. They may be difficult to obtain. Many of the newer microwave links being installed, such as the University of Lowell's, use the relatively less crowded frequencies at 18.0 or 23.0 GHz.[46]

[43] Peter W. Huber, *The Geodesic Network 1987 Report on Competition in the Telephone Industry* (Washington, DC: U.S. Government Printing Office, January 1987), pp. 2.13-2.14.

[44] Ibid.

[45] Some of the descriptive material in this section comes from Karen Kitchen and Will Kitchen, *Two-Way Interactive Television for Distance Learning—A Primer* (Alexandria, VA: National School Boards Association, May 1988).

[46] For more examples, see Bruce Jennings, "Short-Haul Microwave—A Versatile Solution," *Telecommunications*, vol. 22, No. 6, June 1988, pp. 47-48.

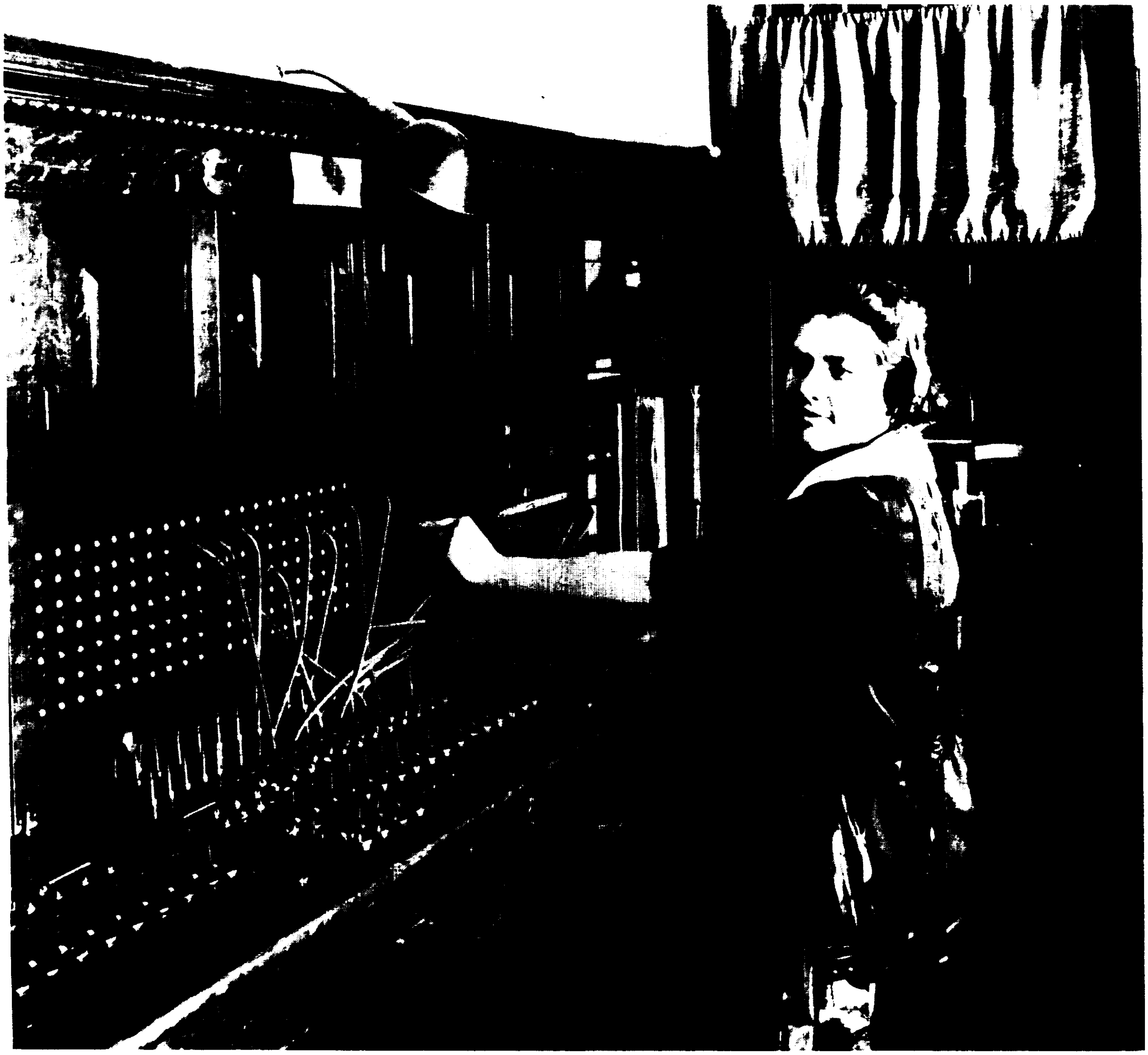


Photo credit: Library of Congress

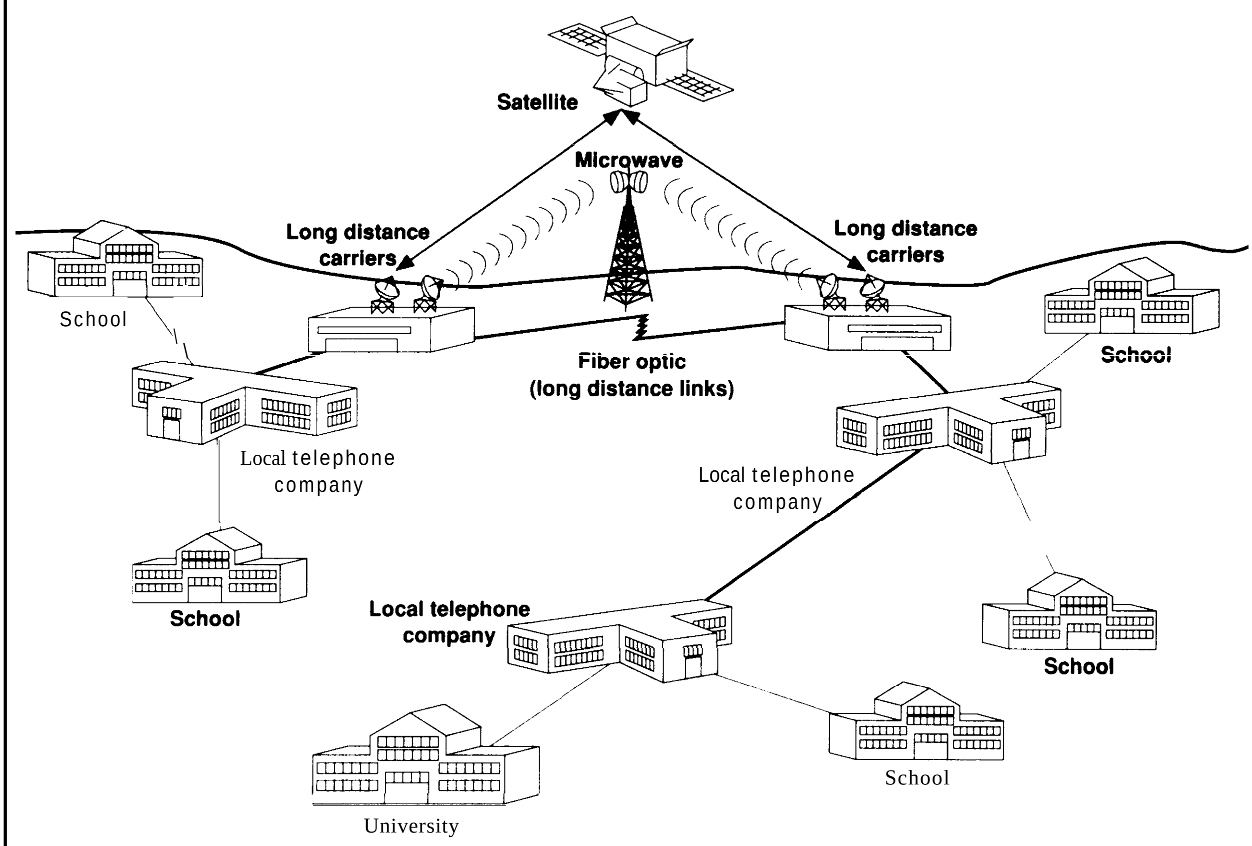
The public telephone network has come a long way since the early days of operators asking, "number please." Today's digital switches connect up to 300,000 calls per hour.

Public Switched Telephone Network

The Public Switched Telephone Network (PSTN) uses a combination of technologies including fiber optics, copper wiring, satellite, and microwave to transmit audio, data, and limited video signals. (See figure 3-9.) PSTN has several characteristics that make it unique among the systems examined so far. It is a public network; anyone can use it. The network is ubiquitous; it goes just about everywhere.[47] It is a switched network. Each user has a unique address (telephone number), which allows

47 National Telecommunications and Information Administration, op. cit., footnote 36, p. 206.

Figure 3-9-The Public Switched Telephone Network



The public switched telephone network uses many technologies to connect subscribers near and far. Although used primarily for voice services today, **in the future the public telephone network may become more a public information network, capable of** carrying **conversations, computer communications, and video programming.**

