DOCUMENT RESUME

ED 134 231 IR 004 459

AUTHOR de Sola Pool, Ithiel
TITLE Some Hypotheses about the Cost/Effectiveness of Satellites in Education in the United States.
SPONS AGENCY National Inst. of Education (DHEW), Washington, D.C.
PUB DATE 16 May 76
NOTE 38p.; Paper presented at the Conference on Educational Applications of Satellites (Arlington, Virginia, February 2-3, 1977). For related documents, see IR 004 458-468

EDRS PRICE MF-$0.83 HC-$2.06 Plus Postage.
DESCRIPTORS *Communication Satellites; Community Benefits; *Computer Assisted Instruction; Cost Effectiveness; *Educational Technology; Educational Television; *Estimated Costs; Information Dissemination; Information Retrieval; Master Teachers; Teacher Education

ABSTRACT

This paper first enumerates ways in which satellites can be used in education. Uses include the delivery of video material, teaching to scattered students, master teaching, teaching of teachers, providing information on current events, video teaching of behavior, information retrieval and computer-aided instruction. It then notes some technological constraints such as bandwidth, real-time needs, dispersion or concentration of network, and other aspects of network configuration that make satellite delivery of messages more or less advantageous than alternative methods. Since relative costs as well as benefits are a concern, consideration is given to the cost of a satellite education system. Costs are estimated in terms of an ultimate nationwide and universal educational satellite system. The paper concludes that the first steps should be the use of satellites for data communication in locations where facilities are not readily available. (Author/WBC)

SOME HYPOTHESES ABOUT THE COST/EFFECTIVENESS OF SATELLITES IN EDUCATION IN THE UNITED STATES

by
Ithiel de Sola Pool

Director
Research Program on Communications Policy
Massachusetts Institute of Technology
Cambridge, Mass.

May 16, 1976

A Paper for the National Institute Of Education

ABSTRACT

The paper holds that the most important immediate uses of satellites in education in the USA are for information in the USA retrieval and computer aided instruction in such low density and disadvantaged areas as Alaska, Appalachia, Indian reservations, and rural regions.

In the first section the paper attempts to enumerate ways in which satellites can be used in education. While some uses may be more important than others, all have some importance. The uses listed include the delivery of video material, teaching to scattered students, master teaching, teaching of teachers, providing information on current events, video teaching of behavior, information retrieval and computer aided instruction.

In the second section of the paper we note some technological constraints such as bandwidth, real-time needs, dispersion or concentration of the network, and other aspects of network configuration that either make satellite delivery of messages more advantageous or less advantageous compared to alternative delivery methods.

In the third section of the paper we make a rough cut at some economic analysis of costs, for any choice of direction of effort depends not only on benefits but also on relative costs. We try to get some bounds on what different parts of a satellite educational system would cost. We estimate the costs in terms of an ultimate nationwide and universal educational satellite system so as to see where the first steps might eventually lead.

In the final section of the paper we draw the conclusions noted above, that the most important first steps should be use of satellites for data communication in locations where such facilities are not as readily available as in the major metropolises. We note inthis section that though the earlier parts of the paper had been couched in terms of a national system, such a system could only evolve gradually through taking of useful first steps.

STATEMENT OF OBJECTIVES

The purpose of this paper is to identify :

1) Topics that need to be researched in order to decide on whether satellite facilities will be useful for American education;

2) Directions in which initial educational satellite efforts should go.

SOME HYPOTHESES ABOUT THE
COST/EFFECTIVENESS OF SATELLITES
IN EDUCATION IN THE UNITED STATES

"Nothing But":

A satellite, we are told, is "nothing but" a carrier for microwave circuits routed up and down instead of across.

Computers are "nothing but" machines that perform the logical operations that they are told to perform.

Nuclear weapons are "nothing but" explosives like any others except with a bigger bang.

TV teaching is "nothing but" the same lessons with the words coming out of the box instead of out of a book or the teacher's mouth.

* * * * * * * * * * *

All those statements are in some respects profoundly true and in other respects profoundly false.

In each case it is true that the new technology is just a vehicle to deliver some result that people had previously delivered in other ways. Yet in each case it is also true that in some situations and in certain respects the new vehicle is so efficient that the whole pattern of outcomes may be modified.

If it is true, as it is, that satellites in education are "nothing but" a vehicle to provide electronic circuits to educators, then four questions must be answered in deciding how valuable satellites are to them: (1) What needs do schools have for circuits to deliver educational materials? (2) What alternative types of networks are available to them? (3) Under what circumstances are satellites the cheapest way to provide desired material? (4) What are the the most useful initial steps to stimulate use of satellites in education?

