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MASTER

DETERMINATION OF THE COMPARATIVE ENGINEERING COST-EFFECTIVENESS OF TERRESTRIAL, CELESTIAL, AND MIXED TERRESTRIAL-CELESTIAL INSTRUCTIONAL TECHNOLOGY SYSTEMS

by

Carl Mitchell

for

Academy for Educational Development, Inc.
1424 Sixteenth Street, N.W.
Washington, D.C. 20036

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MASTER

INTRODUCTION

In the United States and throughout much of the Western world there is a growing awareness of the enormity of the task that has been defined for the various national education systems. Educators, for several reasons, are referring to the situation as the "crisis in education".[1,2] The principal reason being given is the lack of funds to provide a basic education by traditional methods to the burgeoning numbers of people for whom such an education may well mean the difference between living and merely subsisting.

Because the core of education is communication, it is perhaps only natural that telecommunications technology is being investigated as an ingredient of both more efficient and possibly, at the same time, more effective educational systems. Surely, the potential is there. Yet, it is being tapped, with few exceptions, in a piecemeal fashion that nullifies the one clear advantage it has, in terms of efficiency, over traditional classroom-teacher situations -- that of being capable of reducing the student-teacher ratio. The importance of this advantage was pointed out by the Academy for Educational Development following a study to investigate the new instructional technologies with regard to school finances. In a summary statement before the President's Commission of School Finance, the Academy's Executive Vice President, Sidney G. Tickton, said "The only way to reduce unit costs substantially is to increase the pupil-teacher ratio dramatically."[3]

The advantage of transmitting educational programs by radio-waves using a geo-stationary satellite is immediately apparent. A satellite offers to a large country or group of countries lacking adequate ground communications (and this is almost always the case, as far as educational technologies are concerned, for some regions of every country) a system that can cover a geographic area of a million square kilometers. The satellite signals can reach isolated, mobile, and dispersed populations with ease, and recent studies show that the cost of the distribution system for television programming can be significantly less by satellite than for comparable terrestrial facilities.[4]

In the case of a less developed country (LDC) it is inconceivable that an undertaking of such magnitude as to provide educational television by satellite for the whole country would not be joined, if not

controlled, by the national ministry (department, bureau, etc.) of telecommunications or a comparable entity. In any event, it would be very desirable from an economic standpoint. For little additional cost, a revenue producing service could be provided using the same satellite and slightly enlarged earth stations.

Section B of this report describes progress toward the development of a model to determine the least-cost joint system.

Inasmuch as a telecommunications system may be used to carry a variety of technological approaches designed to enhance the educational process, some evaluation as to which approach or approaches to use would be desirable. Section A of this report presents the progress to-date in this effort as given in the literature.

Section A

EDUCATIONAL TECHNOLOGY
A Summary Of Recent Evaluations

> "The forms of society we shall see in the twenty-first, century in my judgement, will depend less upon our relationship as workers to the means of production of goods and services and more -- much more -- upon our relationship as total social beings to the means of production of information, ideas and images."
>
> -- Rose K. Goldsen
> Cornell University

Education, as contrasted with instruction, is seen as "a preparation for life through more adequate adaptation to one's environment." [1] It is regarded as being concerned with the "whole student" and as relating to "his mental, emotional, physical, social, cultural, and technological adjustments." [2] Or, put another way: "In the broadest sense the aims of education include the transmission of knowledge, the installation of values and the development of intellectual, physical, social, and artistic skills and competencies." [3]

It may be argued that attempting to evaluate the effectiveness of any particular educational system or process in contributing to the above implied objectives is tantamount to measuring (quantifying) the whole individual and the "usefulness" he is imputed by society. Surely, there is no more herculean task!

Most people are well aware of this problem. For instance, Jamison and Suppes in discussing alternatives for improving productivity and efficiency in education state their belief that "clearly categorizing and measuring the outputs of an educational system is presently an impossible task." [4] In their view, "much of the work that would be required in such an endeavor would involve assessment of values, not facts, and even if...(one) were to reach a concensus, both the desirability and capability of...(a government's) acting on this concensus are dubious."

As a result, most evaluations of alternative educational processes are based largely on the ability of these processes to perform the instructional part of education and are, thereby, implying that the affective component of education is invariant under the several alternative processes. Thus, Jamison and Suppes adopt as their definition of the output of educational systems, with susceptibility to measurement clearly

in mind, two types of proxy measures: "1) enrollments weighted by time and type of exposure, and 2) distributions of scores on achievement tests."

