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EDUSAT - AN EDUCATIONAL TELEVISION SATELLITE SYSTEM FOR THE UNITED STATES

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Introduction

The advent of earth orbiting satellites has brought us the capability to distribute television to large audiences quickly, easily, and economically. Although early television distribution satellites required large ground receivers, proposals have now been made for satellite systems requiring only small, comparatively inexpensive receivers. In the future, homes throughout a nation may receive television programming directly from a satellite through use of small outdoor antennas connected to conventional television sets.

Almost as soon as the capability to have such a system was recognized, its use to distribute educational television to mass audiences was suggested. To date, many studies have been made as to the characteristics of an educational television satellite system. Usually, however, these studies have concentrated upon the technical aspects of the system. The studies often neglect to investigate completely the need for the system and the objectives of the system. Proper evaluation of the system would also consider the inter-related aspects of programming to be provided, audience acceptance, management, and costs and funding --- all related to the specific technical system proposed.

The following preliminary design for an educational television satellite system for use within the United States in the mid 1970's considers both the social and technical aspects of the system. The design was prepared by a multidisciplinary faculty design team as a result of an eleven-week study. The faculty were participants in the 1968 ASEE-NASA Summer Faculty Fellowship Program in Engineering Systems Design. The program was sponsored by the National Aeronautics and Space Administration and conducted by Old Dominion College in conjunction with the Langley Research Center. The fifteen university professors participating in the program came from institutions throughout the United States and represented the disciplines of business management, economics, education, engineering, political science, psychology, and systems analysis. A brief description of the program is contained in the appendix.

The system proposed by the faculty is entitled EDUSAT (Educational Satellite). The name EDUSAT can alternately represent the system, the operating corporation, or the satellite.

Although the faculty proposal for EDUSAT presents a detailed investigation of the social and technical aspects of the system, the emphasis of this paper is upon the social aspects. Special attention is given to the need for having such a system and the methods used to assure its acceptance and continued use by the public.

Need For A Satellite Educational Television System Within the United States

The proposal for EDUSAT is founded upon the educational needs of the United States and the concomitant needs of educational television within the United States.

The educational needs of the United States are quite broad. No one system will satisfy all of these needs. It is important to determine if having the capability to distribute television to large areas by satellite will satisfy any of these needs, and if it can satisfy these needs better than present systems or alternate proposals for future systems. It is particularly important to resolve the conflict that television distribution satellites are intended primarily to serve large geographical areas, whereas, in the United States, education is primarily a local issue.

Included in the general educational needs of the United States is a need to establish a minimum standard level and quality of education across the nation. Presently, the level and quality of education vary widely from state to state, community to community, and school to school. There is the continuing national need for the improvement of the nation's educational systems to include formal and informal instruction both in and out of the classroom for people of all ages. Attention must be given to job training for the young, job retraining for those needing to find new professions, and job updating for those whose profession requires continued education. There is the need for an increased awareness and understanding of public issues. And, there is the need for a stronger feeling of national unity as well as an understanding of other nations and cultures.

These needs must be satisfied, but they are occurring in an era of increasing shortage of teaching personnel and facilities. To alleviate the shortage, television must be used to extend and to complement the traditional teaching methods in the classroom and to increase the dissemination of public and cultural information.

Television is now playing a key role in both formal and informal educational efforts. Although commercial television has had a significant impact on public understanding of national and world events, its resources serve the public more as a source of entertainment than as an educational tool. Educational television (ETV), on the other hand, seeks to serve both the community and the nation's school rooms with programming in public affairs, cultural interests, and instructional uses.

The intended service is of noble cause; yet, if a look is taken at the country as a whole, the present services provided by ETV become more a testimony to vision and to potential than to sustained accomplishment. As the Carnegie Commis-
ETV has the ability to satisfy many of the educational needs of our nation, but in its short history it has also generated its own set of needs. Recognizing the elements of strength in the existing educational television systems, but also recognizing the present limitations of the system, the following specific educational television needs of the United States are recognized:

1. The need to interconnect existing and future ETV stations for more rapid networking distribution capabilities, and a broader base for sharing resources.

2. The need to reach the entire populace of the United States, including remote areas unable to receive television.

3. The need to reach schools which do not have access to ETV station programming.

4. The need to reach special audiences with common concerns, and to enable the sharing of information among common interest groups.