NEEDS FOR CIRCUITS

Movies:

Whether delivered by bicycled films, or video cassettes, or over the air broadcasts, or CATV, or satellite transmissions, motion pictures clearly have some value in education. Every competent school system uses some of them. They are useful for showing students historical re-enactments. They are particularly helpful in enabling students to see good drama and opera which they would rarely have a chance to see live. They are useful for demonstrating non-verbal techniques such as swimming form, or how to hit a ball, or how to bandage a wound. They are more useful than words alone in exposing students to locations and cultures they will not meet directly, so geography, art history, and anthropology classes use them extensively. For that reason they are particularly valuable in expanding the scope of experience of students who have limited exposure to cultures other than their own, and whocome fromconfining cultural milieus. The most expansive experience American children of that kind now have is from TV, which is a seriously deficient source for developing empathy with the outside world. Movies in school can be a valuable corrective to the TV image. (1)

Yet when all is said and done, visual material is a substantially lesser portion of the curriculum than is verbal; how much less I do not know. One figure needed for any good cost/effectiveness analysis would be, for each grade level, the proportion of such visualizable material in the curriculum. Can the educators give us a reliable figure on that? I suspect it would be a surprisingly high figure.

What is more, we must realize that we are dealing with a visually literate generation that grew up on TV. Movies may work well with them.

So one use of circuits may be to provide motion picture material to the classroom. It is a significant, but limited function.

<u>Dispersed audiences:</u>

Sometimes a student population, instead of being concentrated in a classroom, is widely scattered. Among examples, is bedridden

---

(1) For analysis of the role of the media in broadening of empathy see Daniel Lerner, The Passing of Traditional Society, Glencoe, Ill. The Free Press, 1958. For a discussion of the contents of TV imagery see George Gerbner, forthcoming article, Journal of Communication, vol. 26, summer 1976.

dents, students in sparsely settled rural areas, or students taking highly specialized courses for which there are only a handful of candidates in any one school or other location. Electronic circuits can be useful to deliver course material to such scattered individuals.

One dispersed audience of some importance is adults who have left school, but are interested in continuing their eduction at home or at work through "open learning" systems. (1) The kinds of circuits that will do the job economically are highly sensitive to the topography of the audience distribution. If the task is to reach bedridden students in their homes, then useful devices are likely to be those that reach the home anyhow: the telephone, radio, or television. If the task is to aggregate small groups scattered in many institutional locations, such as for example medical specialists at several hospitals or Esquimo children in arctic villages, then specialized institutional networks that serve those communities may be used. A particularly important use in ordinary schools, if there were a special satellite or other broadband network, might be to permit the offering of specialized courses. One can imagine, for example, a situation in which advanced calculus might be made available in every high school in the country, or likewise some variety of foreign languages. This would be particularly important in impoverished areas whose

---

(1) Norman C. Dahl, "The Use of Satellites in Open Learning Systems", in Norman MacKenzie, Richmond Postgate, and John Scupham, Open Learning, Unesco Press, 1975.

schools are less good than elsewhere.

<u>Master teaching:</u>

In many places the teacher in the classroom is acknowledged to be less competent than one would like. Film or video cassettes, or broadcasts, or CATV or satellite transmissions can be used to deliver a superior teacher's teaching. Radio also can be used, for the master teacher's words may be what is important, rather than any visual effects.

There are serious objections to importing teachers electronically. It denigrates the teacher who is there live with the students. The remote teacher may not understand the local culture of which the classroom teacher may be a part. The remote teacher is less flexible in adapting to what the students are doing and are capable of understanding at a given moment than is a teacher on the spot; a film cannot take account of whether there was a softball fight the moment before. Done in broadcast ways, master teaching may require all classes to be doing the same thing at the same moment; putting the master teacher on cassettes or films to be shown under the local teachers guidance avoids that. Whatever the objections, however, there are times and places when the master teacher is enough better, so that delivering a master teacher electronically makes sense. In particular, it is not an all or none choice. The classroom teacher may be able to discuss and explain a film or broadcast, just as he or she discusses the textbook.

In general, the need for delivering master teachers is small in developed school systems with professionally trained teachers. It may be more frequently useful in underdeveloped lands.

Teaching teachers:

In a number of underdeveloped countries it has been found that the most effective use of educational broadcasts was not to deliver material directly to the classroom , but to deliver guidance to the teacher before he enters the classroom. Teachers have to be dispersed physically to the locations where they teach. It is hard to bring them together frequently for orientation or guidance. Circuits or cassettes that can reach them where they are, and help them teach better are of great value.

This is particularly important in underdeveloped areas where the teachers are poorly trained and in rural areas where teachers are away from centers of orientation and guidance. It is not unimportant, however, even in the best school systems for superintendents or supervisors to be able occasionally to hold teleconferences with the teachers from the various schools in the system, or for teachers to have available broadcast or taped courses on new or advanced materials.

Current events:

In an era in which most people get most of their national and international news from TV, it is clearly useful to the teacher to be able to bring video of current events into the classroom, either live or taped for replay. Quantitatively, current events are not a major part of education, but they are not trivial either.

<u>Video teaching of behaviors</u>:

Most of what is taught in the classroom is verbal, but a certain portion consists of learning how to do things with ones body. This includes not only such activities as sports, but also such expressive activity as oral presentations. One of the best ways to teach all such activities is by providing the student with video feedback so he can see just what he did. This is a very valuable form of teaching of skills in intercultural contant for relatively non-verbal youngsters who belong to subcultures. This audiovisual activity, however, is usually done entirely with local equipment. It requires a video camera and monitor to tape a students behavior and enable him to see it, not a cable or satellite circuit.

