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ABSTRACT

Selected aspects and results of an interdisciplinary research and education program to examine the potential and problems associated with the use of communication satellites to help meet educational needs in the United States are summarized. The progress of the program to date in four major areas is described: needs analysis, communications technology studies, systems synthesis, and the educational impact of the program on Washington University. In the area of needs analysis, some of the problems facing education, such as educational costs and equality of opportunity, and some of the available communications media and educational technology have been assessed. Several studies of communications technologies are being carried out in such fields as satellite and terrestrial communication techniques, still-picture television distribution, and Gunn-effect wideband Ku-band amplification. Progress has been made toward identifying and structuring a small number of alternative systems which could provide educational satellite services in the near future. Two of the results of the program at Washington University have been the creation of a new master's degree program in technology and human affairs and the increased interaction of faculty members, professional staff members, and students from a wide variety of backgrounds. (JY)

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TO EDUCATIONAL DEVELOPMENT

WASHINGTON UNIVERSITY

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APPLICATION OF COMMUNICATIONS SATELLITES TO EDUCATIONAL DEVELOPMENT IN THE UNITED STATES

by

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RESUME

Le programme de Washington University est interdisciplinaire en recherche et éducation. Il examine le potentiel et les problèmes associés à l'utilisation des satellites de communications pour aider à satisfaire les besoins en éducation des Etats Unis. Le but principal est la synthèse d'un petit nombre de différents systèmes de satellites d'éducation pour les mettre à la disposition des organismes de décision après une soigneuse analyse des facteurs techniques, éducatifs, sociaux, légaux, économiques et politiques. Cette présentation décrit les progrès à ce jour dans quatre domaines: évaluation des besoins; études des techniques de communication; synthèse de systèmes; et impact éducatif du programme à Washington University.

ABSTRACT

Washington University (St. Louis) is undertaking an interdisciplinary research and education program which is examining the potential and problems associated with the use of communications satellites to help meet educational needs in the United States. A major objective is to synthesize and to make available to decision makers a small number of alternative educational satellite systems in which technical, educational, social, legal, economic and political factors have been carefully analyzed. This paper describes progress to date in four areas: Needs analysis; Communications technology studies; Systems synthesis; The educational impact of the program on Washington University.

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I. - INTRODUCTION AND BACKGROUND

1.1 - Objectives

Washington University (St. Louis) is undertaking an interdisciplinary research and education program which is examining the potential and problems associated with the use of communication satellites for improving education in the United States. The broad objectives of this NASA-supported program* are:

*The work reported in this paper is supported by the National Aeronautics and Space Administration, Grant No. Y/NGL-26-008-054, Office of University Affairs. The results and conclusions are those of the authors and do not necessarily represent the views of NASA.

(1) to assess the role of communication satellites as a means of helping to meet educational needs; (2) to generate basic knowledge which will aid in making rational decisions about satellite application in the field of education in the years ahead; (3) to devise systems and strategies for improving education utilizing communication satellites and (4) to educate individuals who will be knowledgeable about aspects of satellite communications policy which transcend any single discipline and which relate to a potentially important societal area of application, namely education.

In this paper, selected aspects and results of the program, which was initiated in September, 1969, will be summarized. Although the systems analysis and synthesis work is in an intermediate stage, the methodology being employed is describable and some specific results have emerged. From the point of view of the university, we view this program as an experiment in learning how to carry out socially relevant interdisciplinary research in the uses and assessment of technology within a university framework. A more detailed description of progress through November, 1970 can be found elsewhere.[1]

1.2 - Program organization and management

Figure 1 is a schematic diagram which shows the arrangement of various program elements and the overall structure of the Satellite-Education Program. Participating in the program are faculty members and students from such diverse fields as electrical engineering, computer science, physics, law, economics and education, in addition to professional staff members associated with the program coordinating unit, the International Development Technology Center. Although in many cases, principal contributions have been made by individuals in areas closest to their disciplinary fields, there has been a good deal of interaction through the mechanism of seminars, courses, workshops and regular weekly meetings.

1.3 - Systems planning

One major objective of the program is to develop and make available to decision makers a small number of carefully conceived and analyzed alternative systems for utilizing communication satellites to aid in improving education in the United States. To attain this objective, a synthesis must be achieved which takes into account not only technical feasibility but also educational requirements and social, economic, political and legal factors.

Figure 2 shows the systems approach which is being employed for the identification and assessment of domestic educational/instructional satellite system(s). The scope of our present effort is limited to the left-hand side of the diagram, terminating at a point where decision makers are supplied with potentially attractive alternatives and the detailed analyses which support those alternatives.

Unlike other academic programs, considerable effort is being made to obtain feedback from potential users and decision makers at an early stage of the synthesis process. Feedback is obtained through a variety of visits, workshops, seminars and review meetings. Only through a series of iterations will it be possible for the final alternatives of this iterative-synthesis process to be realistic and responsive to real-world concerns.

Figure 3 is a Study Plan Diagram which illustrates the systems aspects in more detail. The primary elements are Needs Analysis, Communications Technology Studies and Systems Synthesis. The time scale for the current effort is