5. The need to provide alternate programs to commercial television.

6. The need to increase the quality and quantity of programming for ETV.

7. The need to reach states and territories outside of the continental United States.

8. The need to provide educational opportunities for the public outside of the classroom.

It is proposed that these needs are best satisfied and are most conveniently satisfied by a national educational television satellite system—EDUSAT. It is technically feasible to have a satellite in synchronous orbit which can distribute television programs directly to homes, schools, community centers, and ETV stations. The system could be used to distribute programs instantly to ETV stations throughout the nation. It could provide ETV to all homes and schools regardless of location. And, it could provide programming economically to audiences who, though widely separated, have similar interests, tastes, and needs.

**General Description of EDUSAT**

The EDUSAT educational television satellite system provides service aimed at satisfying the needs of the general audience, common interest groups, and the school population. Its services include public television, special television and instructional television. Its services are provided directly from a satellite to homes, community centers, schools, and educational television stations.

The system provides for the transmission of four television programs, in color, to a satellite in synchronous orbit for broadcast to the United States and some of its territories. All four programs are relayed to ground receivers using channels in the microwave frequency band. One of the programs is also relayed using UHF frequency.

Direct broadcast of the UHF frequency is used to distribute a single channel of programming directly to the home and to provide minimum required educational television programs to the school. This is accomplished by the use of low cost receiver accessories (approximately $100) attached to conventional television receivers. The home and school could select to receive this channel directly if no service is available from a local educational television station. Additionally, the school could choose this channel if its needs and finances did not dictate receiving all four channels.

Educational television stations, community centers, and schools may be equipped to receive all four channels of programming through the utilization of more expensive receiver accessories (approximately $3000). The educational television station has the option of rebroadcasting to its audience, live or by tape, any of the four programs available from the satellite or of providing its own programs. The community center may serve as a re-broadcast station when educational television stations are not receivable and when the economy of the community is such that the costs of home receiver accessories are prohibitively expensive. The school may wish to receive all four programs directly if service from an educational television station is not available or if it is dissatisfied with the station's service.

The major population centers of Alaska and all of Puerto Rico are served by the satellite, but more sophisticated ground receiving equipment must be provided. Hawaii is served by a special beam from the satellite, but "direct to home" transmission is not provided. United States possessions not served directly by the satellite still benefit from the EDUSAT system in the form of improved programs available.

Programs to the satellite may originate from any of four ground transmitter facilities located across the country. These facilities collect the programs, either live or by tape, from existing educational television stations, networks, and programming organizations.

The EDUSAT system anticipates no difficulty with the time zone differences that exist across the United States. A single beam transmits to the entire nation. Many of the programs (public events, information transmission, . . . ) transmitted are insensitive to time. Through careful program scheduling, including the use of video tape recording, and delayed ground rebroadcast, problems that arise, caused by differences in time are solved in a manner similar to that used by commercial networks in the United States.

It is proposed that the system be managed by a non-profit corporation, also entitled EDUSAT. The corporation is fashioned in a manner similar to the Corporation for Public Broadcasting. The corporation recognizes the need for intensive cooperation with the Corporation for Public Broadcasting, local educational television stations, educators, and various interested government agencies and private corporations. It considers the problem of political pressure. It establishes costs and proposes funding from public and private sources.
Although EDUSAT does not produce programs, it increases both the quality and variety of programs produced by others through its ability to distribute the programs and their costs over large audiences. It also recognizes that programming is the responsibility of the Corporation for Public Broadcasting.

**Public Acceptance of EDUSAT**

The EDUSAT system is intended to meet national needs administered through the basic principle of local control and selection. Each recipient (the home, the community center, the school, the local ETV station) has the opportunity to determine the extent of its participation in the system. To establish and operate a national satellite ETV system successfully within the United States, methods must be used to assure acceptance of the system. The system will not be imposed upon the people. By giving the recipient the opportunity to determine the extent of his participation, the EDUSAT system is considered to be more acceptable to the American public.

It has been stated that the first need of ETV within the United States is to interconnect existing and future ETV stations. Once interconnected, ETV stations will have a larger base for sharing resources and a capacity for more rapid transmission of programs. EDUSAT helps satisfy this need. It provides four channels of programming continuously to all stations. A station may select programs from the satellite for direct or delayed transmission to its audience. The station may also select to transmit a program of its own or one received from another source. It is free to determine the extent of its participation in the EDUSAT system.