<u>Information Retrieval</u>:

The audiovisual functions listed so far are all routinely done today in at least some school settings. They have their merits and perhaps should be substantially expanded, but they represent nothing revolutionary. We turn now to applications about which it is reasonable to speculate that fifty years hence the classroom practice will be drastically different from what it is anywhere today.

Looking up information is such an application. Computerized information retrieval systems are just now beginning to have an impact on research and teaching. A couple of years ago Arthur D. Little estimated the on-line electronic publishing business to be over $100,000,000 a year and growing at about 25% per annum. Most of the impact so far, however, has been on commercial and industrial information seeking. In business firms a persons time spent looking up information is an accounted expense. If, therefore, a computerized information retrieval costs $5 or $50, but saves hours of labor it may well be worthwhile. Research in educational institutions is not accounted that way. A student's time is treated as valueless, and even faculty time is not considered seriously. Time spent in libraries appears nowhere on school budgets. For that reason billed computerized information retrieval systems have barely entered education so far.

Within the coming decades, however, that is bound to change. In the first place the cost of information retrieval is bound to fall drastically. We may anticipate falling costs of computer memories, long distance telecommunications, and computation, at the same time as rising costs of publishing and paper handling.

To the extent that computerized information retrieval becomes a conventional mode of searching for information, access to remote data bases by telecommunications will become normal. For reasons that we shall later examine more fully, it is often far more economical to incur communication costs for use of a single data base than to replicate the data base in many remote locations. Virtually all the large information retrieval systems today operate on that conclusion. Lockheed and the Systems Development Corporation which offer the widest range of information services today, each have their computer on the West Coast (not even in the center of the country) and are accessed by customers via telecommunications from anywhere. The added communication costs are far offset by economies from centralization.

As computerized information retrieval begins to filter into American schools, circuits for the purpose will be needed first in school libraries, and eventually in individual classrooms.

<u>Computer aided Instruction</u>:

CAI is also only at the beginning of a long process of growth. Occasionally oversold by enthusiasts, it has nonetheless been highly successful in some pedagogical situations. The first prerequisite is the arduous development of high quality software. No more than in hard copy publishing, can large amounts of that be produced overnight.

A second prerequisite, as in the case of information retrieval, is a substantial reduction in cost. In this instance, as in information retrieval, the use of the new technology has spread faster in industry and the armed services where student time is an item of expense, than it has in schools and universities. The goal which some CAI developers have set for themselves of getting costs down to about 30 cents an hour (on the belief that more expensive systems would not be adopted) testifies to how we evaluate student time.

CAI is much less dependent upon remote access than is information retrieval. It may well turn out that CAI courses in subjects like math or languages are as economically or more economically packaged on tapes or similar devices for use on dispersed minicomputers than if operated on large systems accessed from afar. On the other hand the reverse may turn out to be the case. (1) Besides that, some subjects that are less formal than math or languages, may require information retrieval operating on large data bases as part of the computer aided instruction. The activities of CAI and information retrieval are apt to grow together with time.

TYPES OF CIRCUIT REQUIREMENTS

The variety of ways in which electronic messages can be delivered for education includes the telephone lines, CATV, and physical transport of cassettes or tapes, as well as satellite distribution. Indeed most actual activities use these in combination thanks to the interconnected character of the nation's communications network. For example, a CAI tape may be

---

(1) Cf. John Ball and Dean Jamison, "Computer-Assisted Instruction for Dispersed Populations: System Cost Models", Instructional Science, February 1973, pp. 469-501.

mailed to a computer center to be loaded on a machine which is accessed by dial-up lines that may well travel over satellite circuits. However, insofar as satellites enter the educational communication network only as an alternative carrier for long lines traffic, educators need pay no special attention to them. When and if they are cheaper channels than microwaves or cables the common carrier will use them, and the ultimate consumer need not even know it.

The satellite applications that NIE needs to take under study are those that call for a dedicated educational satellite or dedicated set of transponders that deliver their signals to schools over dedicated or partly dedicated ground stations. The configuration of greatest interest to educators is that in which there is a high powered satellite like ATS-6 permitting low cost antennas to be placed right at the schools for direct reception of educational materials.

It is not sensible to be either for or against such a system in the abstract. There are purposes and situations in which such a system is likely to be useful and others in which it is likely to be uneconomic. Only after considerable research will the limits of cost/effectiveness of such a system be well understood. Here all we can do is to lay out a few of the parameters that must be included in any such analysis. Let us take note of half a dozen characteristics of the communication system which affect the usefulness and economy of such a system.

Bandwidth requirements:

The RCA Satcom launched last December has 24 transponders each capable of carrying one TV color picture, or 1000 voice grade circuits, or 64 million bits per second of data. Those figures convey the ratio between the large bandwidth required for video, the medium bandwidth required for voice, and the small bandwidth required for data. A character of text transmitted as data requires 6 to 9 bits; using 8 as our divisor, 64 million bits means 8 million characters of text per second or about 533 typewritten pages.