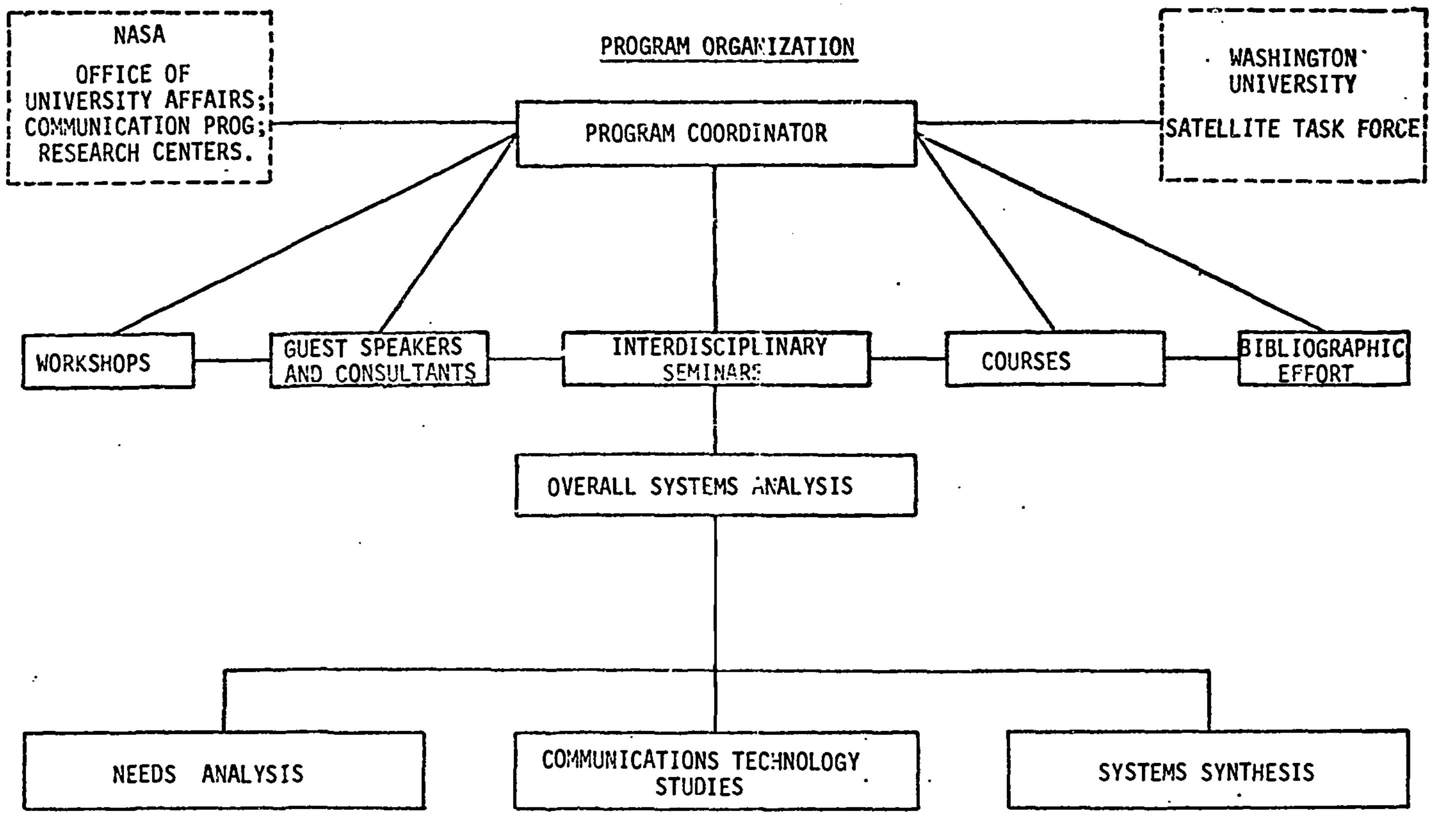


Figure 1. Program Organization

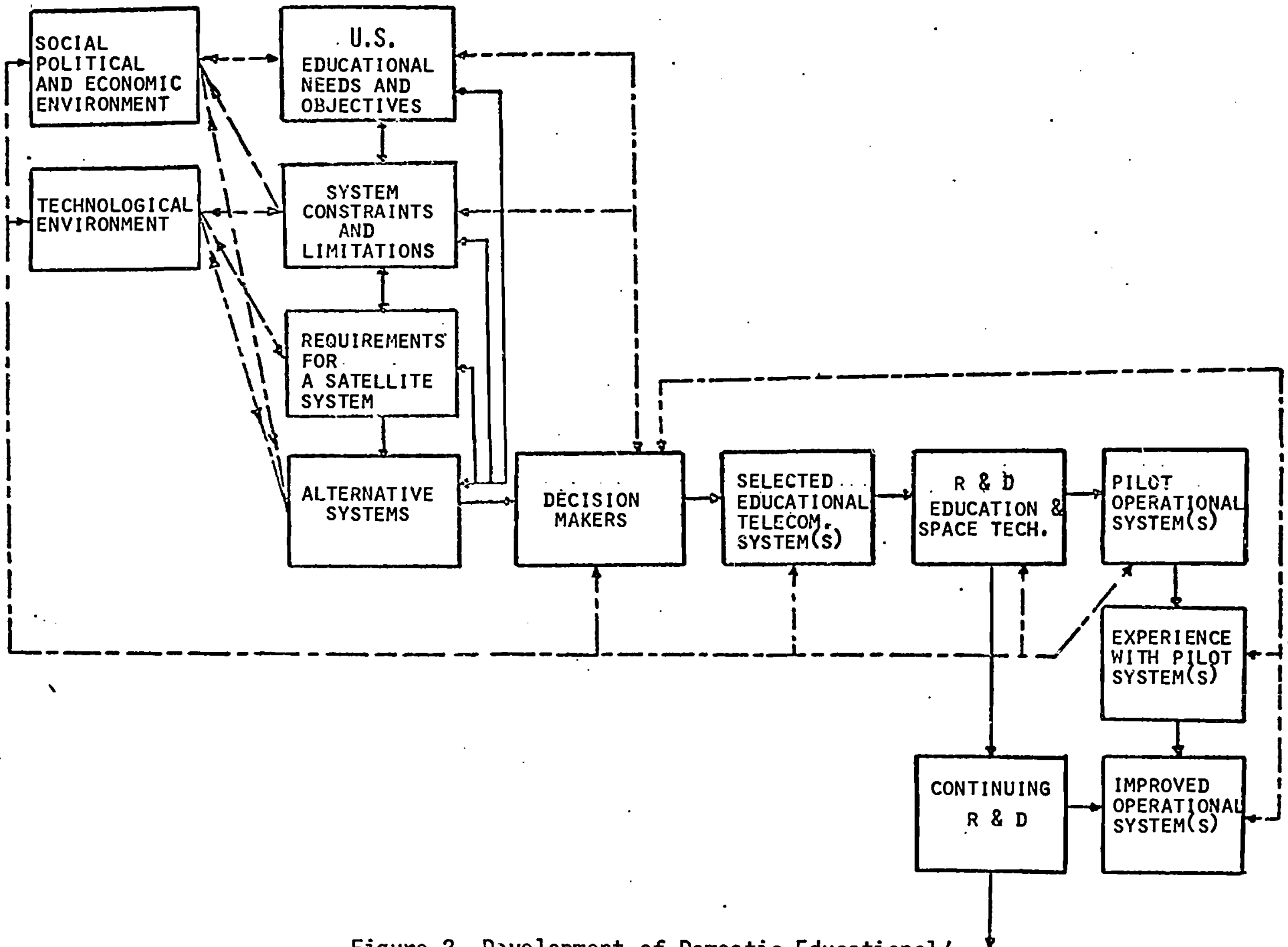


Figure 2. Development of Domestic Educational/ Instruction Satellite System(s)

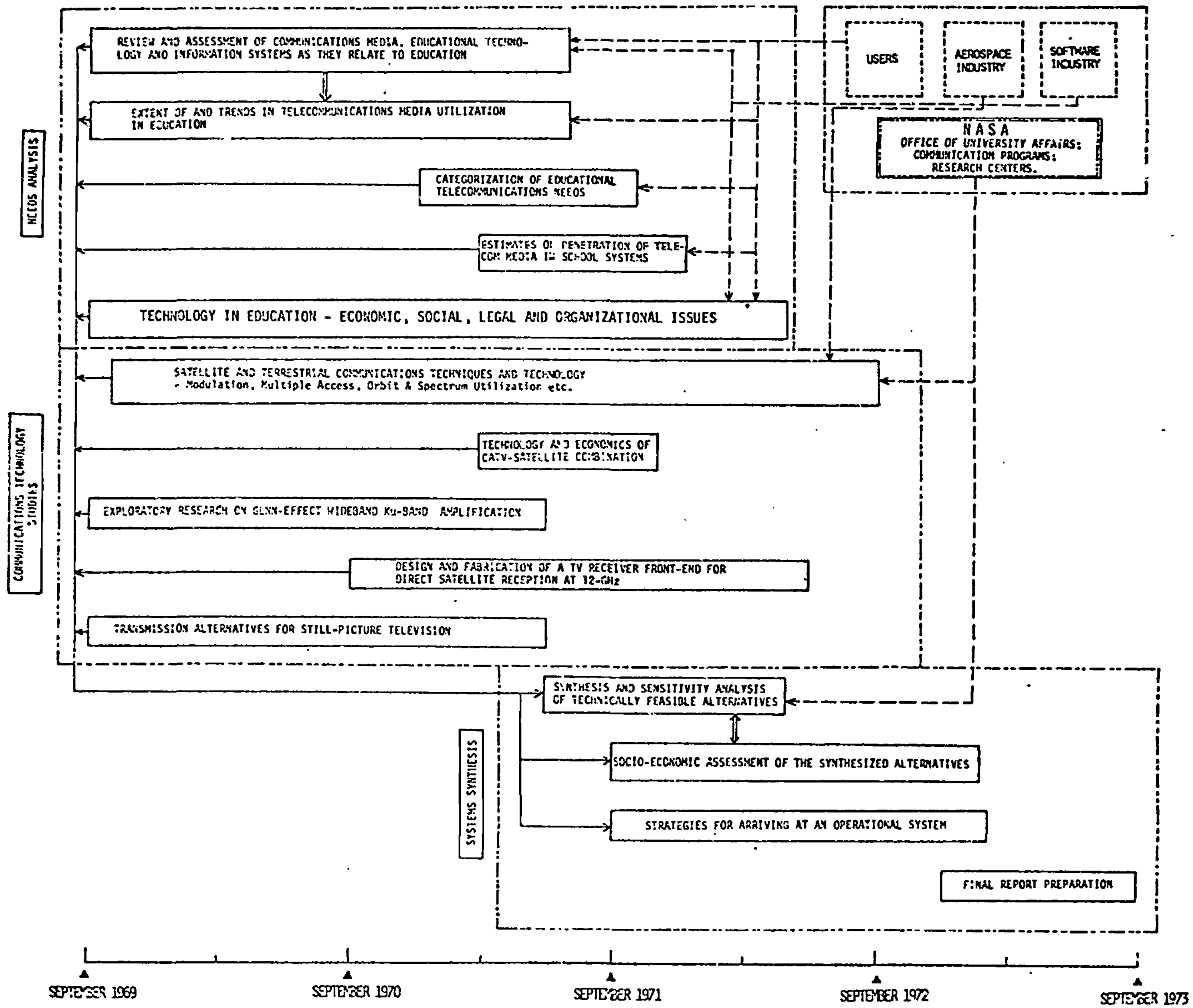


Figure 3. Study Plan of Washington University Program on Application of Communications Satellites to Educational Development

shown. Each of these elements will be discussed in this paper. A concluding section will examine the impact of this program on our university.

2. - NEEDS ANALYSIS

2.1 - Introduction

In considering the application of satellite communication technology to aid in improving the U.S. education system, an important input is an understanding, in as quantitative terms as possible, of the educational system, its needs and its requirements. Such an assessment should include an understanding of current issues in education, as perceived by teachers, students and the general public. Educational telecommunications requirements should spring from real needs which are constantly changing. Furthermore, when considering a specific educational communications technology, one must be aware of alternative technologies, either existing or under development which might also suffice.

A recent article on the magnitude of the American educational establishment[2] indicates that in the United States in the 1970-71 academic year, there are more than 62 million students, teachers or administrators in the U.S. educational enterprise. In the last ten years, student enrollments in all categories have increased by 13 million to a level of 59 million students. During the same period, while enrollments were increasing by 129%, the costs of education have risen by 160% to 70 billion dollars and one million new teachers have increased the teacher population by 151% to over three million. In the past, the primary approach for coping with increasing enrollments has been the multiplication of the number of classrooms and teachers to the point where there are now approximately 117,000 schools in 18,000 local school districts in the United States. This extensive system has been primarily controlled by state and local authorities. Only in recent years has there been any federal input to elementary and secondary education.

In spite of the unprecedented success and outreach of mass education in the United States, there is considerable uncertainty and apprehension about U.S. education today. Among the key issues are:

a. The Cost of Education. In many areas, taxpayers refuse to pay more to support public schools. For the first time in recent years, there is reported to be a "surplus" of teachers.[3] This condition exists not because educational needs are being met but because of budgetary restrictions. Education is the most labor-intensive of all major U.S. economic sectors, with over 60% of current outlays going to salaries for instructors. Some people believe that increasing the productivity of teachers through technological innovation is a key requirement for coping with the rising costs and enrollments in education.[4] Others feel that "unschooling America" may be the answer.[5]

b. The Style of Education. Much has been written lately of the need to develop alternatives to the current mode of schooling in which students are fed packages of information within walls for a fixed period of time each day.[6] "Free schools", stressing experiential learning and individualization, are springing up as are alternatives to existing public schools. Some new experimental forms make use of educational and communications technology.

c. Equality of Educational Opportunity. The inequalities in the U.S. educational system have been documented in the Coleman report.[7] In this survey, statistics were gathered on six racial and ethnic groups: Negroes, American Indians, Oriental Americans, Puerto Ricans living in the continental United States, Mexican Americans, and whites. The report indicates that whites and Oriental Americans achieved at comparable levels in such areas as verbal and mathematical skills whereas the other minorities achieved at sharply lower levels. The gap grew greater as the children progressed through the school system.