EDUSAT will not compete with the local ETV station for the attention of the ETV audience. Although schools and homes can obtain the capability to receive programming directly from the satellite, the majority will prefer to receive their programming from the ETV station. One reason for this is the added expense associated with direct satellite reception.

Many areas in the United States are without local ETV stations. People living in these areas may choose to receive ETV directly from the satellite into their homes through the use of low cost UHF receiver accessories. It is also anticipated that additional people throughout the nation will, through interest, curiosity, or "prestige", decide to erect outdoor antenna equipment to receive from the satellite. They may be interested in the technical aspects of satellite reception. They may be curious as to how the satellite programming differs from local programming. Or, they may wish their neighbors to know that they have EDUSAT reception capability.

For the schools in remote areas not having the service of local ETV stations, EDUSAT will provide basic ETV programming through its UHF channel. This programming could be used to establish a minimum standard level and quality of education for the entire United States. As the receiving costs for the UHF channel are considered to be within the reach of all schools, the EDUSAT system will assure that every school in the nation has the services provided by ETV.

Should a school within the range of an ETV station become dissatisfied with the station's service, it may establish antenna facilities to receive the four microwave channels directly from the satellite. The EDUSAT system encourages the school to cooperate with the local ETV station for programming, but it does not make it dependent upon the station.

The emphasis on transmission of programming through ETV stations in effect minimizes direct-to-school transmission from a satellite in many areas. Traditionally, the American public school system is locally based, with its programs, policies and finances determined principally by those responsible at the state or community level. For this reason, national programming for instructional use would necessarily be limited. The use of television for instructional purposes is therefore expected to continue in the nation's classrooms only at the pace determined by local school systems. Autonomy of the local ETV station and local determination of curricula therefore limits direct programming from national sources and necessitates keeping the choice of programs at the local level.

If local school systems should become more receptive to "outside" influence of TV curriculum development, there may be increased use of the satellite's capacity to provide direct-to-school broadcasting. This may serve to free air time of ETV stations for non-instructional uses, a service compatible with the increased emphasis on public television and concern for broader community service by ETV stations. In the meantime, many schools not located near an ETV station may choose to receive direct-to-school broadcast. This would provide an immediate test of the capability of the proposed satellite system, as those schools could demonstrate the pros and cons of such a choice.

If EDUSAT is to serve the public with its full potential, it is obvious that the public must be aware of and receptive to the programming available through it. Since EDUSAT attempts to do more than amuse the public, definite steps must be taken to assure its acceptance.

1. EDUSAT, through its acceptance standards and ability to draw on many programming sources, transmits programs of highest quality.

2. EDUSAT recognizes and is reconciled to the lack of homogeneity of its audience. Both its program selection and program format are intended for specific audiences ("inner city" groups, rural groups, . . .). It attempts to attract all members of a particular audience some of the time.

3. EDUSAT encourages University and Cooperative Extension Services to play an intermediary role between the viewing public and the services provided. The Cooperative Extension Services (CES) is a land-grant university-based organization with federal, state, and local financing. The system has from one to thirty professional educators in each of the counties of the United States and its territories. The CES employs an informal, out of school approach to education whose programs are determined in cooperation with the clientele it serves. Its familiarity with local problems and needs and its facility in securing adoption of new practices places CES in a prime position to promote the acceptance of ETV via EDUSAT. Moreover, the CES, in cooperation
with members of the local community, can effectively identify the needs and interests of the local audience in the determination of programs that are aired over EDUSAT.

4. EDUSAT gives the individual teacher the opportunity and responsibility to select programming and scheduling which is appropriate for his or her class. Numerous programs presenting similar instructional material in various manners and levels are transmitted. Teachers are encouraged to video tape, for replay in class, programs of their own selection. In addition to providing material in a manner most suitable to a class, this format insures the teacher's interest, enthusiasm, and participation in the EDUSAT system.

Educational Television Services
Provided by EDUSAT

EDUSAT transmits four channels of programming to the United States. This number of channels is selected to satisfy the minimum national educational television programming requirements, to allow additional future experimentation with the system, and to be consistent with satellite capability.

In order to accomplish the educational objectives of EDUSAT, three major categories of educational television are provided: Public Television (PTV), Special Television (STV), and Instructional Television (ITV).