SOURCE: Office of Technology Assessment, 19S9.

the network to connect any two points directly. It is a two-way network; **any site on the network can both send and receive. Any site can originate transmission and programming.**[48]

Since the divestiture of the Bell Operating System in 1984, PSTN has been changing rapidly. Several trends are driving this change. The network is increasingly digital. The use of digital fiber optic lines is pushing implementation of other digital technology such as digital switches. These switches (which are actually specialized computers) are essential for the development of the intelligent network and the Integrated Services Digital Network (ISDN), Further, **fiber optics and digital technology are the prerequisites for advanced broadband networks capable of carrying high-speed data and switched video applications. Broadband**

[48] This is different, for example, from cable or satellite systems, which usually function as point-to-multipoint broadcast technologies; they have limited switching and addressing capabilities. In addition, these systems are essentially one-way; they are not usually designed for two-way operation (this is less true now with satellite data networks).

capabilities in PSTN are not expected to be widespread for 5 to 20 years.[49]

ISDN represents the next step in the integration of voice, data, and video services. ISDN is an end-to-end digital network that will allow users to send audio, data, and video signals over the same line simultaneously. Although not all the relevant standards have been worked out, manufacturers are already making ISDN equipment, and there are more than 60 trials under way.[50] As yet, no distance learning projects have been attempted over a public ISDN facility.