To date, rapid developments in new technology do not seem to have had any major impact on education in the United States. Although 75% of the U.S. public schools have television sets and 26% have video tape recorders,[8] instructional television utilization appears to be limited and has met considerable resistance.[9] A reasonably high-budget, pre-school program, "Sesame Street", has shown that given the resources, public television can compete with commercial television and educate children as well. However, this program is designed primarily for use outside the school system.

Teaching machines and audio-visual aids are being used on an experimental basis in "performance contract" programs in which the contractor is paid in accordance with how successful he is in bringing about measurable improvements in reading and mathematics skills. These experiments may provide useful information on costs for bringing about a given increase in skills.

Although it is clearly not possible to quantify all aspects of an educational system and its needs in the manner in which one models a mathematical system, a careful study of educational needs is an essential prerequisite for rational systems synthesis and assessment. Studies are underway to determine the extent to which technology is actually utilized in U.S. schools. Future work will concentrate on devising new organizational arrangements to allow for better utilization* of technology.

2.2 - Review and assessment of communications media and educational technology

Communications satellites represent a new technology of great potential utility to education. However, parallel technological developments in cable-TV, cassette and disc video recording, microfiche, and computers, to name only a few, have confronted the educational user with a tremendous variety of alternatives and combinations of technologies to consider. A study has been performed which assesses many of these developments and provides essential background material for future efforts to devise alternative systems for satellite-based education which make optimum use of new educational and communications technology.[11] Among the topics considered were:

a. Still-Picture Television

Analysis of the needs of learners in many different instructional situations shows that the complete array of stimulus variables available through the television medium (pictorial, color, motion, sound) is not always essential in particular instructional situations, and may even distract from the objectives of the program designer. Still-picture television techniques could provide many more programs in the

*Anderson[10] has suggested separating the teaching of skills from the human development aspects of education. This process, which remains to be evaluated, would make use of technology for the former.

bandwidth occupied by one full-motion television channel. Other potential advantages of the still-picture television medium for instruction include a greater diversity of programs from which to draw, lower program production costs, and a relatively greater independence of picture and sound information.* Potential disadvantages include an increase in the cost and complexity of ground-station equipment, and possibly a higher signal-to-noise ratio than necessary in conventional television to overcome frozen noise.

b. Computer-Based Instruction

Pilot experiments are underway to evaluate a variety of computer-based instruction (CBI) systems. Major problems confronting advocates of large-scale CBI utilization are (1) the conflict between the organization of the traditional school system and optimal methods of employing compute -based instruction, and (2) the need for further cost reduction. Large-scale and intensive utilization is the key to low per-pupil costs. Some means of low-costs telecommunications must be found if rural communities are to benefit. Communications satellites seem to hold distinct advantages over existing commercial telephone communications in the U.S. for linking remote terminal clusters with a central computer where computer-cluster separation is 150-200 miles or greater.

c. Electronic Versus Physical Distribution of Educational Materials

In general, whether electronic or physical distribution of educational materials is to be preferred depends upon a number of factors, such as the following per-message criteria: total allowable delivery time; total cost; reliability; security; number of addressees; fidelity; retainability; feedback requirements; and message priority. Nevertheless, an analysis of the growth of mail delivery versus telephone messages in the United States indicates an over-all trend towards the replacement of physical with electronic means of distribution for many types of messages.

d. Facsimile and Microforms

Although too expensive today for most educational requirements by an order of magnitude, facsimile transmission could be a useful alternative to physical distribution of educational materials in printed form, particularly in conjunction with microimaging and duplicating technologies. Microforms offer great compactness, lightness, low-cost and ease of duplication. A marriage of microfilms and computers (COM) offers speed and cost advantages of more than an order of magnitude over conventional text composition techniques.

e. Cassette and Disc Program Storage Systems

Video cassettes are now making their debut (see Table 1), and should become as convenient for sight and sound as the audio cassette is for sound alone. However, serious problems of incompatibility among the various systems coming to market are likely, and the costs of both equipment and cassettes is likely to remain considerably higher, perhaps by an order of magnitude, than is the case with audio.

For educational use, a most promising technology appears to be electronic video recording (EVR), which essentially makes every TV

*As part of our program effort, a small number of still-picture television [illegible]ams have been developed.

TYPE	RECORDING MATERIAL, MANUFACTURER, AND TRADE NAME	PROBABLE MARKETING DATE	RECORDING TECHNOLOGY	REPRODUCING TECHNOLOGY	PICTURE RESOLUTION	AUDIO	EXPECTED PLAYER COST, IN DOLLARS	ACCESSORIES[7] AND COST, IN DOLLARS	CASSETTE OR DISC PLAYING TIME, Min.	UNIT COST OF CASSETTE OR DISC, Dollars	UNIT RENTAL COST OF CASSETTE, DOLLARS	COMMENTS
1	MAGNETIC TAPE CASSETTS		helical-scan magnetic head	helical-scan magnetic head	~250 [all]							
	Ampex/Toshiba[Toamco] Instavision	'71	1/2" tape[1]			2 tracks	800	1000, record/play 400, camera	30[5]	13, blank	----	Camera has zoom lens and elect. viewfinder
	Avco/Admiral Cartavision	'71	1/2" tape[2]			1 track	450	850, including TV set; 1000, incl. TV and Camera	<120	10-25, blank 8-25, prerecorded	3, up	
	Philips/Norelco VCR	'71	1/2" chromium dioxide tape			2 tracks	250-350	500-600 record/play	<60	25, blank	----	Independent tuner for recording; Timer
	Sony VideoCassette	'71	3/4" chromium dioxide tape			2 tracks	350-450	500, record/play 600-650, incl. camera	<100	25, blank	2-5 [to record programs]	
	Matsushita/Panasonic	---	3/4" tape			----	--	----	----	----	----	
2	SILVER-HALIDE FILM											
	Nordmende Colorvision; Vidicord; etc. [Super-8 cartridge TV adapters]	'71	optical	flying-spot scanner	250	magnetic stripe	250?	25-250 [home movie camera]	<30	40, blank[8]	----	
	CBS/Motorola EVR [Film Cartridge]	'70	electron-beam recorder[3] [8 3/4mm film]	flying-spot scanner	600[4]	2 magnetic stripes	759	possible color-encoding film camera in future	<25[6]	15-30	----	
3	EMBOSSED VINYL PLASTIC											
	RCA SelectaVision[10] [Tape Cartridge]	---	multiple-beam holography	laser & vidicon	250	unknown	400	-----	<60	10[9]-20	----	Black-and-white only demonstrated
	AEG-Telefunken/Teldec [Video Disc]	'72	stylus recorder	pressure scanning	250	PPM in vertical interval	125-300	-----	5 to 15	2.50-5.50	----	Black-and-White only demonstrated; recordings on one side of the disc only

[1] compatible with EIAJ Type 1 [reel-to-reel] standard
[2] only records every third field
[3] records 2 fields in each frame
[4] limited to about 320 lines by RF circuitary in average home TV receiver
[5] 60 minutes at half-speed extended play mode
[6] <50 minutes for black-and-white
[7] TV cameras will be black-and-white initially
[8] including processing
[9] 1/2-hour program
[10] RCA apparently will market an alternative system while working out SV problems

Table 1. Video Cassette and Disc Recording/Reproducing Systems

set a motion-picture display device. Also, it is the only video cassette system with inherently high-resolution capability, and referencible still-picture capability. However, copies of EVR programs must be made in complex centers, while magnetic-tape video cassette systems offer local and immediate recording capability. Also, from the cost standpoint, video discs are likely to attain the greatest mass market of any of the systems.

In spite of the seeming competition between physical materials packages and communications satellite distribution, it is possible that the development of these two technologies will reinforce each other. A decline in the price of recording devices may increase the amount of material which can be distributed economically by communications networks. In particular, the impact of new forms such as EVR on communications requirements needs to be evaluated in detail.

f. A Multimedia, Multipurpose Educational Satellite Service.

Given the equivalent of one or more satellite-based full-television channels, one can conceive of many different types of media, and information services being provided to schools, community centers, and other public agencies (see Figure 4). Although the full bandwidth of a television channel can be used for regular ITV on a real-time basis, it may also be used to carry such media as videotapes, films, filmstrips, telelectures, radio, facsimile, and data.

In addition to these satellite-based services, a full-complement ground receiving center could share its digital processing capability with local schools for such needs as CAI, CMI, data-base interrogation, desk-calculator computations, and time-shared and remote-batch stored-program computer use via wire, cable or ITFS.

Satellite technology can add new and unique elements to existing curricula, bringing in the wide world beyond the classroom, and making possible the sharing of intellectual wealth on a world-wide basis. Economic and technical studies are required to determine which possibilities are feasible.

2.3 - Educational telecommunications requirements

Educational telecommunications systems may be divided into three categories:

a. Information Dissemination and Broadcast Services: Radio and television, ITFS, cable, responsive television, etc.

b. Interactive Telecommunications Services: Teleconferencing, talk-back television, on-line information retrieval, computer-based instruction.

c. Computer Interconnection Services: Remote batch processing, resource sharing, distributed intelligence, computer utilities (time-shared services).