There are nearly 110,000 schools and colleges in the United States with between 2 1/4 and 2 1/2 million classrooms. (1) If it were economic to provide a satellite of the size of RCA Satcom exclusively for education, and if each school could have a full size 96 foot earth station, that would mean that at peak hours each school could receive 24 video transmissions, or alternatively have 13 minutes out of the hour available for telephone contact, or handle 280 words a second of text (14kbs), or some combination of these. Each classroom could have a choice of the same 24 television programs, or 35 seconds per hour of

---

(1) The Digest of Educational Statistics for 1974 reports 107,006 schools and 2,665 institutions of higher education for 1972-73. It reports 1,918,000 schoolrooms in use in elementary and secondary schools in 1971. Since there were 47.0 million primary and secondary students in 1971 and 46.3 million in 1973, and 9.2 million students in higher education in 1972, the total number of classrooms must be around 1/5 greater than the 1.9 million figure for primary and secondary schoolrooms. In calculations below we will use the figure 2.[illegible] million for the total.

telephone conversation, or traffic of 13 words a second of text (668bps), or some combination. Of course, no school would have a 96 foot earth station; the penalty for smaller earth stations is taken account of in estimates below. (1)

Some obvious conclusions follow from these calculations. A satellite system can deliver a limited choice of on-line TV, but not individualized video on demand. It can provide occasional use of voice feedback for specialized purposes, but not on a routine basis at will. It can, however, provide the capacity for individualized digital interaction such as occurs in CAI or information retrieval. The bandwidth that can be made available to education by a dedicated satellite system is large -- very large by any economic comparison of what could be done by present terrestrial networks --, but it is far from unlimited, and does set constraints on what can be done.

<u>Real time requirements</u>:

The cost/effectiveness analysis of a satellite system differs quite markedly depending on whether the transmission has to occur

---

(1) This is a back of the envelope calculation. It takes no account of such unfavorable factors as congestion degredation, or of scheduling algorithms; indeed the kind of packet system that we shall discuss below would in fact allow for only about one third of the throughput of the theoretical limits here given. On the other hand the calculation takes no account of such favorable factors as increasing capacity with improving technology in the decade or so before any such system would come into existence. The basic conclusions to be drawn from these calculations depend, however, on order of magnitude results and are likely to stand up to such refinements.

at the time that it is used, or whether the transmitted material can be stored for later use. In the former case the cost of satellita transmission at peak hours has to be compared to the costs of other real-time facilities such as telephone lines, or leased lines, or CATV for the same hours. In the latter case the comparison may be with postal or other delivery; use of the satellite system can take place in nighttime or other low use periods. In general, a satellite system's cost will be easier to justify if there are soma important real-time requirements.

In the first part of the paper where we listed educational uses of telecommunication circuits we noted a number of them in which real-time interaction is important. Teaching of dispersed classes requires two way communication if it is to be more than taped lectures. Also, interactive computing, whether for information retrieval or for CAI, requires real-time feedback.

Table 1 illustrates the relation between various uses and real-time and bandwidth requirements. Dispersed teaching requires video (which is high bandwidth) downstream from the teacher, and it requires availability of voice for student responses upstream (i.e. it requires medium bandwidth.) Movies require high bandwidth, but can be taped at night on VTRs started and stopped by automatic timers. CAI and information retrieval require low bandwidth, but they do require operation in real-time.

CAI and information retrieval pose requirements that are met well by a satellite system. Dispersed teaching can be done, but only

	Bandwidth		
	High (Video)	Medium (Voice)	Low (Data)
Interactive in real-time		Dispersed teaching	CAI Info. retrieval
Delayed	Movies		

Facilities Required By
Some Applications

Table 1

on a scale that does not exhaust the available video transponders or the audio feedback capacity. Since such specialized teaching can well be relegated to non-peak hours, that may not be an intolerable constraint.

Audience topology:

The advantages of a satellite network with low cost earth stations is greatest where the receiving locations are quite dispersed and where terrestrial communications among them are not yet in place. There is no better way of reaching arctic villages or the 500,000 Indian villages. Yet even for India, when the cost/benefit analyses were made in planning for the SITE system, it became clear that a hybrid system would be most economical. Where villages were sufficiently densely located or close to big cities, it turned out to be economical to provide them with television by line of sight broadcasting. If Esquimo villages are one extreme, then American central cities may be the other. A rooftop microwave network or some CATV channels (where the city is cabled) may well be a more economical way of doing the same thing as would be done with a satellite earth station.

There is, therefore, no obvious a priori answer as to the economics of an educational satellite system for the United States as a whole. The calculations need to be made. If, as seems highly possible, they turn out to justify investment in a satellite system for eduction, than the balance may tip even for many central city locations, for once the satellite is in place and transmitting, the costs of receiving from it directly may in many instances turn out to be no higher than the costs of receiving indirectly via a terrestrial redistribution system. A satellite system may turn out to provide an example of a kind of Pareto optimum situation in which some gain, while others do not gain, but do not lose either.