The timeframe for ISDN services remains unclear. Narrowband ISDN technologies (which can operate at 1.544 Mbps, but cannot offer full-motion video services) are being offered now, but broadband applications of ISDN, including video, are not expected to appear until 1995 or be widely available until 2000. The rate of ISDN (broadband and narrowband) deployment will depend on technical factors such as how quickly digital switches are installed, the implementation of new signaling systems such as SS7,[51] and the cost and availability of optical fiber. The regulatory environment and the demand for wide bandwidth services, such as videophone applications and high-speed data transfer, will also influence the rate of deployment.[52]

PSTN is becoming increasingly intelligent. New and varied services give users more control over their telephone. Hardware and software development is making it easier to control and customize communications. Network management, services, and features reside increasingly in software instructions rather than hard-wired connections. These software-defined switches and networks are more flexible than in the past and are easier to change. In many cases, upgrading a system or providing new features means only changing a circuit board or software module, not rewiring the whole system. Such applications may serve as the precursor to more advanced services including educational services. For example, users could dial in and gain access to various multimedia courseware provided by independent providers.

Current regulation has opened up the network to more competition,[53] while stifling the development of new services and hardware in some fields, especially new information and video services.[54] As competition intensifies in various parts of the network, more choices may open up for schools. The continuing problem for State and Federal regulators is how to assure innovation and competition while still protecting the consumer; it is a tense balance between the opportunities of competition and the threats of monopoly.

Future development of PSTN is closely tied to the implementation of fiber optics. Fiber is increasingly being used as the public network becomes digitized. The trends and issues surrounding the deployment of fiber optic technology will have a direct impact on PSTN.

Fiber Optics

Fiber optic systems work by converting the analog electronic signals of voice and video and the digital signals of data into light signals and transmitting them over thin strands of glass. Usually, these systems send information digitally, although some video applications do use an analog format. For digital transmission, analog signals are converted to digital bits, and then are transmitted by lasers or light emitting diodes (LEDs) as pulses of light along the

[49] As of 1986, digital switches accounted for 40 percent of central office switches. Eighteen percent of Bell Operating Companies (BOCs) switches were digital in 1986, but the independent telephone companies, which account for more than one-half of the installed base of central office switches had a much higher percentage of digital equipment. Fifty percent of their access lines are digital, while the BOCs access lines are only 33 percent digital. At this point, analog switch growth is limited to additional lines being added to existing analog switches. National Telecommunications and Information Administration, op. cit., footnote 36, pp. 312, 314; Bob Keely, district manager, Bell Communications Research, personal communication, Mar.31, 1989.

[50] Michael Warr and Ellis Booker, "Open the Box and Look Inside," *Telephony,* vol. 215, No. 24, Dec. 12, 1988, p. 30.

[51] Signaling System 7 is the latest in control systems for the public network. It allows greatly enhanced services to be provided to users such as customized 800 services and caller identification.

[52] For a discussion of the factors surrounding the development of ISDN see, Rolf T. Wigand, "Integrated Services Digital Networks: Concepts, Policies, and Emerging Issues," *Journal of Communications*, vol. 38, No. 1, winter 1988.

[53] An example is the proliferation of regional backbone networks (which are primarily fiber-based) that offer an alternative to traditional long distance carriers. Proposed systems in many States, including Indiana and Wisconsin, have met stiff challenges from local and long distance carriers. Mary Walker, "Competition in the Local Exchange," *Telephone Engineer and Management*, Aug. 1, 1988, p. 82.

[54] The Modification of Final Judgment and the Cable Act of 1984 restrict the phone companies to only transporting video, they may not originate or own the content passing over their lines.