Public Television is an alternative non-commercial program available to the public. It informs the audience about the society, politics, and economics in depth, presents programming in the traditional and contemporary arts, and permits the viewer to observe local events.

Despite some excellent "special programs," commercial television lacks sufficient time to offer public affairs programs in depth at the time most viewers watch television. In the view of commercial networks, cultural affairs programs do not develop sufficient viewer interest to warrant regular showing. In short, networks inform the public rapidly of current world events, and give a taste of culture consistent only with their efforts to attract the maximum audience.

EDUSAT, through its public television transmission, reverses this process. It gives substantial air time to the discussion of problems of concern to the public and regularly presents cultural programs.

The aim of public television is to attract all of the audience some of the time. This is accomplished through the variety of programs offered by the four channels to the local ETV station for selection. The station manager chooses according to the dictates of his audience. These audiences may include "inner city" inhabitants, rural groups, and "intellectuals." Through national educational television distribution by satellite, these audience with common interests and problems, though widely separated, receive programming of individual interest.

Special Television is the inter-connection of common interest groups for conference and training. It is also used for information and data exchange for libraries, universities and research organizations. Finally, it is available on stand-by basis for emergency application by the government, by industry, by organizations, and by institutions. Generally, STV provides for a wide range of interaction of groups and individuals needing nationwide exchange of information.

Currently, limited use is made of ETV for special audiences such as medical groups, law enforcement agencies, college and universities, and research organizations. No channels are nationally available to provide opportunity for experimentation with possible new uses of television in emergencies, training of special groups, information transferring and review, and the integration of television with other communication media. EDUSAT provides such channels.

Instructional Television is the use of television for direct, formal instruction. It is an omnibus term meant to describe the use of television for formal courses (regardless of age or grade level, or whether or not given for credit) and for in-school instruction in parts of courses. It is intended for direct teaching, in-service training, or lecture-demonstration. It may also be used in conjunction with the computer.

Through EDUSAT, school systems have at their disposal instructional programs from (1) their local ETV station productions, (2) other school systems and ETV stations, and (3) from national program sources. This has the effect of spreading the heavy development costs of ITV programs over many school systems and enables them to draw on a much larger pool of creative talent than is available to any single system.

Organization of EDUSAT

It is proposed that an educational television satellite corporation, EDUSAT, be formalized under the Nonprofit Corporation Act of the District of Columbia. EDUSAT would be organized along the same general lines as the Corporation for Public Broadcasting. The nonprofit corporation form is selected to assure the noncommercial educational television and radio broadcast systems and local educational television stations maximum freedom from interference, control of program content, or other activities.

Existing corporate forms, related to the utilization of satellites, were examined and determined to be inappropriate for the reasons indicated below:

The Public Broadcasting Act of 1967 established the Corporation for Public Broadcasting (CPB), as a nonprofit corporation. Although permitted to assist in the establishment and development of one or more systems of interconnection, the corporation was prohibited from owning or operating any television or radio broadcast station, system, or network, community antenna television system, or interconnection, or program production facilities. Since communication satellites are classified as interconnections, this corporate form could not include EDUSAT under its present legal limitations.

The Communications Satellite Act of 1962 established COMSAT as a profit making corporation under the District of Columbia Business Cor-
The corporation was deemed to be a common carrier and was primarily established to provide the United States with a private corporation to cooperate with other countries in establishing a global communications satellite system. The international aspects of the corporation's responsibilities do not appear to be compatible with the domestic educational needs of the United States.

The National Aeronautics and Space Act of 1958 established NASA as a civilian agency, predominantly devoted to research and development in aeronautical and space activities. NASA was specifically charged with the development, construction, testing and operation for research purposes of aeronautical and space vehicles. NASA was thereby excluded from the supervision or control of a domestic operational satellite for educational uses.

The establishment of a nonprofit corporation therefore appears to be the most appropriate corporate form. Since the educational system of the United States is historically rooted in local centers of control, this corporate form will provide a channel through which the voices of the people can be expressed as to their particular local interests. The retention of the proposed corporation in public control both protects the use of the frequency spectrum to the public and also returns to them a portion of their extensive investments in the development of satellites.