Receive-only vs two-way:

While a number of originating centers such as university schools of education, or the headquarters locations of major metropolitan school systems, or educational broadcasting production centers may have two way video antennas, we are postulating that ordinary schools will only be able to afford a receive only dish for video. Audio and digital transmissions, however, can and should be two way.

Point-to-point vs. star:

Since audio and digital transmissions may be two-way, they can in principle go not only to the originating center, such as the computer in CAI or in information retrieval or the teacher in a studio of a telecourse, but also between pairs of persons on the system. For example, there can be communication between classrooms working on the same subject in different schools. (That might be particularly interesting as a way of relating remote arctic villages or parts of an Indian reservation to each other.) If, however, that kind of communication were quantitatively a major aspect of the system, the design would be quite different. The switched telephone network has been designed for that; it establishes circuits between any two arbitrarily determined individuals. A large part of its cost is its switching system. The type of dedicated satellite system that we have described above will turn out to be economic, if indeed it turns out that way, in large part because it dispenses with the costs of switching since there will be few such pairwise circuits demanded.

Fortunately, the alternatives are not quite polar. For data communication today, and maybe for voice too in the future, the development of message switching and multiple access satellite systems change the picture considerably. The basic idea of packet switching is that the high speed trunk circuits are kept full of standard length pieces of messages (packets) which have addresses on them. As they reach their destined computer their address is read and they are kept and reassembled into the original message. (1) If a satellite is used as a transmission medium it can broadcast all the packets instead of sending them on a switched multipoint net. At each receiving station the computer reads the addresses on all packets and retains those packets addressed to it. (2) In random access packet switched satellite communication, each earth station transmits packets at random times to the satellite. Since the originating earth station, like all the others, is listening to all the traffic, it verifies after a quarter of a second the correctness of reception of its message, and the non-overlap of its transmission with that from

---

(1) The ideas behind the ARPAnet were outlined by Paul Baran in the mid 1960's. (Cf. "A Briefing on the Distributed Adaptive Message-Block Network", Rand, P-3127, April 1965. It has been described in many places, e.g. Lawrence G. Roberts, "The ARPA Network" in Norman Abramson and Franklin F. Kuo, eds., Computer-Communication Networks, Prentice Hall, 1973. The present commercial application of packet networking in the United States is Telenet. A large number of packet networks are now being developed in various places, among them the French Cyclades, the European EIN, a British Post Office experimental net, and a trans-Canada net.

(2) Norman Abramson, "Packet Switching With Satellites", National Computer Conference, 1973, pp. 695-702. Leonard Kleinrock and Simon S. Lam, "Packet Switching in a Slotted Satellite Channel", op. cit., pp. 703-710. Lawrence G. Roberts, "Dynamic Allocation of Satellite Capacity Through Packet Reservation", op. cit., pp. 711-716.

another station. In the event of an overlap or garbled transmission the sender (after a random delay which helps prevent a second overlap) retransmits. Using such techniques, throughput of 16% of total channel capacity can be achieved without any centralized control. By a modification of the system so that bursts are not wholly random, but are slotted at specified time intervals, a throughput of 37% of capacity is achievable. A more complex scheduling technique described by Roberts achieves a yet higher throughput.

These levels of throughput may seem wasteful of satellite capacity, but if on a network there are a large number of small users whose traffic has to be co-ordinated, there is probably no way of achieving higher efficiency. According to one estimate, at the 7 characters per second average rate for interactive communications experienced on existing networks, over 300 users could be serviced on a single voice channel. (1) Abramson has made an estimate that a single Intelsat IV transponder with 36 Mhz bandwidth could feed 10 mbs into small earth stations. Given the rate of interactive communication by users of alphanumeric terminals, this would permit 100,000 active users. This corresponds to our cruder earlier calculation that a full satellite devoted to data transmission could come close to servicing every classroom in the country simultaneously.

---

(1) Robert P. Blanc, Review of Computer Networking, National Bureau of Standards Technical Note 804, January, 1974.

SOME COST CONSIDERATIONS

If at some time in the future an educational satellite system provides circuits to every classroom in the country, the dominant costs will not be those for the satellite, but rather those that recur in each classroom. None of the figures that we use in this paper are anything but starting approximations for further research, yet the conclusion is fairly robust no matter what detailed data we use. The crucial point is that whatever is done in each school is repeated 100,000 times over, whatever is done in each classroom is repeated more than 2 million times over, while whatever is done in the space segment is done one, two or three times only.

As we require larger and more powerful satellites to work with small ground stations we may expect the costs of the space segment to go up. Today one might perhaps build a modest communication satellite for $15 million and launch it for $9 million. Let us assume three such satellites so as to be sure of adequate backup. That means a space segment cost of $72 million. But consider instead a more sophisticated satellite costing $30 million apiece and $18 million apiece to launch. Again multiplying by three, that is $144 million. A still more powerful satellite might cost as much as $80 million and a launch might cost $30 million, making a total for three satellites of $330 million. Depreciating the cost over three years we find that the space segment has to recover between about $100 million a year and a quarter of that. This is in line with present rentals of a transponder which may range from $1 million to $3 million a year. Multiplying by 12 or 24 would suggest that our above figures are perhaps on the high side. The basic conclusion in any case is that the space segment costs even without allowing for falling costs with improvements of the technology, are likely to amount to somewhere between $5 and $20 per classroom per year when the whole country is connected. That is clearly the smallest part of the total cost of a national educational satellite system.