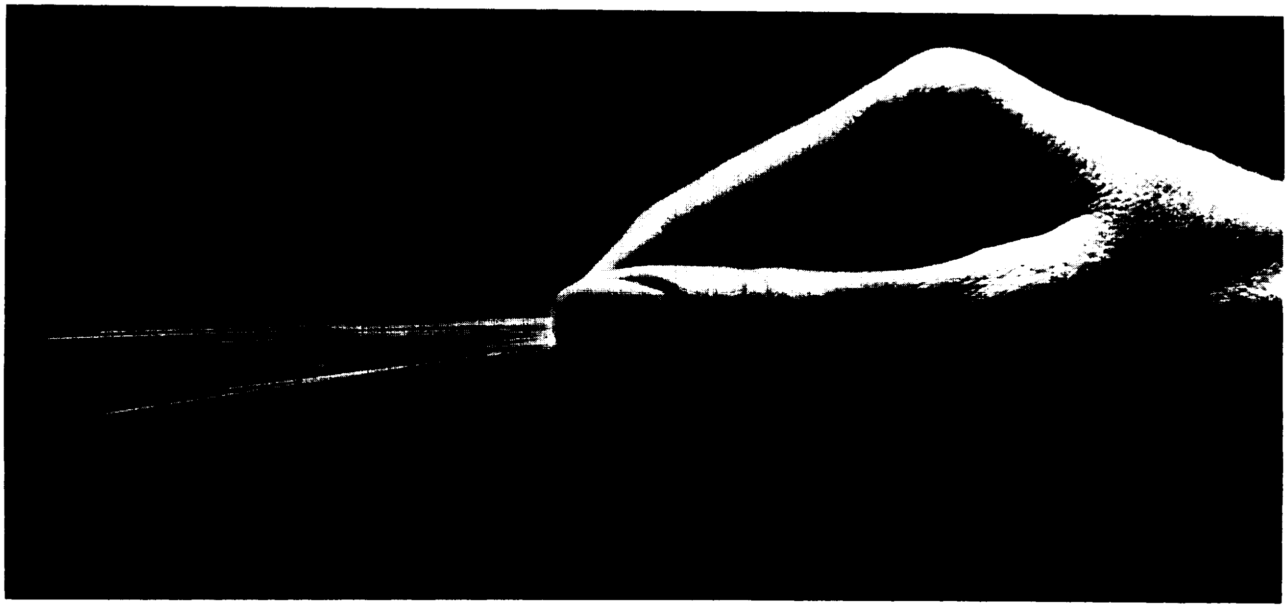


Photo credit: Bellcore

Is it **spaghetti? No. Fiber optic systems use hair thin strands of glass and signals of light to carry voice, video, and data.**

fiber strand. Receiving equipment senses these light pulses, converts them back to electronic digital signals, and then back to analog form for output. The cost of analog fiber optic systems is lower than digital systems because digital systems require expensive equipment to convert the signals from analog to digital and back. Digital transmission, however, allows signals to be combined and compressed, permitting many more signals to be transmitted. Signal quality is comparable for both systems. In theory, **fiber optics offers almost unlimited speed and capacity for voice, data, and video applications.** Because information is transmitted as light, fiber optic signals are much less susceptible to interference from weather, radio frequency transmissions, or electromagnetic "noise," which limit most conventional analog transmission systems. In practice, however, the capacity of fiber optic systems is limited by the speed of the transmitter and the sensitivity of the receiver.[55] The capacity of these systems, however, is still far greater than other transmission media.

Fiber optic systems have been implemented rapidly by the telephone companies and in large private networks whose data or video needs cannot be met by PSTN.[56] At first, the high cost of such systems made them economical only for high-density applications such as long distance telephone trunk routes or video applications. As costs have fallen, fiber has been deployed in many new areas and applications. Continued advances in fiber optic technology promise even higher capacities, lower costs, and more rapid deployment. For example, in a trial currently being conducted around the country, fiber is being used to deliver broadcast video from five television networks to eight cities.[57] The system is expected to offer lower cost, higher quality transmission, greater security, and the ability to

Mm fastest fiber optic systems commercially available today run at 3.4 giga (billion) bits per second (Gbps); most systems operate at 565 Mega (million) bits per second (Mbps). The average length between repeaters is approximately 30 miles.

56Fiber optics is spreading quickly in the Nation's telephone system, First used almost exclusively for long distance links on high traffic routes, fiber is now being installed in the local loop and even to individual (new) homes in some areas. One projection says that most of [he homes in the United States will be served by at least one fiber optic link by 2008. Robert M. Pepper, *Through the Looking Glass: Integrated Broadband Networks, Regulatory Policy and Institutional Change* (Washington, DC: Federal Communications Commission, November 1988), p. 16. Presently, 50 percent of all intercity traffic is now carried on fiber. All the major long distance carriers have extensive fiber networks, and regional networks are proliferating as well. National Telecommunications and Information Adrninstration, op. cit., footnote 36, pp. 76,219,260.

57"Fiber Optic TV Trials Take Key Step," *High Technology Business, vol. 8, No. 12,* December 1988, p. 37.

deliver as yet undefined services. The development of digital television receivers will eliminate the need for expensive video codecs. The accessibility and availability of fiber optic systems should increase dramatically in the next several years.[58]

Regulation

Regulatory decisions will play an important role in determining how the public network develops. The huge capacity and high cost of broadband development present the telephone companies and regulators with a classic problem. At present there are no services the telephone companies can offer that justify putting in fiber optic lines directly to end users. Putting in capacity for future use that consumers pay for now, called "gold plating," has not been popular with State regulators. Development may go slowly depending on demand for new types of services and features, and how regulators react.[59]

The restrictions placed on the Bell Operating Companies (BOCs) by the Modification of Final Judgment (MFJ) regarding manufacturing and design of equipment, provision of long distance services, and provision of information services may hamper BOCs' ability to offer the enhanced services needed for distance learning. BOCs cannot offer the complete service schools want, in many cases, especially when video is desired. In other instances, BOCs find it uneconomical because of restrictions or requirements of the MFJ or State public utility commissions. Telephone companies are currently prohibited by the Cable Act of 1984 from providing video content, although they can transport video signals. Easing restrictions may encourage the telephone companies to make more resources available to education. The resolution of the cable/telephone company cross-ownership debate, changes in the Cable Act and the MFJ, and evolving State regulation will impact what (video) services the telephone companies provide.[60] The final outcome of these deliberations will significantly affect the range of options for distance education delivery systems.