Some people may have fears regarding a national educational television system within the United States. EDUSAT must be free from government interference and not be used as an instrument of publicity for executive, legislative, or judicial governmental agencies.

Government operation of media of information, by tradition, opposed by the American public. It has been established by legal precedent that a government agency cannot own stations or produce television programs. The EDUSAT corporation is a private corporation and as such, can engage in television operation.

As a local ETV station can, at little expense, fill its air time with local programs, the danger of a strong national network imposing its program decisions on the station does not seem likely.

It should also be recognised that an additional political impact can be achieved through public affairs programs on public television. By disseminating information of public interest, millions of people will be able through television to participate in national, state, and local political processes and to attend governmental meetings. Through televised discussions and interpretations, it is expected that the public will become better informed and be able to make more intelligent choices.

In view of the public nature of the corporation recommended for the implementation of EDUSAT, it is recommended that federal funds provide the major financial support.

It is suggested that the $23 million dollars required for the research and development of the proposed satellite be made available within a future NASA budget. It is also suggested that at such time as the satellite and its booster are ready for implementation in the mid 1970's, the additional fixed capital cost of $67 million be provided to NASA. (It should be noted that these capital expenses cover two satellites and two boosters to provide for the continuity of the system).

The funding of the four ground transmitters, with a total cost of $6 million dollars, should be obtained from the Corporation for Public Broadcasting. This corporation is legislated so as to support such activities.

Ground receiver costs are to be primarily supported by the receiving agency. This is the receiving ETV station, school, community center, or home. In some situations where it is deemed to be in the national interest, government funds may provide support for certain ground receivers.

The total system annual costs of approximately $11 million is funded by a combination of federal funds and voluntary contributions from individuals and private foundations, organizations, and institutions.

Technical Description of EDUSAT System

The technical parameters for the proposed EDUSAT system are based upon both proved capabilities and projected mid 1970's capabilities.

One satellite is proposed. It is located in synchronous equatorial orbit at 105° west longitude. The satellite is capable of relaying four color televised channels simultaneously. General satellite characteristics are:

1. A 3° x 7.5° elliptical beam pattern to cover the 48 contiguous states.
2. A broad beam receiving horn.
3. A parabolic antenna of elliptical cross-section having a major axis dimension of 27 feet for transmitting one of the four channels in the 800 MHz range using frequency modulation.
4. A parabolic antenna of elliptical cross-section having a major axis dimension of 3.2 feet for transmitting all four channels in the 7.3 to 7.75 GHz range using frequency modulation. This antenna is mounted inside the larger antenna.
5. A separate beam and four channel service to Hawaii.
6. A prime dc power requirement of 10 kw necessitating 1300 square feet of sun-oriented solar cell panel. The power supply consists of four 2.5 kw roll-out solar cell arrays which are mounted at the "top" and "bottom" of the antenna.
7. A sealed nickel-cadmium battery system for energy storage so that power can be supplied for the satellite housekeeping subsystem during solar cell period. No television transmission takes place during shadow operation, which occurs for a maximum of 72 minutes during portions of the year. Total battery capability is 800 watt-hours.
8. A total satellite weight in the neighborhood of 1800 pounds.
9. An estimated satellite lifetime of 5 years.

10. An Atlas-Centaur launch vehicle.

The channel in the 800 MHz range is proposed for direct broadcast to lessen the cost of the receiver accessories required to receive the channel on standard television receivers. Frequency modulation is selected since satellite RF power requirements for amplitude modulation are much higher.

The four ground stations for up-link transmission have 30 foot diameter parabolic antennas, have power outputs of 10 kw per channel, and use the 8.025 to 8.4 GHz frequency band. They employ frequency modulation. Programs may be originated at the facility or may be relayed through the facility from other points of origination (e.g., nearby ETV stations.)

The basic down-link to the viewing audience is by means of ETV stations. The cost to each ETV station to receive the microwave channels is approximately $3,000. This cost includes a 15 foot parabolic antenna, a low noise preamplifier, and frequency and modulation converters.

The individual home owner or school can receive the UHF channel provided the required accessories for satellite reception are purchased. The cost of such accessories has been projected to possibly be as little as $100, installed, by the mid 1970's.7 This estimate includes the cost of the antenna, mounting hardware, transmission line and low noise amplifier-frequency and modulation converter for converting a wide-band FM broadcast to the standard television signal.