Much more significant costs are the terminal and audiovisual equipment for each school and classroom. To some degree that fact already makes a case for satellite distribution since most, but not all, of that equipment would be required if one were to use terrestrial distribution to introduce modern communication facilities into classrooms. There are four sets of earth segment costs that must be considered if a serious cost/benefit analysis is to be made, and three of these apply whether or not satellites are used: 1) there is the cost of internal wiring in school buildings; 2) there is the cost of computing equipment including concentrators and terminals; 3) there is the cost of audiovisual equipment; and 4) there is the cost of earth stations.

1) Internal wiring :

We have not had a chance to explore that even in a preliminary way in this paper. The technically essential cost is small, but it must be recognized that building code and union requirements may often push such costs up to a significant level.

2) Computing equipment:

Table 2 shows three main elements of cost in providing the in-school end of CAI and information retrieval capabilities. These are the communication costs, the terminals themselves, and

	1974 Costs	Possible assumptions about change in a decade
Terminals	$1000 to $4000	Halving every 5 years
Concentrator	$20,000	Halving every 5 years
Telenet charges per port packet charges	 $25.00/month .60/1000 packets	 Drop to $10. Constant

Some Cost Elements
For Interactive Data

Table 2

any concentrators or interfaces. The necessary equipment to permit effective CAI and information retrieval can perhaps be estimated by examining present costs that are being incurred on terrestrial networks. Educom, for example, is engaged in an experiment with Telenet. Students at various colleges are using

Dartmouth, MIT, and SUNY facilities via the net. Experience shows that a terminal user is likely to use about 500 packets an hour, thus incurring a packet charge to Telenet of 30 cents and hour.

That, however, is only part of the cost. There are other communication costs which are not a function of usage. A concentrator which can service up to 96 terminals costs $400 a month at the present time. Since we are assuming that the average school would have only one terminal in each classroom or about 20 terminals that means $20 a month each. In addition there is a port charge for each terminal of $25 per month. Thus the fixed cost for each terminal would average $45 per month. To translate that into a billion dollars a year for coverage of all classrooms would be a mistake, however, for these costs will fall greatly in the coming years and with volume. A concentrator now is a $20,000 device; given the trend in costs of computers, memories, and microcircuitry, there is every reason to believe that within a decade that cost will be cut in half two or three times. Nonetheless we anticipate an investment in such equipment substantially larger than the investment in the satellites themselves.

A couple of related points should be noted. At present connection to the Telenet network costs also on the average of $200 a month in telephone company charges for a high speed line from the concentrator in the school to the nearest point on the network.

That charge would not be incurred on a satellite system. For all schools in the country to be connected, that charge would come to over a quarter of a billion dollars, i.e. substantially more than a satellite system.

Schools in many places can avoid that charge now by accessing the network via dial-up local calls. They then have to pay an extra charge of 70 cents an hour to Telenet added to the 30 cent packet charge. In most cities the present practice of unlimited local calls makes the telephonic part of the service free, but if such usage increased very much one could be sure that that exploitation of the telephone system would not be allowed to continue.

We also have to add the cost of terminals themselves. Relevant terminals today sell for $1000 to $4000 dollars. Tektronix is advertising its graphics terminal for $3000 in quantities of one. Amortized over three years and allowing for maintenance contracts we are again talking of an item of between one and two hundred million dollars a year for all classrooms, at present prices. But, once again there is every reason to expect the prices to come down significantly.

Putting all these items together at present charges would lead to the quick conclusion that the cost of providing CAI and information retrieval access to all classrooms would be prohibitive, even without considering software. However, if research confirms the quick impression that present rates are likely to be cut in half not just once but at least twice, then the prospect becomes very attractive. We would then be facing equipment costs in schools of about $17.50 per student per annum, i.e. under $450 per classroom per annum to provide physical access to a satellite channel to CAI and to information retrieval services wherever they are to be found. These would then be available at usage rates that even now are only about 30 cents an hour.

3) Audiovisual equipment:

The present costs for in-school audiovisual equipment to take advantage of a satellite communication system seem to come out at about the same level as the computer equipment. While those costs will also fall, perhaps they will not fall as fast.