Issues and Future Implications

There are a host of issues that will determine how the public switched network evolves in the next decade.[61] **PSTN may become less a telephone network and more a general-purpose broadband network capable of carrying all types of traffic, including audio, data, and video.** Because telephone companies cannot yet provide all the services many educators want, a few schools have built their own customized systems. In the future, schools may not have to bypass the public network. Transmitting a live telecourse with full audio and video interaction may be no more difficult than making a telephone call is today. **However, because of the many political, economic, and regulatory issues involved, the timeframe for the development of this network is uncertain.**

The future of ISDN is unclear. The trials and services now available are all narrowband applications for which services and pricing are still evolving,[62] Broadband ISDN (B-ISDN), which is not available yet, will offer users advanced data and voice services as well as full-motion video applications in addition to existing narrowband services. Some of the services that broadband fiber optic networks are expected to offer include: videoconferencing and video transmission, high speed data and fax, and HDTV.[63] (See figure 3-10.) Many of these services have clear applications in distance learning projects. Since delivery of these services will require the capacity of fiber optics transmission, the rate of fiber deployment may determine how and when such services become available for school use. B-ISDN

[58] Pepper, op. cit., footnote 56.

[59] Long amortization and depreciation times, for example, mean that the phone companies cannot recover costs on equipment with short lifecycles. This may prove to be a disincentive to future investment in the network. The debate about universal service and what it should be is also relevant, because if universal service is redefined to include access to high bandwidth services such as video, the introduction of fiber may accelerate.

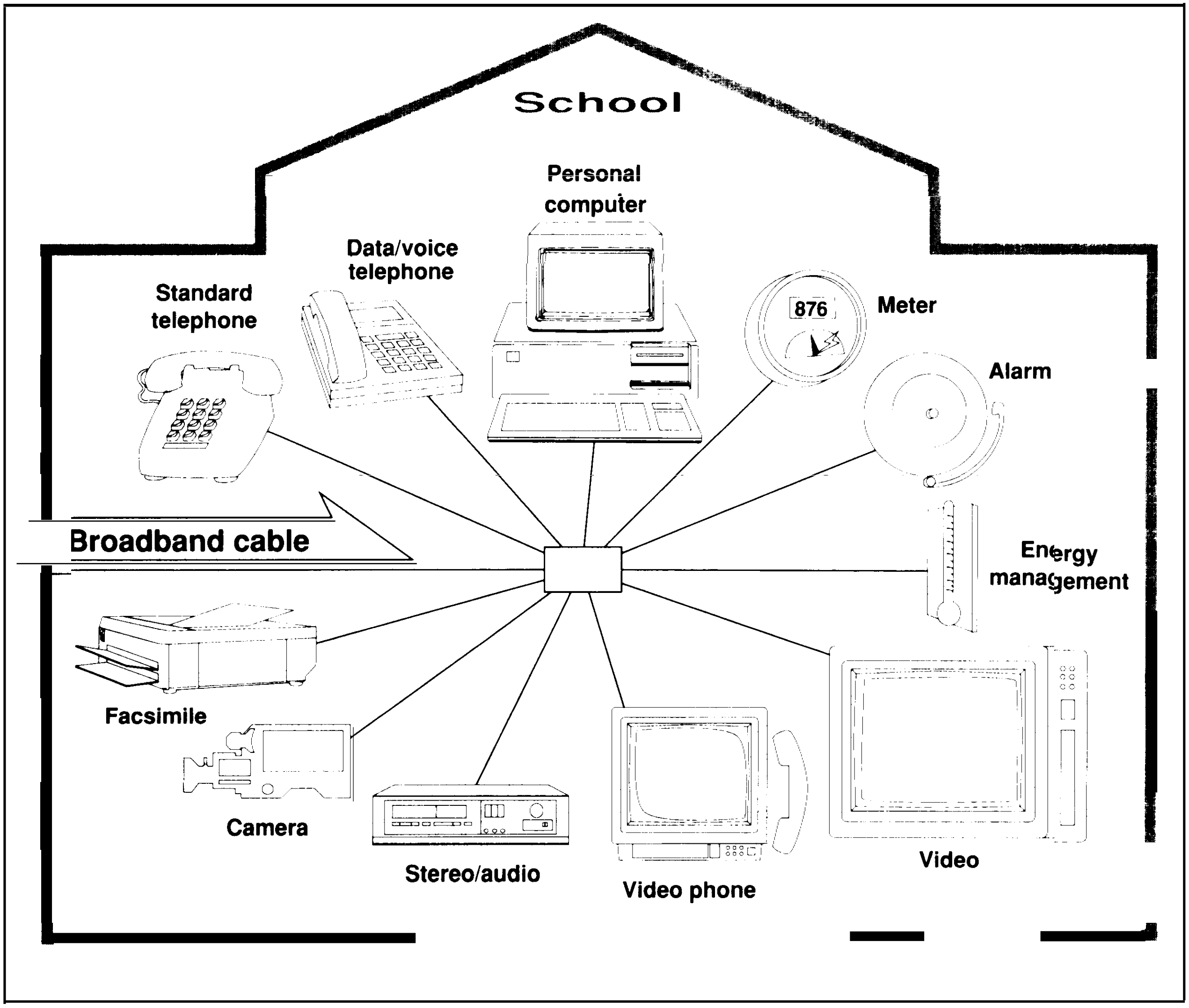
[60] For a discussion of the legal and regulatory issues surrounding the telephone companies' provision of video services see Pepper, op. cit., footnote 56.