Individual schools and communities, either not serviced by an ETV station or dissatisfied with available service, can install their own receiving equipment for the microwave channels or the UHF channel.

Frequency Selection

For the earth to satellite communication, only two frequency bands recommended by the CCIR have, the required band spread for the four 50 MHz channels required, 36 MHz for video and 14 MHz separation.8 These are the 5925 to 6425 MHz and the 8025 to 8400 MHz bands. The 8025 to 8400 MHz band is selected for EDUSAT.

Similarly, for the satellite to earth communications, only two bands of frequency recommended by the CCIR has sufficient space for the four 50 MHz channels. These are the 3400 to 4200 MHz and the 7300 to 7750 MHz bands. It appears that neither frequency band has particularly unique advantages over the other. For the microwave channels in the proposed system, the 7300 to 7750 MHz band is used. This permits a smaller satellite transmitting antenna.

The selection of a carrier frequency near 800 MHz and the use of FM for the direct to home TV channel is based on the reasons listed below:

1. The amplifier-converter costs are consistently lower (2 to 1 for 7.6 GHz) compared to any other potential frequency.

2. A less expensive antenna is required compared to microwave frequencies.

3. There is present a heavy development of converters in this frequency range that should result in reducing the cost.9

4. Advanced technology satellites (ATS) F & G models plan experimental FM-TV relay broadcasts near this frequency.

5. Higher efficiency power amplifiers are available for FM.

6. FM requires less satellite power than AM.

Ground Receivers

There will be two different types of receivers for the satellite television reception:

1. The UHF receiver for the single program at 800 MHz.

2. The microwave receiver for the four programs broadcast in the 7.3 to 7.75 GHz frequency band.

Since the signal transmitted by the satellite is a broad band FM signal, it is not compatible with the standard TV receiver, which is designed to receive a relatively narrow band signal consisting of an AM-VSB signal for the picture and an FM signal for the voice. Therefore, it is necessary for the receiving converter to change the form of the modulation to make it compatible with the TV set.

The UHF receiver, which is also the basic module of the microwave receiver, performs the functions of:

1. Low noise amplification.

2. Conversion to a lower frequency.

3. Demodulation of the FM signal to obtain the composite video signal plus the audio FM carrier at 4.5 MHz.

4. Separation of the video and the audio signals.

5. Amplitude modulation of the picture carrier with the video.

6. Translation of the audio carrier to the proper frequency relative to the picture carrier.

7. Combining the two signals with filtering to provide a signal compatible with the standard TV receiver.

It is recommended that the entire receiving unit be constructed in modular form and mounted in a weather proof enclosure on the antenna. In this way, the signal transmitted down to the receiver is similar to any other TV broadcast signal. Power will be supplied to the receiver through the transmission line. Since frequency drift of the conversion oscillators may be a problem, provision should be made for voltage control to provide fine tuning adjustments. If servicing of the remote unit promises to be too great a problem, the preamplifier, the first fre-
quency converter and part of the i-f amplifier may be mounted on the antenna with the remainder of the receiver located at the TV set.

The microwave receiver in the 7.3 - 7.75 GHz band will differ from the basic UHF receiver in that:

1. It has a low noise microwave preamplifier.

2. It has a pre-converter at the antenna which converts the 7.3 GHz to the 800 MHz of the basic UHF receiver.

3. It has four basic UHF receivers each tuned to select one of the four television program channels.

Costs of EDUSAT

Transmission Costs

As explained in the Carnegie Commission Report, the need for network connections for ETV stations within the United States is as great as it is for commercial television. The annual cost of land connections between the 380 ETV stations suggested in the report was estimated to be $17 million. This figure covers the lease of 10,000 miles of interstate circuitry from the telephone system which would connect one point in each of the 48 contiguous states to the national network, and it includes the yearly cost of over 28,000 miles of intrastate circuitry purchased by the states or the ETV stations in those states. The intrastate connection would provide only one channel of service for a period of eight hours per day.

The satellite distribution linkage as envisioned in this report has an approximate annual cost of $11 million, including the annual costs of the four central facility stations. The satellite connection would provide four channels of service to the 48 contiguous states on a 24-hour day basis.

The 28,000 miles on intrastate terrestrial circuitry to be provided by the states or ETV stations as suggested in the commission report would have fixed or capital costs of approximately $42 million. The capital costs of the satellite system and the four central ground facilities necessary for satellite networking would be approximately $96 million.