We priced out a system which assumes a color monitor and tape deck in every classroom, two color VTRs, editing facilities and tapes in every school, so as to permit nighttime recording of video material off the satellite and editing of it. Equipment prices are indicated in Table 3. Equipment costs were again written off in three years. The overall result was again about one and a half billion dollars a year at present prices. Expert opinion suggests that costs of color VTRs is falling now from the recent range of $1800 to $3400 down to about $1000 for a record-play back (non-editing) deck. Similarly, the development of solid state imaging technology (e.g. Fairchild Industries' or

RCA's charge-coupled devices) could yield order of magnitude declines in prices of cameras. Discs also must be borne in mind as a potentially inexpensive video distribution medium. Master

1976 Costs

	In each classroom	In each school
Monitor	$300	
Tape deck	900	
Tape (30 hrs.)	450	
	1650	
Portapak (BSW)		1800*
2 VIRs		5400*
		7200

*Likely to drop in cost

Some Cost Elements
For Audiovisual Equipment

Table 3

disc recorders in the $30,000 price range have been mentioned. One may, therefore, hypothesize for further research the possibility that effective use of video from a satellite could also be brought into the classroom for costs of about $25 per student per annum, i.e. less than $653 per classroom per annum. This again excludes software development costs; it is the cost of interacting with the satellite for video material.

4) Earth stations:

There is a large literature on the prospective cost of small earth stations. (1) There are efforts such as the NHK experiment int in Japan to get the costs down as low as $300, but that is just for few channels of home television reception. A terminal that can recieve a number of channels of TV, can handle two way voice, and also data will be considerably more expensive. Terminals for data alone are being developed which can be carried on a man's back or made part of a small and low cost sensor. Such terminals will apparently be in the one to four thousand dollar range. Similarly, community TV antennas for Indian villages or for Alaska or the Canadian Arctic have been developed at figures like three or four thousand dollars. However, when one moves up to the type of multi-channel, two way digital and voice antennas we are talking about, the costs are inevitably in the tens of thousands range. As in so much of this analysis, date is a crucial variable in the price. An antenna that may cost $65,000 today may cost $25,000 some years from now. It is meaningless to name any one figure without substantial research on both antenna characteristics and assignment of a precise date. Even the spectrum assignment of the service makes a substantial difference

---

(1) Cf. Bruce Lusignian, "Low Cost ETV Satellite Receivers,", American Institute of Astronautics and Aeronautics, Paper 70-439, April 197[illegible]. Dean Jamison, "Uses of Communication Satellites for Education", Proceedings of the IEEE Fall Electronics Conference, Oct. 18-20, 1971, Chicago. Howard H. Hupe, "An Education Satellite: Costs and Effects on the Educational System", Educational Technology, Oct. 1974, pp. 48-52.

in the cost.

Using a three year write-off, a $10,000 earth station on each school would cost about $366 million dollars a year nationwide; a $20,000 earth station twice that; a $30,000 earth station three times that, etc.

These rough calculations suggest that the least expensive part of a total educational telecommunications system using a satellite is likely to be the space segment itself, with the earth stations next, and the data communication terminals and processing equipment, and the video equipment in about the same ball park in terms of cost. All of these together could come to a rather substantial national investment in absolut terms, (perhaps $3 1/3 billion a year if it were so successful that every classroom was using it), but that seems less exhorbitant when stated as under $60 per student per year including usage charges for communication, though not software costs. If that hypothesis is correct that could be an extraordinarily sound national investment. In leaving these figures, however, it is important to state that they are hypotheses only, and have been spelled out to indicate the problems that need to be explored in making a cost/benefit analysis in this area.

Let us turn now to the somewhat subjective matter of potential benefits.

WHERE THE BENEFITS LIE

It has been the premise of this paper that there are a good many potential uses for electronic communication into the classroom ranging from delivery of movies to CAI. Yet at this point it should be possible to lay down some hypotheses about relative values.

It seems probable that the greatest cost/effectiveness of satellite systems for education will be in the area of data transmission, i.e. CAI and information retrieval, rather than in voice or video, though those are useful too. In the first place, the limitations of capacity place marked limits on what can be done by satellite delivery of video downstream, and even more severe limits on the amount of voice that can usefully be carried upstream. (1) Dependence on live video imposes an external rigidity on school programs that is most undesirable; the teacher could lose control of schedules and pacing. On the other hand, running several channels during off hours to automatic VTRs may be a cheap way of bicycling tapes. Yet that is a far less significant impact on education than the real-time interaction that is possible in the low bandwidth data communication area.

The inherent advantages of a satellite system are its ability to carry information instantaneously over long distances and with almost no difference in cost as a function of location. Thus its

---

(1) Almost no video is likely to be carried upstream.

greatest importance is for on-line interactive communication, and particularly for locations away from the well served metropolitan centers.

All of these advantages are particularly well illustrated by the possibilities of information retrieval activities via a satellite system. Libraries and other information stores are extremely unevenly distributed. There are great libraries only in about four American metropolises. There is no easy way to remedy that situation. The cost of reproducing those great collections is prohibitive. The creation of on-line information retrieval systems, however, reverses that inequality. Anyone anywhere can access the best and most advanced data wherever it is.

The use of satellites to make it possible to teach dispersed audiences is also of special value in such areas as Alaska, Appalachia, American Indian reservations and rural areas. In metropolitan areas one is likely to find 20 people within commuting compass with the same specialized interest. In impoverished areas there is less density of population precisely because there are less opportunities to attract people there. One practice that develops in such sparsely settled underdeveloped areas as Alaskan villages or Indian reservations is to bring the pupils together at schools so far from there homes that they nave to board. This is an expensive and probably socially harmful solution. Improved telecommunications may make it possible to keap children in their home communities longer, and at the same time deliver adequate education to them. In small schools in such locations, a number of the applications of tele-eduction which we listed in the first part of this paper appear particularly relevant. Electronic delivery of film instead of physical carriage, master teaching, teaching of the teachers, imparting information about world events, and delivery of specialized instruction are alluseful in such circumstances, as well as remote access to information bases and CAI.