We are currently reviewing and assessing the status and costs of selected technologies and systems, as well as utilization studies for the above categories. Previous studies which provide limited information have been performed by SRI [illegible], Lockheed[13], and General Dynamics/Convair[14].

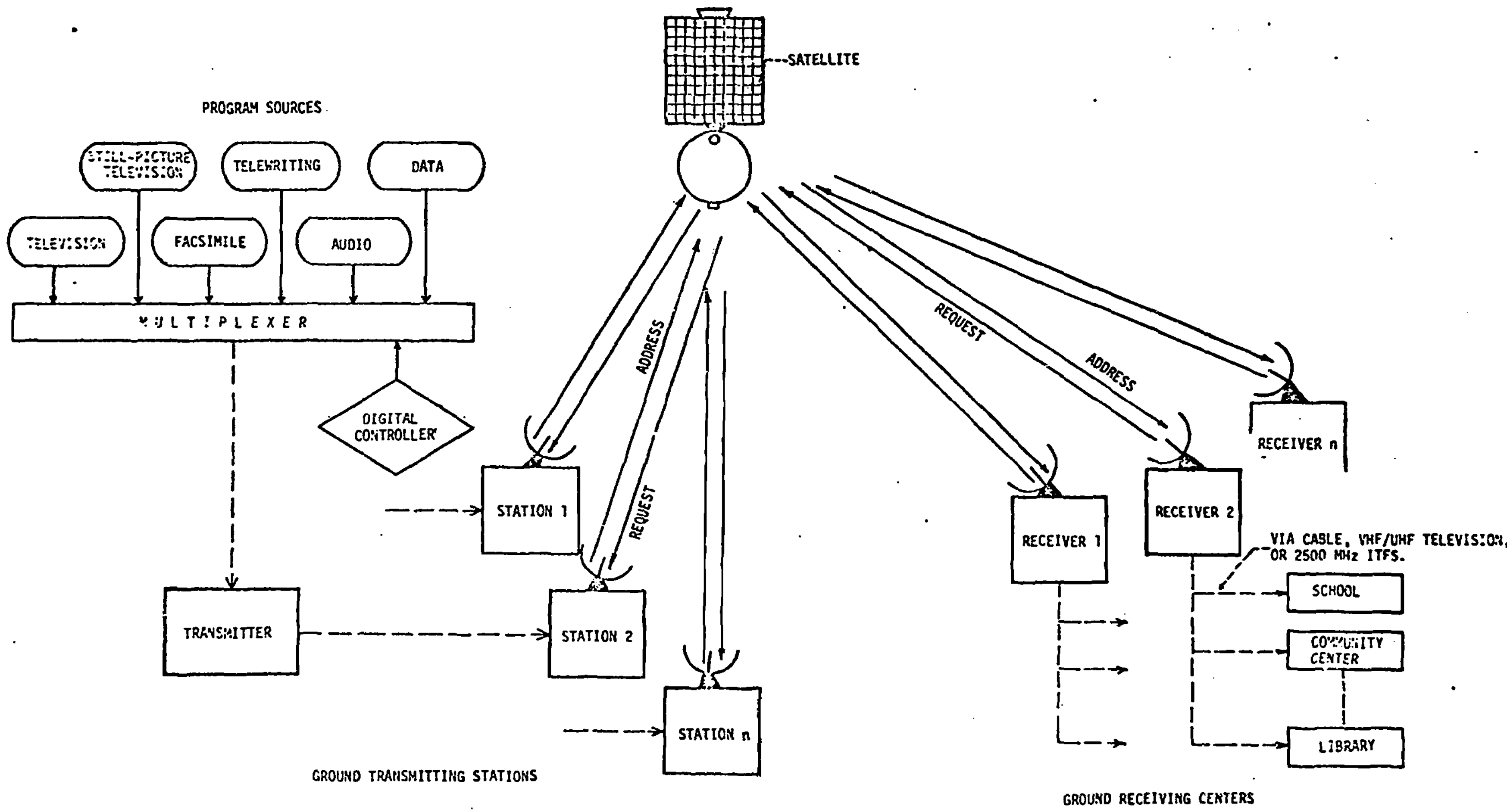


Figure 4. Multimedia, Multipurpose Educational Satellite Service

Among the potential instructional/education user categories are:

a. Primary and Secondary School Instruction

b. Instruction and Research in Institutions of Higher Learning

c. Vocational Education

d. Inter-Library Services for Resource Sharing and Remote Information Retrieval

e. Continuing Education (Adults/Professionals)

f. Public Television and Radio*

g. Special Television Services*

For each of the above services, information is being gathered on current status, existing plant, utilization and problems. The situation will then be analyzed from the viewpoint of availability of low-cost telecommunications facilities. Economics, trends in services, educational function and resistance forces will be evaluated.

An important aspect of an educational satellite system requiring careful evaluation is the availability of local outlets for rediffusion of programs. Data is being gathered on existing terrestrial network patterns. The United States has extensive ground communications facilities. Systems for satellite deployment must be designed with this fact in mind. Both inter- and intrastate educational television networks exist. Data on the number and geographic distribution of cable television facilities, computer-based instruction centers, inter-library networks and ITFS systems tend to all fall in a pattern which leaves certain portions of the United States relatively uncovered. Such data provide clues as to possible satellite deployment.

Figure 5 shows locations of ETV and Educational Radio (ER) stations in the United States. Most ETV stations are located in densely populated areas of the eastern part of the country. Large areas of the central and western states do not have ETV and ER coverage.

It is conservatively estimated that there will be some ten million cable television (CATV) subscribers by 1975 (see Figure 6). The large channel capacity of cable plus its projected dynamic growth make the satellite-cable-TV combination an important one to explore in this program. It should be noted that the projected cable-TV geographic development pattern in the U.S. parallels the development of ETV stations, leaving remote areas and rural areas without service.

*The phrase "Public Television" (PTV) is generally used to describe non-commercial television intended for the general public whereas instructional television (ITV) is intended for formal instructional purposes such as the teaching of skills in a classroom. According to current usage, educational television (ETV) is defined as being made up of public television and instructional television, i.e. ETV = PTV + ITV. "Special television" is used here to designate services to minority groups, be they cultural, ethnic or professional.

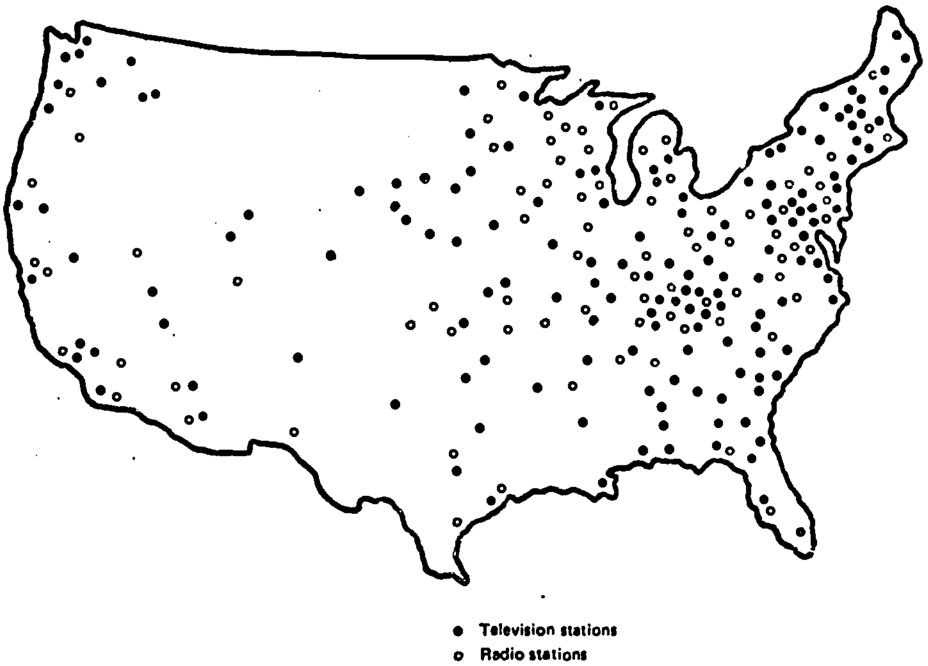


Figure 5. Distribution of ETV and ER Stations in U.S. (From reference 15)

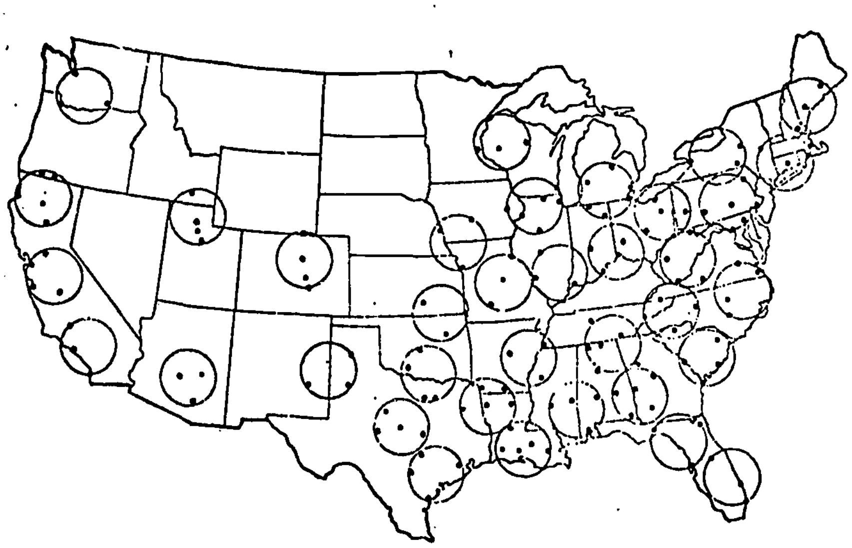


Figure 6. Projected CATV Service Areas in 1975 (from Ref. 19)

For this latter situation, the ability of a communications satellite to distribute information over wide areas might make it feasible to link relatively small numbers of people with similar interests over wide areas*, making use of direct broadcasting to augmented receivers in schools or community centers. Groups or regions with specific telecommunications needs requiring further study include (1) Alaska and the Mountain States, (2) Appalachia, (3) American Indians and (4) migrant workers. Such studies must range from the kinds of software which would be needed for bilingual or, in the case of American Indians, multilingual situations to identification of existing terrestrial telecommunications facilities which could be utilized either in connection with or as an alternative to a satellite system.