It is important to note that the proposed EDUSAT satellite would provide signals not only to ETV stations, thereby establishing a network, but also to school districts, schools, community antennas, and to homes; whereas the Carnegie proposed ground system would link only the ETV stations.

Table 2 Cost Summary

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<th>Space Segment Costs</th>
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<td>Includes back-up satellite as insurance against launch failure.</td>
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<th>Fixed Capital Costs</th>
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<td>Research and development</td>
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| Spacecraft (2) approximately 1800 lbs. | $38 million |
| Atlas-Centaur boosters (2), launching, telemetry and control | $29 million |
| Total Cost of Transmitting Equipment | $90 million |

Annual Costs

Based on 5 year life amortized over 10 year period $9.5 million

Ground Segment Costs

Includes 4 central facilities, each capable of sending and receiving 4 TV signals to and from satellite

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<th>Fixed Capital Costs</th>
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<td>4 central facility sites</td>
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Annual Costs

Includes overhead and 10 year capital amortization $1.5 million

Receiving Costs

Television receiver accessories will be required at each receiving location in order to obtain the satellite signals. Schools, ETV stations, community TV systems and school districts will have to install antennas, amplifiers, mixers, oscillators and transmission line to receive the four weaker signals at 7.3 GHz directly from the satellite, at a cost of approximately $3000 per site (expected with quantity production). Any institution or home wishing to receive the stronger TV signal at 800 MHz will be able to do so with receiver accessories costing from $100 to $500. The lower figure is based upon projected future electronics capabilities and a projected large quantity demand; the higher figure represents current production capability and a projected small quantity demand.

Predicting the future cost of the 800 MHz receiver accessories is difficult. The cost is dependent upon such interrelated factors as the technology available, the buyer demand, and the method of production.

It is difficult to assess the effect of technological advances upon the cost of the receiver accessories. It is recognized that the advents of semi-conductor devices replacing vacuum tubes and printed circuit techniques replacing hand wiring have had varying (often not significant) effects upon price reduction for electronics within the United States. If the proposed receiver accessory instrument were assembled and installed today the cost would be approximately $500.

It is difficult to determine the buyer demand (and its associated effect upon production costs) within the United States. If the home owner is not sympathetic to reception of the channel in his house, and if only one-fourth of the schools select this system, then, spread over a ten year period, only 2,000 to 3,000 units need be produced.

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It is difficult to anticipate the method of production that would be used. The development cost for the accessories may be subsidized by a United States governmental agency; it may be indirectly borne by a foreign government developing its own satellite television capability; or it may be included in the direct cost to the buyer. The production may be by an individual company or by many competing companies. In any event, it is recognized that the receiver accessory costs within the United States will be higher than the costs proposed for receivers in developing nations. A developing nation will probably have large production with little or no private profit. Within the United States there will be small production with private profit.

Acknowledgment

The author wishes to acknowledge that the results reported in this paper represent the combined efforts of the fifteen ASEE-NASA University Summer Faculty Fellows in Engineering Systems Design.

Appendix

The purpose of the eleven week, NASA Summer Fellowship Program in Engineering Systems Design was to acquaint the visiting faculty participants with the educational methods used to teach an engineering systems design course in the hope that they would introduce such a course at their own university. A second purpose was to acquaint the participants with NASA's activities in space technology and research, primarily to identify areas that are of importance to engineering faculty and students in normal academic courses and research. The third purpose was to prepare the preliminary design of an educational television satellite system for the United States in the mid 1970's.

The goal of the Engineering Systems Design course is to give a student experience in and an appreciation of the overall problems involved in carrying out the preliminary design phase of a typical complex engineering system. At the same time he has the opportunity to investigate in detail one or two particular aspects of the system. This is accomplished by having students from all disciplines form a design team. Lectures regarding fundamental technologies (orbital mechanics, communication theory, economics, politics, etc.) are provided by the faculty and lectures regarding state-of-the-art technology are provided by guest speakers from government and industry. Management of the course is vested in the students with the faculty serving only as advisors. The students' final report is published and an oral presentation regarding final results is given to the public.

References


7. Costs of Broadcast Satellites Linked to Local, TV Quality, Technology Week, pp. 36-37, February 20, 1967.