[61] These are discussed in more detail in Dennis Gilhooly, "The Politics of Broadband," *Telecommunications*, vol. 22, No. 6, June 1988, p. 51.

[62] They offer speeds of either 144 kbps (2B+D) or 1.544 Mbps (23B+D), which allow the transmission of enhanced voice and data services, but only limited video applications.

[63] Many see video services as driving the deployment of fiber optics and the development of a broadband public network, See Andrew C. Barrett, "The Potential of Fiber Optics to the Home: A Regulator's Perspective," *Public Utilities Fortnight), vol. 123*, Jan, 19, 1989; Pepper, op. cit., footnote 56. A limiting factor in the deployment of broadband video applications is the switching equipment available. Video switching technology is still in the early developmental stages. Although technically possible, widespread application of broadband switching technology will depend on standardization and demand, and is still probably many years away. Keely, op. cit., footnote 49.

Figure 3-10--Information and Communications Services of the Future



In the not-so-distant future, schools will have access to a wide variety of information and communications services. Advances in transmission and switching capabilities will bring audio, video, and data services from many sources directly to the school.

SOURCE: Office of Technology Assessment, based on reformation from Bell Atlantic, 1989.

may evolve gradually, as fiber capacity is put in, or it may (in some areas) "leap-frog" existing technologies, moving users directly to advanced broadband applications. Availability of broadband services will be uneven across the Nation for some time.

Because of the newness of these services, prices have yet to be determined. Pricing policy, especially in the area of video services, is evolving as the telephone companies gain more experience with video transmission and processing technologies. No standardized price structure or tariffs exist for multichannel video service,[64] and in many cases, the telephone companies have had to price services on a case-by-case basis.

Integrating the various ISDN "island" field trials may be difficult because each trial uses equipment

[64] Dennis Pellant, executive vice president, Tele-Systems Associates, Inc., personal communication, Aug. 10, 1989.

and software made by different manufacturers. Schools using ISDN in one part of the country may not be able to connect with schools served by other phone companies, or the services and features offered by one phone company may not be available outside that company's service area. As ISDN moves into the implementation phase, standardized equipment and interfaces could resolve these differences.[65]

One of the fundamental problems schools face as they try to interconnect their networks is the lack of uniform national standards governing digital video and computer interconnection.[66] With the proliferation of new technologies and new competitors, and in the absence of a national standard-setting authority, many interpretations of standards have emerged. Uncertainty about standards and compatibility may complicate schools' hardware and software decisions.

Distance education needs may help justify broadband and ISDN applications. In exchange for permission to add capacity, telephone companies may agree to install advanced systems in schools. Education could bean important factor in expansion of the telephone network. The telephone companies are beginning to recognize the potential of the education market, and schools that want fiber optic systems will be seeking help from local, regional, and national telephone companies and providers.

In most instances, schools implementing a fiber system have to build **the system "from the ground up," laying new fiber from school to school and classroom to classroom. In the near future, this may not be the case.** With an increasing prevalence of fiber in PSTN, and with improved switching capability, districts may be able to hook onto existing fiber routes and only have to incur "final mile" costs to link schools and classrooms. In that case, fiber may be competitive, for example, with buying a satellite dish.

Even when ways are found to economically **deliver advanced information and video services to schools via the public telephone network, most school buildings lack the internal wiring to fully take advantage of new PSTN capabilities. Telephone connections in individual classrooms are rare.** To use computer networking, compressed video, and full video resources, classrooms will require wiring—a telephone jack, a cable outlet, or a connection to an outside satellite or fiber equipment. While new schools can be planned and wired easily, retrofitting some older buildings may prove difficult and costly.[67]

PSTN was engineered for analog voice applications. Newer services, such as high-speed data transmission and videoconferencing, strain system capacity and switching capability. While long distance lines and major trunk lines are increasingly fiber-based and have huge capacities, local telephone lines remain largely copper, limiting their ability to handle high-speed or high-bandwidth applications. Some copper lines can be "conditioned" to provide transmission rates up to 1.544 Mbps, but even this may not be enough for some video applications.

COSTS OF TECHNOLOGY SYSTEMS

> [T]here are no simple formulas to help estimate the cost of a technology system.[68]

The costs of distance learning technologies are difficult to analyze because technological options are so varied and are changing so rapidly. The technologies used in distance education are more powerful today than in the past, offering advanced capabilities and improved performance. At the same time, costs for the electronic components that make up these technology systems have been steadily declining. (Equipment and related costs for individual technology systems are discussed in appendix B.) These two trends have produced systems that are increasingly less expensive for the capabilities they offer teachers and learners. Local schools and

65 There are broadband applications available with today's technology, however. Switched Multi-Megabit Data Service (SMDS) is a service concept that will offer high-speed (45 Mbps) data communication services for computer communication using technology available now. This service will be available in the early 1990s.