The primary output of the needs analysis will be estimated upper and lower bounds of telecommunications requirements for each educational service, first in aggregate terms and then as much as possible for various geographic regions for 1975 and 1980. These requirements will be translated in terms of bandwidth, signal quality, message volume (bits/second, day, year). An important aspect of this analysis will be estimates of the extent to which technology may penetrate the field of education for the target years in question.+ Such an estimate is being carried out by a team of economists and educators, making projections based on existing data on enrollments, costs, etc. As part of this process, the costs and benefits associated with various degrees of technological input to education are being examined. In addition, legal, organizational and social issues are under study.

3. - COMMUNICATIONS TECHNOLOGY STUDIES

3.1 - Introduction

A variety of studies are being carried out in this category for the purposes of providing technical inputs to the systems synthesis and to generate new knowledge which may prove useful in future applications of satellite technology.

3.2 - Satellite and terrestrial communications techniques and technology

A review and assessment is being carried out of new developments in spacecraft and earth station technology, demand assigned multiple-access techniques, TV signal transmission, digital transmission and issues related to the efficient utilization of the geostationary orbit and rf spectrum. Particular attention is being paid to the economic and efficient access to the satellite from a large number of small and remotely located, low-capacity and low duty-cycle terminals, and digital transmission techniques.

3.3 - Transmission analysis of still-picture television distribution

A master's thesis has been completed[19] which examines alternative transmission schemes for multi-channel audio and still-video signals which could then be processed and displayed on a conventional television set.** In contrast to

*Harley has developed this idea to some extent.[17]

+A recent report by Doyle and Goodwill[18] predicts widespread adoption in North America of educational technology during the late 1970's and 1980's.

**The advantages and disadvantages of still-picture television have been summarized in Section 2.2.

previous work which has emphasized slow-scan television in which less than the full television bandwidth is utilized, this study develops new information on a time-shared video, time-compressed audio technique in which the entire TV bandwidth is used. The study is analytical. Further work on technical and economic feasibility remains to be performed.

Figure 7 presents the theoretical number of channels (programs) that can be accommodated in the bandwidth normally occupied by a single standard TV channel, as a function of average frame updating time and various audio compression ratios.

From the figure, it can be seen that some 25 still-picture program subchannels can be transmitted in place of one normal TV signal if a channel updating time of 1 second is assumed with a 300:1 audio compression ratio. For the same compression ratio, but a 10 second frame updating time, as in calculations for the TICCET system,[20] some 150 still-picture program channels could be accommodated in the spectrum space needed for transmitting one normal TV signal. In a real-time system, the frame-updating time represents the shortest time duration in which one still frame can be displayed on a television set. In designing still-picture TV programs, this time duration would appear to be an important variable from the point of view of the learning process, and worthy of further study.

3.4 - Exploratory research on Gunn-effect wideband Ku-band amplification

A master's thesis has been completed on theoretical and experimental aspects of broad-band microwave amplification using the bulk negative resistance properties of the Gunn effect[21]. Using simple, low impedance, X-band waveguide structures, gain-bandwidth products as large as $G^{\frac{1}{2}}BW = 6.3$ GHz ($G = 10$ db, $BW = 2$ GHz centered at 10 GHz) have been observed in the laboratory. Narrow band (500 MHz) operation at gains up to 30 db has also been obtained, with output powers as high as 200 milliwatts. These initial results demonstrate the potential for low-cost, high-performance microwave amplification as a first stage of rf amplification in a satellite communications receiver. Additional work is required to control and predict the amplifier behavior, to explore means of achieving acceptable noise figures, and to develop a systematic design procedure for meeting performance specifications. Results of this study are available in the technical literature.[22]

3.5 - Other studies

Work is underway under the direction of Professor F. J. Rosenbaum to design and fabricate the front-end of a TV receiver for direct reception at 12-GHz. In addition, combined technical and economic studies of cable television-satellite interfacing is being initiated. Participating in the latter study are Professors H. J. Barnett and E. Greenberg, who have written extensively on cable television and the "wired city" concept.[23]

4. - SYSTEMS SYNTHESIS

4.1 - Introduction

Progress has been made towards identifying a small number of alternative systems of interest for providing educational satellite services in the near future. Figure 8 indicates the starting point from which this analysis was made. We have broken the system down into six components: (a) the type of satellite, (b) the type of service, (c) the downlink transmission frequency, (d) the modulation scheme, (e) the ground reception arrangement, and (f) the educational usage.

N = number of subchannels (each comprised of one still-video plus one compressed audio frame)

T = composite frame time for transmittal of N subchannels

$v_1, v_2, \ldots, v_N$ = still-video frames transmitted during T

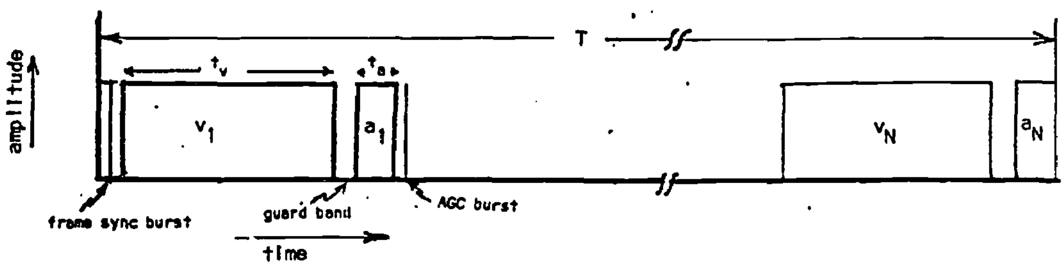
$a_1, a_2, \ldots, a_N$ = compressed-audio frames transmitted during T.

t_v = time to transmit one still-video frame

t_a = time to transmit one compressed-audio frame

$C_a = \frac{T}{t_a}$ = audio compression factor (also equal to ratio of original video to audio signal bandwidths)

(all times in seconds; time guard bands, and AGC and frame sync bursts ignored)



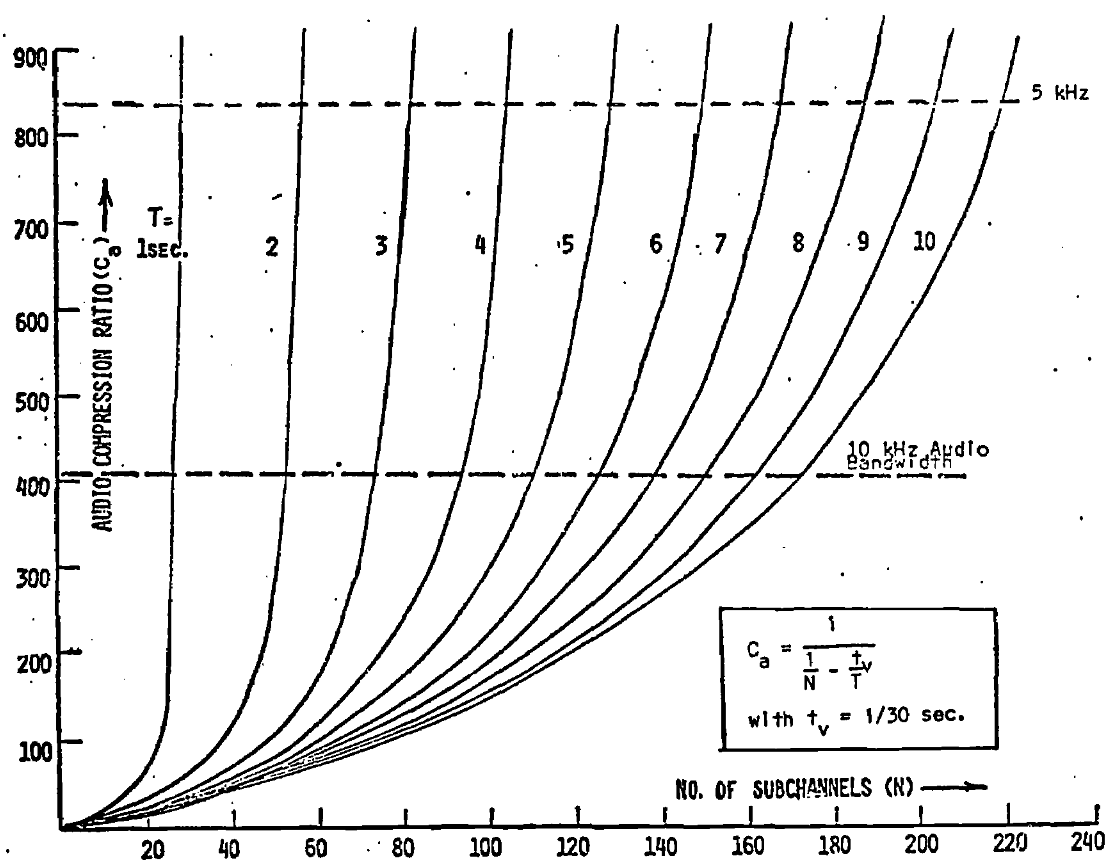


Figure 7. Time-Shared Video with Time-Compressed Audio (after reference 19)