If we have stressed the latter two applications it is because it appears that those are likely to provide the staple traffic for an educational satellite activity at least in the early years. The other useful services that can be delivered by satellite will then piggyback on those two, initially perhaps sporadically. Consider early experiments before there is a dedicated satellite and when circuits must be obtained from the existing commercial vendors. Consider also that in the early stages, before many of the costs have fallen, while volume is low, operations are likely to be expensive and require some subsidy. CAI and information retrieval require only a voice grade line. They represent steady needs day in and day out. Some of the software lready exists, and what exists can be used over and over. In constrast, special courses and films are events; they occur sporadically, important as they may when they happen. They require much more expensive broadband channels

These considerations have a great deal to do with the process of taking first steps. In the earlier parts of this paper we engaged in the thought-experiment of asking what a satellite service would do if fully assimilated into the totality of American education. We asked what that would cost and what uses it might be put to. However, no system is going to come into existence full blown. It will grow step by step.

Fortunately that is possible. We note that even a large 24 transponder satellite would have trouble meeting the full needs of a mature national educational communications activity. Yet for many years a dedicated satellite would have much excess capacity. There are, however, satellite channels available on multi-purpose satellites. Experiments can get started. More important than sheer experiments, actual services can be started on a small scale. They may need to be subsidized at first for every investment runs for some period at a loss. But only real life efforts, rather than sheer experiments, build up a growing body of experienced people who come to rely upon and trust the new way of doing things.

Where should one begin? Clearly part of the answer is with data communication activities. The economies of electronic bicycling of tapes only appear in large systems; the advantages of putting remote and underprivileged locations on-line to intellectually stimulating activities are there from the beginning.

So clearly the way to start is with services to regions that are in need of development. Those disadvantaged regiors are the one that the Federal government would be justified in investing in, and new communications services are going to have to be treated as long run investments. Furthermore, those regions are the ones that will benefit from a device that breaks down the barriers of distance.

It is important, however, that satellite educational development be seen not as an act of charity. We noted before the concept of the Pareto optimum. It is relevant here. The existence of a satellite will not draw onto it any activity that can be more efficiently done without it. People will continue to meet face-to-face or use their local telephones when those are more convenient. Satellite facilities will probably be less used by metropolitan school systems than by others because the situations in which the satellite has a distinct advantage for them are fewer. But nobody loses. Remote, underdeveloped and low density areas will use the satellite services the most. They are therefore the logical place for initial investment of money and effort in satellite educational activities.

Bibliography

Abramson, Norman, "Packet Switching with Satellites", National Computer Conference, 1973, pp. 695-702.

Ball, John and Dean Jamison, "Computer-Assisted Instruction for Dispersed Populations: System Cost Models", Instructional Science, February 1973. pp. 469-501.

Baran, Paul, "A Briefing on the Distributed Adaptive Message-Block Network", Santa Monica, California, The Rand Corporation, Report P-3127, April 1965.

Blanc, Robert P., Review of Computer Networking, National Bureau of Standards Technical Note 804, January, 1974.

Dahl, Norman C., "The Use of Satellites in Open Learning Systems". In Norman MacKenzie, Richmond Postgate, and John Scupham. Open Learning, Unesco Press, NY, 1975.

Digest of Educational Statistics, 1974.

Gerbner, George, forthcoming article, Journal of Communication, Vol. 26, Summer 1976.

Hupe, Howard, H., "An Education Satellite: Costs and Effects on the Educational System", Educational Technology, Oct. 1974, pp. 48-52.

Jamison, Dean, "Uses of Communication Satellites for Education", Proceedings of the IEEE Fall Electronics Conference, Oct. 18-20, 1971, Chicago, Ill.

Kleinrock, Leonard and Simon S. Lam, "Packet Switching in a Slotted Satellite Channel". In Norman Abramson and Franklin F. Kuo, (Eds.), Computer-Communication Networks, Englewood Cliffs: Prentice Hall, 1973. pp. 703-710.

Lerner, Daniel, The Passing of Traditional Society. Glencoe, Ill: The Free Press, 1958.

Lusignian, Bruce, "Low Cost ETV Satellite Receivers,", American Institute of Astronautics and Aeronautics, Paper 70-439, April 1970.

Roberts, Lawrence G., "Dynamic Allocation of Satellite Capacity Through Packet Reservation". In Norman Abramson and Franklin F. Kuo, (Eds.), Computer-Communication Networks. Englewood Cliffs: Prentice Hall, 1973. pp. 711-716.

Roberts, Lawrence G., "The ARPA Network". In Norman Abramson and Franklin F. Kuo, (Eds.), Computer-Communication Networks. Englewood Cliffs: Prentice Hall, 1973.