66 With electronic mail (e-mail), for example, it has just become possible to send an electronic message through various services or from One company to another. All the various e-mail systems have been (and most probably remain) incompatible; each has its own formats and protocols, which make interconnecting them very difficult.

67 See footnote 38.

68 National School Boards Association, *Planning for Telecommunications: A School ~&r's Primer* (Washington, DC: 1989), p. 10.

districts are finding that they can now afford (often with some help) the technology tools they need. Five examples are illustrative:

- The Panhandle Shar-Ed Video Network was installed at a total cost of $340,000. This included laying fiber between four schools, outfitting schools with all necessary hardware, and maintenance and operation for 5 years. Annualized costs come to $17,000 per site. After 5 years the local telephone cooperative will charge the schools a minimal fee for continued maintenance and use.
- In the Missouri Education Satellite Network, participating schools pay a one-time fee of $8,000 for equipment and an annual programming fee of $1,000. Tuition costs for student courses and staff development are extra. Participating schools that choose to lease hardware and services pay an annual fee of $3,500 plus tuition.
- The Kentucky Educational Television initiative will construct a satellite uplink, install satellite downlinks at each of the State's 1,300 elementary and secondary schools, and build a new Telecommunications Center, at a cost of $11.4 million.
- Houston's InterAct ITFS transmitting equipment cost $330,000. This system reaches participating schools within a 50-mile radius around the city. Participating schools have invested an average of $12,000 for hardware.
- Since 1985, the Pennsylvania Department of Education has provided $952,000 to fund the Pennsylvania Teleteaching Project, a statewide audiographics project. Funding has supported a pilot program and has purchased equipment for 48 schools. Funds have also been used to upgrade software and hardware, for staff training, and for maintenance. heal schools pay telephone charges, about $45 per month depending on use.

Varying equipment requirements, use of local resources, and the individual nature of each system makes cost comparisons between different technologies impractical. For example, one study that compared costs at five hypothetical districts linked by a variety of technologies showed real differences in the absolute cost of the various configurations,[69] but the results were judged to be of limited value because the hypothetical construction was too contrived, and because the capabilities of the systems varied so greatly .70 Key factors affecting overall cost of distance learning systems include:

- *Instructional design:* what types of connections are needed? Instructional design requirements, particularly interaction, will affect the cost and type of system chosen.
- *Scope of the system:* how many sites will the system serve? More sites will increase the cost of the system, but costs per student or site may decrease as economies of size are realized.
- *Existing infrastructure:* what telecommunications resources are available? Schools with access to local resources, such as cable television systems or university ITFS networks, may be able to use those resources at minimal cost. Other schools may have to build or lease facilities.
- *Partnerships:* who can schools share costs with? Cooperative arrangements with business or higher education can substantially reduce costs by sharing facilities and resources.
- *Engineering requirements of the system:* what are the technical requirements of the system? Longer distance or rough terrain may increase costs.
- *Financial arrangements:* will it be cheaper to buy or lease capacity? Many combinations are also possible, such as owning the hardware and leasing the transmission channels.
- *Programming:* what types of programming are desired? Broadcast quality video production is very expensive. Other forms of audio, video, or computer materials may be far less expensive.

[69] State of Minnesota Task Force on Instructional Technology, State *of Minnesota Task Force on instructional Technology: Report to the Legislature* (St. Paul, MN: December 1988).

[70] Joan Wallin, Minnesota Department of Education, personal communication, June 16, 1989.

Table 3-2--Cost Categories for Distance Learning

Initial:	
Capital	**Infrastructure and hardware costs, such as satellite dishes, Instructional Television Fixed Service and microwave towers, computers, fiber optic or coaxial cable, monitors, cameras. (Equipment and related costs for individual technology systems are discussed in app. B.)**
Development	**Costs needed to actually put the system into operation. These costs cover initial professional training, program development, materials acquisition, staff support, management, and miscellaneous equipment. Such costs are valued not only by** actual dollars **spent, but also in the time invested.**
Ongohg:	
Programming	**Costs paid to acquire, produce, or use** educational programming or instruction.**These include subscription costs, costs for individual courses or materials, and any other costs associated with producing a course or program.**
Operation and maintenance	Costs associated with continued operation of the system. Some costs include: maintenance and repair; salaries**for teachers, aides, and technicians; and expendable materials. Also included in this category are recurring costs associated with training technical staff, teachers, and aides.**
Transmission	**Costs of satellite transponder time, or long distance telephone charges, for example.**
Expansion	**Costs that result from enlarging an existing program. These include: new equipment, personnel, and management costs.**

SOURCE: OTA analysis, from Anne Batey and Richard N. Cowell, *Distance Education: An Overview* (Portland, OR: Northwest Regional Educational Laboratory, Technology Program, November 1986).

- *Training:* who must be trained and what expertise is already available? Experienced teleteachers and support staff will need less training and support. Inservice and staff development costs will vary depending on the types of technology used and how the course is designed.

Schools implementing distance learning systems have two types of costs: 1) *initial costs* that include equipment and development; and, 2) *ongoing costs* that include programming, transmission, operation and maintenance, and system expansion. (See table 3-2.) The most visible costs are the startup costs, which can be quite high, especially if few resources exist and the system has to be built "from the ground up." High startup costs can make some technology options too expensive for school districts to afford on their own.