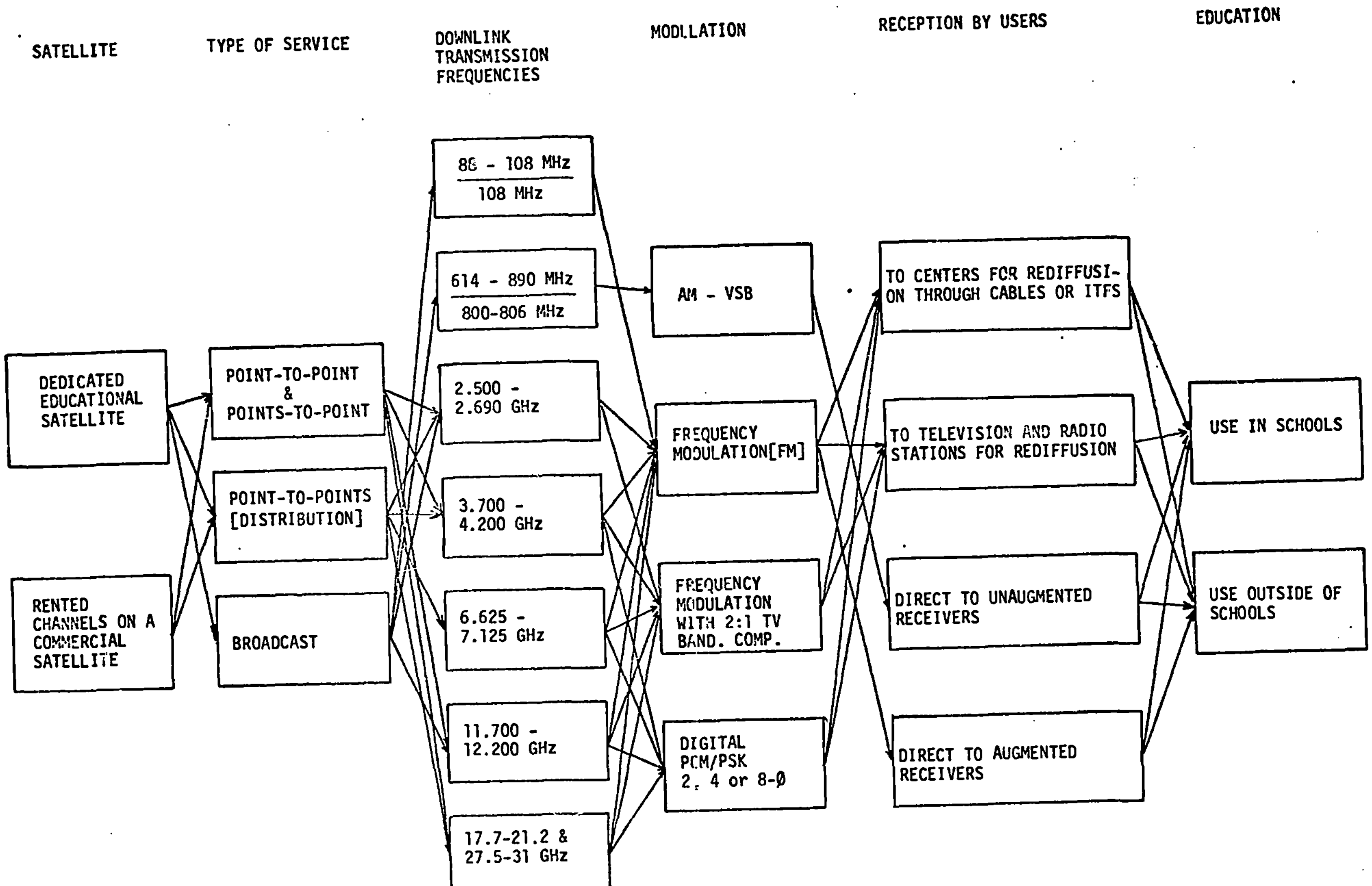


Figure 8. Choices Examined for Communications Satellite Services for Educational Development

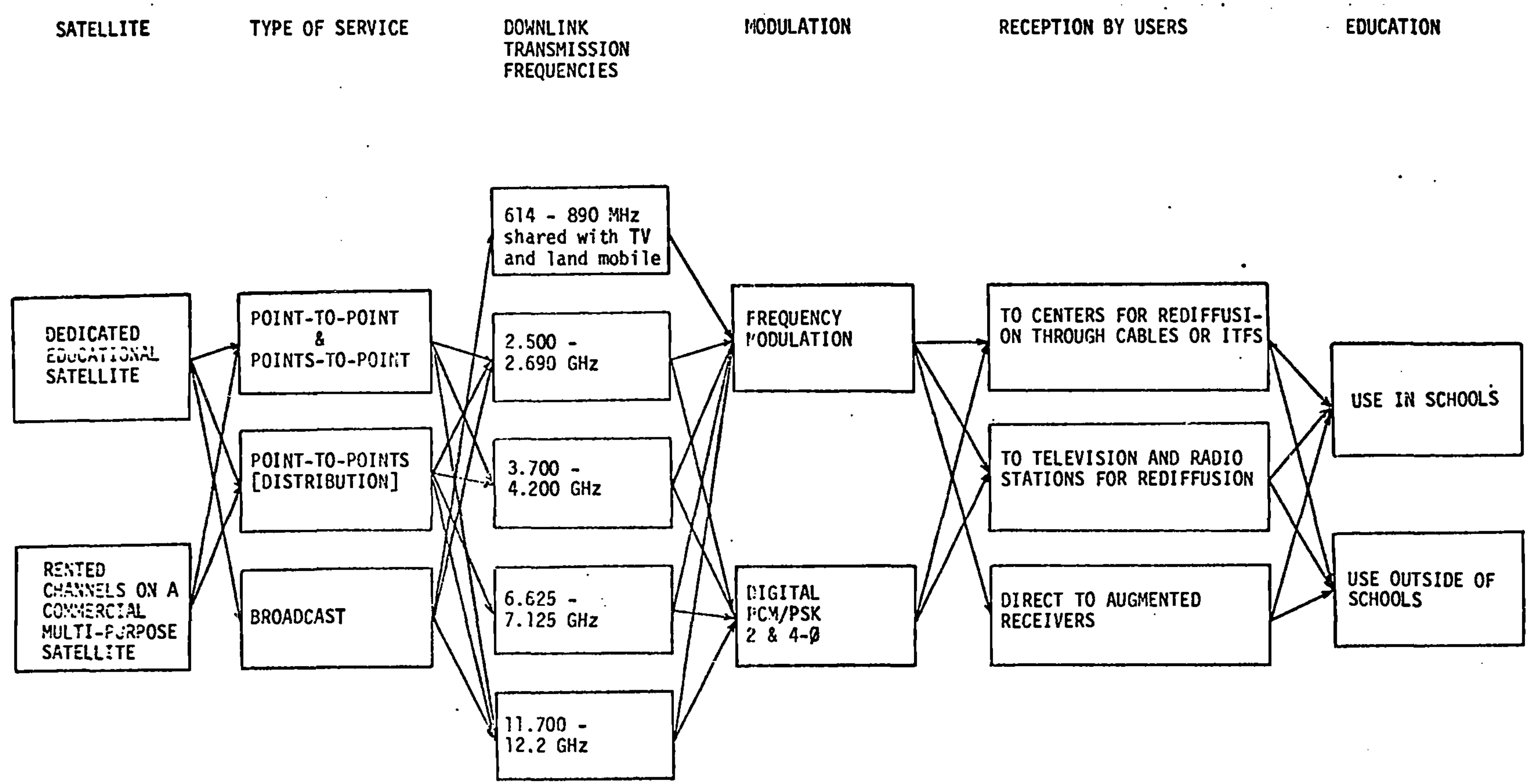


Figure 9. Communications Satellite Services for Educational Development

An analysis has been performed which resulted in the elimination of certain options shown in Figure 8, primarily in the categories of transmission frequency and modulation. This analysis is based largely on considerations of near-term technical feasibility, the current status of frequency assignments in the United States and possible changes which may occur in the 1971 meeting of the World Administrative Radio Conference (WARC). Results of this analysis are shown in Figure 9, which represents our best current evaluation of promising communication satellite systems alternatives of educational services in the early 1970's.

4.2 - Satellite type

In all, two possibilities for the satellite have been considered:

a. A dedicated educational satellite, that is, one devoted totally to providing educational services.

b. A commercial satellite system(s) from which channels are made available to educational users at a reduced rate or free for certain purposes such as ETV interconnection.

To date, the case we have given the most attention to is the dedicated educational satellite. Such a satellite may be required if a large-scale instructional telecommunications service is desired. However, such a development will only come into being if there is much greater interest, response and cooperation than in the past by the educational community and a pulling together of all potential educational users, both in and out of schools.

The Federal Communications Commission, in its Report and Order in Docket 16495 in the matter of Domestic Communication Satellite Systems, adopted on March 20, 1970, declared that applicants proposing multipurpose domestic communications satellite systems should discuss the terms and conditions under which satellite services will be made available for data and computer usage in meeting the instructional, educational and administrative requirements of educational institutions.

The FCC further stated that applicants seeking authorization for domestic communications satellite systems should define the terms and conditions under which satellite channels will be made available for non-commercial broadcast networks, if the applicant's proposed service includes commercial television or radio program transmission. March 15, 1971 was the last date for submission of proposals to the FCC. Eight separate proposals have been filed with the FCC by a combination of aerospace companies and common carriers for authorizations to construct domestic satellite facilities. Table 2 presents a brief summary of these proposals as well as their offerings, if any, for educational purposes. We have recently initiated an assessment of these proposals in terms of their economics and service offerings for educational/instructional purposes.

4.3 - Frequency considerations

Due to space limitations, it is not possible to dwell upon all the System Components described in Figure 8. However, some discussion of operational frequencies would seem appropriate in view of the proximity of the World Administrative Radio Conference scheduled to begin in June 1971 in Geneva. It is of paramount importance from the viewpoint of economics and therefore feasibility of educational satellite facilities, that an allocation, with sufficient bandwidth and with a less severe power-flux density constraint than

Table 2

SUMMARY OF DOMESTIC SATELLITE FILINGS

	AT&T/COMSAT	COMSAT	MCI-LOCKHEED	FAIRCHILD-HILLER
SYSTEM				
No. of Satellites	3 in Orbit 1 ground spare	3 in Orbit 1 ground spare	2 in Orbit 1 ground spare	2 in Orbit 1 ground spare
Orbit Locations [Longitudes]	94°, 104°, 119°W.	99°, 114°, 124°W.	114°, 119°W.	104°, 115°W.
SATELLITE				
Weight at Sync. Orbit	1600 lbs.	1600 lbs.	3900 lbs.	2905 lbs.
Spacecraft Size	110 inches in diameter 230 inches in height	110 inches in diameter 230 inches in height	8' x 5' x 6'[Stowed] x106'[unfurled]	9' in diameter[stowed] 25.3' in length
Stabilization	Spin	Spin	3-Axis [Momentum-wheels]	3-Axis [Momentum-wheels]
Station Keeping	Hydrazine Thrusters	Hydrazine Thrusters	Ion Propulsion Thrusters and Hydrazine Engines	Hydrazine Thrusters
Primary Power	~740 watts [solar cells on drum]	~740 watts [solar cells on drum]	4.4 kW [Solar Cell Array]	750 watts (solar cell cylinder)
Life Time	7 years	7 years	10 years	7 years
Launch Vehicle	Atlas Centaur	Atlas Centaur	Titan III D/Agena	Titan III C
COMMUNICATION SUB-SYSTEM				
Frequency Bands [Receive/Transmit]	5.925-6.425/3700-4.200GHz	5.925-6.425/3.7-4.2 GHz	5.925-6.425/3.7-4.2GHz 12.7-13.25/11.7-12.2GHz	5.925-6.425/3.7-4.2GHz 12.75-13.25/6.625-7.125GHz 2.5-2.69 Trans. Optional
Polarization	Linear	Linear	Linear	Linear
Number of Transponders	24	24	48 [24 for 6/4 GHz operation; 24 for 12 GHz operation]	120 [96 0.1w for narrow-beam point-to-point service; 24 for wide-area TV distr]
Usable Bandwidth per Transponder	34 MHz	34 MHz	36 MHz	34 MHz
Transponder Output Device	TWT	TWT	TWT	TWTs for Wide-area service; Solid State devices for narrow-beam point-to-point
E.I.R.P. per Transponder	33 dbW[beam-edge]	33 dbW[beam-edge]	34.5 at 4 GHz [beam-edge] 46 dbW at 12 GHz	36 dbW for narrow-beams 35.2 dbW for wide-area coverage at beam-center
EARTH STATIONS				
95-105' cooled T/R[G/T= 41.2 db/°K] 4/6GHz	5	2	--	6
42' cooled R/O[G/T= 35 db/°K] 4/6GHz	--	3	--	--
32' cooled T/R[G/T= 33 db/°K] 4/6GHz & 12GHz	--	--	20	--
32' cooled T/R [G/T= 31.5 db/°K] 4/6GHz	--	3	--	--
32' uncooled T/R[G/T= 29.0db/°K] 4/6GHz	--	25	--	--
32' uncooled R/O[G/T= 29.0db/°K] 4/6GHz	--	99	--	--
25' uncooled R/O	--	--	--	Exact No. N/A
PUBLIC SERVICE OFFERINGS	Willing to discuss with CPB the terms and conditions. Nothing Specific.	Willing to work out some sort of preferential service public broadcasting to meet the genuine requirements of the Corporation for Public Broadcastinn[CPB]	Proposes to make available for experimentation in educational service, the equivalent of five TV channels without charge for a period of five years. Also plans to offer equal transmission capacityfor the remaining satellite life at a fraction of regularly established rates.	[1] Two fully non-interruptable satellite transponder channels, at no-cost, to the Public Broadcasting Service; shared use of narrow-beam channels for "off-shore" locations of Alaska, Hawaii, Puerto Rico and Panama Canal zone; [2] Part-time, free-use, of two satellite transponder channels for health-care delivery throughout U.S.; [3] Free service of one or two instructional television channels from the satellite directly to a low-cost terminal for school or community use on 2.550-2.690 GHz band; [4] Free use of the spacecraft segment for a communication system for Alaska.

Table 2 (Cont.)

SUMMARY OF DOMESTIC SATELLITE FILINGS

	HUGHES AIRCRAFT COMPANY	RCA GLOBAL COMMUNICATIONS /RCA ALASKA COMMUNICATIONS	WESTERN UNION TELEGRAPH CO.	WESTERN* TELE-COMMUNICATIONS
SYSTEM				
No. of Satellites	2 in Orbit 1 ground spare	2 in Orbit + 1 at a later date 1 ground spare	3 in Orbit 1 ground spare	2 in Orbit + 1 at a later date 1 ground spare
Orbit Location [Longitudes]	100°, 103°W.	[114°], 121°, 125°W.	95°, 102°, 116°W.	113°, 116°, [119°]W.
SATELLITE				
Weight at Sync. Orbit	452.5 lbs.	638 lbs.	452.5 lbs.	....
Spacecraft Size	73 inches in diameter .. in length	....	73 inches in diameter .. inches in length	....
Stabilization	Spin	Spin/3-Axis [Not decided]	Spin	Spin
Station Keeping	Hydrazine Thrusters	Hydrazine Thrusters	Hydrazine Thrusters	....
Primary Power	220 watts [solar cells on the spinning drum]	~305 watts[solar cells]	220 watts [solar cells on the spinning drum]	....
Life Time	7 years	7 years	7 years	....
Launch Vehicle	Thor-Delta M-6T	Thor-Delta 904/ Atlas/TE-364-4	Thor-Delta M-6T	....
COMMUNICATION SUB-SYSTEM				
Frequency Bands [Receive/Transmit]	5.925-6.425/3.7-4.2 GHz	5.925-6.425/3.7-4.2 GHz 12/13 GHz experimental	5.925-6.425/3.7-4.2 GHz	5.925-6.425/3.7-4.2 GHz 12.75-13.25/11.7-12.2GHz
Polarization	Linear	Linear	Linear	....
Number of Transponders	12	12 for 4/6 GHz operation 2 for 12/13 GHz	12	6 for 4/6GHz operation 6 for 12/13 GHz
Type of Transponder	Linear, Frequency Translation	Linear, Frequency Translation	Linear, Frequency Translation	....
Usable Bandwidth per Transponder	36 MHz	36-37 MHz	36 MHz	....
Transponder Output Device	TWT	TWT	TWT	TWT
E.I.R.P. per Transponder	33.1 dbW for Cont. U.S. 26 dbW for Alaska and Hawaii	35 dbW for cont. U.S. 26 dbW for Hawaii & Puerto Rico	33.1 dbW for cont. U.S. 24 dbW for Alaska and Hawaii	....
EARTH STATIONS				
98' cooled T/R[G/T= 36.7 db] 4/6GHz	2	1	....	....
45' ..... T/R[G/T= ....]4/6 GHz	....	....	7	....
35'uncooledR/O[G/T= 27.80 db] 4/6GHz	7	....	....	....
35'/32' cooled T/R [G/T=31.5 db] 4/6 GHz	....	13	....	....
33' uncooled R/O [G/T = 28.75 db]	....	....	6	....
PUBLIC SERVICE OFFERINGS	One channel on interruptible basis inclusive of transmit and receive earth terminals. Selection of ETV programs in the program package for the cable television industry.	Two transmit TV channels at reduced rates for ETV program distribution. Public Radio program distribution on "piggy back" basis on the channels assigned for ETV. Regular rate provision for Instructional television program distribution. "promotional" rates for experimental I.V services via standby satellite. Allocation of two ITV channels for Alaska.	Willing to offer one or more channels capable of transmitting TV signals if the FCC decides that it is in the public interest that non-commercial ETV networks should be provided satellite channels without charge. Satellite channels would be provided, if the Commission so decides, either by spreading the cost over other users of the satellite, or, from the spare satellite on an interruptible basis.	

*At the time this paper was written, authors did not have access to the detailed filing of Western Tele-Communications, Inc.

that at 4-GHz be secured exclusively for educational satellite services in the neighborhood of the L- and S-bands. These bands have the advantage of relatively efficient primary-power to rf-power conversion, very small or negligible atmospheric attenuation and receiving system with lower noise figures than at 12 GHz for a given earth station cost.