In the long run, the ongoing expenses associated with operating a distance learning system may be much more substantial than the initial costs. The equipment necessary for a school to participate in Missouri's Educational Satellite Network, for example, costs $8,000, but annual subscription costs for receiving programming could soon equal or exceed that amount and will continue to accrue each year that schools subscribe. School districts that only use free programming from public television or cable programmers may have minimal costs. Districts that share local teachers and resources electronically tend to have lower programming costs, although for districts or schools producing their own programming, costs will be higher. Schools that buy courses from commercial providers pay subscription and/or per course costs. Other ongoing costs associated with distance learning include operating expenditures for maintenance and repair, transmission, and any costs associated with expanding the system.

Opportunities exist for local schools to reduce (or even eliminate some) costs by sharing infrastructure resources and programming costs with other districts or education agencies, private business, higher education, and State and local government. In the Panhandle Shar-Ed Video Network, for example, four neighboring school districts secured funding from private foundations and from the State and, working in collaboration with the local telephone cooperative, are sharing the costs of constructing and operating a fiber optic system for the schools and the community. Institutions of higher education, with technology capacity and instructional resources, become natural partners for K-12 distance education efforts.

Growing opportunities exist for schools to share ongoing expenses as well. By expanding the uses of a system, schools can share costs with other user groups. The State of Maine, for example, will use its higher education telecommunications network to serve other learner communities after regular school hours. In this way, the resources of the network are more fully utilized, and costs can be borne by more users. Local schools can similarly reduce operating costs and share benefits with local businesses, governments, and community groups.

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SUMMARY

Improvements in telecommunications and information technology have given schools *many* options for delivering instruction and educational resources to distant students and teachers. Further advances in technology, including more powerful computers and storage devices, the deployment of fiber optics, better signal processing and compression, and the rapid advance of digital technology, promise even more opportunities in the future. The capabilities of distance education will expand as information processing and telecommunications technologies continue to converge, as audio, data, and video become easier to combine, store, and use, and as various technologies and networks are linked.

This explosion of technological possibilities presents schools and educators with a host of new challenges and opportunities. Schools will face an increasingly complex array of technologies and providers. Many new players, including the telecommunications industry and the post-secondary and higher education community, can help sort through the choices. Educational users can become leaders in advancing the development of new education technologies, applications, and experiences. Education and industry can work together.

Today, the technical capability exists for schools to provide effective distance education, and a growing number of efforts utilize available telecommunications infrastructure and information resources. However, access to telecommunications resources varies considerably in different locations. Channels that could be used to provide distance education are saturated in many areas, high-capacity fiber optic lines are concentrated in more populous areas, and schools' internal wiring is often inadequate. As a result, most efforts will require additions to existing systems and/or the construction of entirely new systems.

A major factor in the advance of telecommunications technologies and services is the sometimes confusing regulatory structure in the United States. Regulations and policy regarding computer and telecommunications technologies have been largely promulgated with little consciousness of the needs and concerns of education. Transmission costs can be very high and gaining access to scarce communications channels and resources can be difficult for local schools. Future changes to telecommunications policy and regulation, especially those governing the public telephone network and the Nation's cable television providers, could radically affect the options available to schools. To protect rising interest and investment in educational telecommunications, the education community needs a voice in determining how these policies are defined.

The future promises vastly more sophisticated telecommunications systems for education. These systems will generate new and different applications as the technologies advance and as students and teachers learn to use the systems more creatively and effectively. These systems have the capability of serving more than just the needs of education—telecommunications is achieving greater importance in encouraging economic development, training the work force, and extending the resources of the information age to all citizens.

Policy options serving immediate needs and long-term goals could include:

- **Support technical assistance to schools and States planning distance learning efforts.** Experiences of those already up and running could be shared more broadly.
- **Review and shape Federal and State telecommunications policy to ensure a coherent use of communications technology for education.** Assuring adequate capacity on telecommunications systems for education at reasonable rates could expand the use of such facilities for distance education and promote the improvement and expansion of existing systems, as well as help to justify investment in new telecommunications resources.
- **Support standards and protocols that promote the integration of different technologies and networks.** The growing national infrastructure for distance education is composed of numerous systems with various administrative and technical frameworks. Efforts to expand the communications infrastructure for education could build on resources already installed, while seeking further connections and flexibility.

Telecommunications and information technologies can advance teaching and learning to new levels. The potential of technology for addressing the needs of education cannot be neglected:

> Technology has the capacity to do more than aid the exchange of information and ideas. It can enhance students' powers of analysis, sharpen their capacity to think critically, improve their writing skills, and increase their ability to develop independent judgments. If used properly, it is likely to alter the learning environment to such an extent that the old institutional models of campuses, classes, lectures, schedules, timetables, and tests will not survive in their present forms. How, when, what, and where we teach will change.[71]

[71] Donald R. McNeil, "Technology Is a Hot Topic, But Its Impact on Higher Education Has Been Minimal," *The Chronicle of Higher Education,* June 7, 1989, p. A44.