In the U.S.A., frequencies between 2.500-2.690 GHz are assigned by the FCC for use in the Instructional Television Fixed Service (ITFS). ITFS, established by the FCC in July 1963, is designed primarily as a means of transmitting material from a central point to a number of schools, each with its own closed circuit distribution system to the individual classroom. Thirty-one channels are available in this band, arranged in groups of four channels each, and each group contains alternately spaced channels to facilitate heterodyning down to VHF for closed circuit rf distribution within the school. For educational and instructional satellite facilities, this frequency band is the only band in the 1-10 GHz radio window in Region II* of the ITU which could be made available to educational satellite interests on an exclusive basis. An analysis performed by E. F. Miller and R. W. Myhre of NASA Lewis Research Center[24] established sharing criterion between satellite TV distribution and terrestrial ITFS systems. Positive conclusions on sharing considerations in terms of satellite radiated power flux density reaching earth, and satellite elevation angle also have been reached separately in a U.S. draft report to the CCIR study groups.[25]

Although from the viewpoint of reliable small-terminal operation in Region II, the 2.5-GHz band is the best choice available for the operational frequency, it should be remembered that only 190 MHz of spectrum space is available in this band. To accommodate all foreseeable educational requirements, one may also have to make use of the 11.7-12.2 GHz band. Internationally, the frequency band 11.7-12.2 GHz is currently allocated on a worldwide basis to broadcasting, fixed and mobile services. The fact that this band is allocated, at least in part, to the broadcasting service has led many interests, both within and outside the U.S.A., to propose a number of systems utilizing this band for satellite-based TV distribution for community reception and to conventional stations for rediffusion. However, the increased atmospheric attenuation associated with this band is a serious problem, especially for services in which small-terminals have to have reliable access to each other or to a central facility via the satellite. Though no direct statistics for a 12-GHz satellite-to-earth link is available, it is estimated that a penalty in terms of heavy link margins would have to be paid (6-18 db for 99.9-99.99% link reliability).

4.4 - System organization

The form which systems for delivering instructional programming via satellite will take depends upon a number of interrelated issues. A variety of alternative plans may emerge, depending upon the outcome of the needs analysis as well as political realities. In this section, one possible alternative which seems to have merit from the point of view of utilization by teachers and improved software production is described. However, the reader is warned that this represents both an incomplete and preliminary study. Technical and economic factors have not been addressed to any great extent and remain to be evaluated. Other alternatives need to be considered and may prove to be better.

*Region II is principally North and South America.

A study has been undertaken of design considerations and restraints involved in the organization and administration of an instructional satellite system for the United States.[26] Included is a proposal for a cooperative public-private sector effort in which a non-profit instructional satellite corporation controls the satellite and ground equipment and in which software is made available to schools on a competitive basis. In contrast to previous studies, considerable attention is given to the educational portion of the overall system. Trade-offs between educational benefits and systems organization are explored.

Major emphasis in the study is on instructional television and the development of a large-scale distribution system to help satisfy the needs of the educational community. After extensive study of previous efforts to use ITV and experiments such as MPATI,[27] a series of design criteria were prepared which are shown in Table 3. Based upon these criteria, a plan was developed for a system which is designed for educational, social and political acceptance and flexibility.

In the system envisioned, there are two independent spheres of activity and control, (1) the administrative segment, and (2) the program-production segment. Administration is the responsibility of a non-profit instructional satellite corporation organized under the Nonprofit Corporation Act of the District of Columbia. This Corporation would have complete control over the following system segments:

a. The central ground-based broadcasting station or stations,

b. The satellite or the necessary number of satellite channels,

c. The receiving terminals in schools or learning centers,

d. The computerized dial-access and accounting system.

In effect, the non-profit corporation would function like a common carrier. The non-profit corporation structure was chosen to ensure that the organization would provide services to outlying and rural schools where operation might not prove sufficiently attractive to a profit-making corporation. It is in these schools where satellite-distributed instruction may prove to be of great advantage.

The program material to be broadcast over the system would be provided for on a competitive, open-market basis. That is, any producer of educational media which is capable of being broadcast would be given the opportunity to market his product over the system. This separation of the administrative and program-production segments is similar in concept to the separation of programming and transmission operations in space broadcasting proposed by Hult.[28] This arrangement may provide the incentive for the development of adequate amounts of quality software, an important ingredient in a large-scale system using instructional media.

The over-all system would operate as follows. The school or learning center contracts to lease the necessary reception equipment from the Corporation, paying on a monthly basis. The Corporation installs the reception terminal and provides for its maintenance and upkeep. Each teacher is provided with a catalog listing the programs available for delivery. The teacher chooses one of the programs, noting the identification number and price. This information is given to the school's administrative secretary for approval, who calls a central computer. He keys in his school's identification number followed by the program's identification numbers For a continuous curriculum, this order might be placed once or twice a semester. Supplementary or enrichment programming may be ordered in this manner on a twenty-four hour demand basis. In any case, the computer confirms or denies the availability of the program material.

Once confirmation has been granted the computer automatically bills the school for the material and credits the account of the material's producer. The order is then transmitted along with the school's identification number to the distribution center. Preceding the distribution of the program is a list of all the identification numbers of all the schools requesting that particular program. The distribution of these identification symbols selectively activates the automatic recording terminals in those schools which have ordered that particular program. The next day the teacher goes to the school's audio-visual center to find the tape ready for previewing, editing, or dubbing. He may then arrange with the instructional materials coordinator for the playback of the tape any time the program is needed in the educational process.

The kinds of instructional program materials which the system transmits can be divided into two categories: (a) basic curricula for whole courses and (b) supplemental materials. The system is designed to accommodate the equivalent kind of curriculum planning which is now performed by teachers, administrators and local school boards. Curricula for entire courses can be selected on a competitive basis well in advance in the same manner that textbooks are now selected.

Work is now underway to quantify many aspects of this study in connection with the needs analysis, and to explore alternative organizational forms for consideration in the systems synthesis phase of the program.

4.5 - Procedure

The overall systems synthesis phase of the work will proceed as follows. First, technically feasible alternatives will be synthesized and sensitivity analyses performed. Second, a socio-economic assessment of those alternatives will be carried out, resulting in selection of a small number of systems which appear most attractive. Finally, strategies for moving towards an operational system will be considered. Both the potential benefits and disadvantages of systems implementation will be spelled out in detail.

5. - EDUCATIONAL IMPACT ON WASHINGTON UNIVERSITY

The Satellite-Education Program provides a new challenge for a university. The skills and approaches which are required to devise systems, broadly conceived, which relate technology to societal needs must be brought together in ways which make use of the strengths and creativity of the university while, at the same time, circumventing its tight disciplinary structure. Washington University's International Development Technology Center,[29] an organization which cuts across departmental and school lines to focus upon the application of science and technology to help meet national and international needs, provides the mechanism by which faculty members, professional staff members and students from a wide variety of backgrounds can come together to work on problems of mutual interest. (See Section 1.2.)

TABLE 3

AN INSTRUCTIONAL SATELLITE SYSTEM FOR THE U.S.

DESIGN CONSIDERATIONS

A. EDUCATIONAL

1. High-Quality Instructional Programming Material in Sufficient Quantity
2. Five to Seven Day Access to Continuous Curricula Programming
3. 24 Hour Demand Access to Supplementary and Enrichment Programming
4. Ability of Teacher to Preview, Edit, Dub, etc.

B. POLITICAL

1. "Local Control" and Selection of Programming
2. Federal Subsidy without Federal Control of Program Content

C. SOCIAL

1. Equitable Distribution
2. Large, Flexible Source of Programming to Meet Educational Needs of Diverse Groups

D. ADMINISTRATION

1. Effective Billing
2. Royalty and Copyright Protection
3. Good installation, Maintenance and Upkeep

E. ECONOMIC

1. Federal Funding for Non-Software Aspects
2. Development of System on Self-Sustaining Basis Through Users Fees, etc.

Since the inception of satellite-education studies in June, 1969, four undergraduate students, eleven graduate students and eight faculty members have participated in various aspects of the program. Approximately twenty graduate students have taken International Development Technology Studies courses relevant to the satellite program. Pertinent subject matter has also been introduced in an undergraduate General Studies course dealing with Technology and Education.

Student interest in the program is high and is continuing. The application of new technology and current research to a problem with obvious application to human needs has proven to be a strong motivating force for engineering students. Through the personal involvement of the participants, the program has demonstrated that a truly interdisciplinary educational activity, given certain key inputs, can be successfully undertaken within the existing framework of the university.

Partially as a result of our experience with the satellite-education program, a new master's degree, Technology and Human Affairs (THA), is being designed. This program, to be conducted jointly by the Schools of Engineering and of Arts and Sciences, will enable students with backgrounds in the social, physical and biological sciences, as well as engineering, to pursue a course of study centered on the interdisciplinary problems emerging from the interactions of technology and society. Technologists will participate in assessing the social and environmental implications of technology while, at the same time, social scientists will develop a better grasp of contemporary technology. Courses such as the graduate seminar on Satellites, Media and Education developed in conjunction with the Satellite-Education Program, will provide a small unifying core for the THA master's degree. The THA program will provide professional training to meet occupational demands for administrators and officials with interdisciplinary backgrounds.

There is a pressing need for the technologist to understand the realities of our educational system and needs, and for the educator and policymaker to understand the opportunities and limitations which are inherent in any technological innovation. The Washington University Satellite-Education Program provides a framework for this kind of understanding. The program has already resulted in useful data on the role of engineering schools in the development and assessment of technology for aiding in the solution of social problems, and on requirements for carrying out such activity within the overall university setting.[30]

6. - ACKNOWLEDGEMENT

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JULY, 1971

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E. OTHER SELECTED PUBLICATIONS, REPORTS AND MEMORANDA OF INTEREST BY PROGRAM PARTICIPANTS

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