In and of itself, this approach biases the educational reformer toward methods and systems alternatives that reportedly maximize this "objectively" determined transference of information -- with little overt regard to other aspects. I would agree with Miller that such a bias, although understandable, creates the possibility of our "neglecting important variables in the educational systems we are evaluating because we do not have adequate ways to measure them." [5] I feel it appropriate to reiterate the following caveat of Bruner and Olson. [6]

> The assumption that knowledge was central to the educational enterprise and that it was independent from the form of experience from which it derived and the goals for which it was used has had several important and persisting effects on educational thought. First it has led to a certain blindness to the effects of the medium of instruction as opposed to the content, a blindness which McLuhan has alerted us to, and secondly, it has led to an unsatisfactory and restricted conception of ability. As the effects of experience were completely assimilated to the account of the acquisition of knowledge, experience was considered less and less central to the acquisition of ability. Since knowledge was all, ability could be taken for granted -- one had abilities which may be used to acquire knowledge. Abilities were then projected rather directly into the mind in the form of genetic traits (Jensen,) while the culture and experience were both ignored as possible candidates to account for their development. The effects of this strange turn has been to obscure the importance of developing abilities, often thereby making schooling irrelevent.

Of course, technology is but an instrument and in the strict sense of the word is neutral. The final judgement on the effectiveness of various technologies will depend almost entirely on the software, on the programs which they are used to disseminate. With this view, the educational technologies are seen as tools to be used in the educational process much as a textbook -- i.e., that they are not capable in and of themselves of more than imparting information, nor were they ever intended to do more. [7] To the extent that this is true, it is quite sensible that evaluations of technologies deal only with the cognitive, not the affective, component of education.

Nevertheless, it would be hoped that the current trend in some schools of education toward an emphasis on the recipient of education, on learning theories and away from an emphasis on the dispenser of information, on teaching methods will be furthered by the introduction of technology. Certainly the potential for encouraging this shift in emphasis is inherent in much of the recent technology. Especially designed curriculae can place the major burden of the informational, cognitive aspects of education on the technology and free the teacher to improve the affective content of the interaction with and among students.

The point of view adopted here in reviewing the findings to-date of educational effectiveness studies is that it is rational to suppose that telecommunications technology is neutral. The context in which such technology is used will determine the effects of its use in the affective domain. If evaluation of the learned-information capability of various technologies shows differences among them, it is fitting to use them when the ratio of this capability to the corresponding cost if implementation is larger than when conventional methods are employed.

Findings

Now, what have the various studies of and experiments with educational technology shown? The results which seem of most relevance here are that: 1) remote television instruction can teach at least as well as a conventional classroom lecture situation if some form of feedback to the instructor is provided; [8,9,10] 2) instructional radio and radio-vision (aural material supplemented with still pictures provided by one of several means such as facsimile, slow-scan TV, pre-distributed handouts, predistributed film strips, etc.) can be , in some instances as effective in teaching as television (sometimes it can be even more effective); 3) a balanced approach to using the technology will produce the most learning. That is, in general, "use the simplest, barest, clearest, and least distracting presentation possible." This result, coupled with the previous one, indicates that television as presently used may be optimal only a small percentage of the time; 4) "considering 'dollars alone' and 'measurable results' no one knows whether instructional technology is worth the cost." [11,12] (It is probable that this statement

was focused on the American scene where only a few "experiments" in ETV have sufficient audience to benefit to any extent from economies of scale, since, in the same report, it is noted, with implied enthusiasm, that El Salvador's present systematic approach to improving education never could have been possible without advanced instructional technology.) However, when other effects are included, most practitioners are enthusiastic about the results and the low cost levels being achieved.

A word regarding some experiments that are now in the planning stage may be indicative of the perceived value of one technology in comparison to the others. Of the several being given attention in the current literature, there are none which involve purely radio. All are using television! This may be due, in part, to the recognition that most people, given a choice between radio or television, will choose television. Also, the effectiveness of radio may not be known and the entertainment aspects of television are probably not seen as a possible deterrent to learning. Strong pressure is thus created for "keeping up with the Joneses." ETV is clearly the newer medium and will attract its share of proponents if for no other reason. As Forsythe points out, "If present circumstances were the product of systematic planning and convincing evidence, few would resist them, but that, unfortunately, is not the case. On the contrary, it is more reasonable today than ever before to regard radio as a versatile, a practical, and an effective instructional medium." [13]

The probable outcome of all this is that television will continue to be provided in the educational context not only because there are some applications in which it is more effective than other technologies, but also because of its popular image. (As Skorhia puts it, "It has been generally assumed that communication through more than one sense is better than communication through only one: For example, that television teaches better than radio, sound-film better than silent film, movies better than still pictures, color TV more effectively than monochrome, and so on.") [14] Whether in these applications the added benefits of television exceed its added cost is moot

because we are accustomed to thinking of education in terms of the classroom setting and are trying to duplicate

the classroom at the remote location. As one technologist said, "I consider the optimum system as one that establishes an environment for the off-campus student which, as closely as possible, approximates the situation of the regular full-time student on campus." [15]

In this same light, I believe that the following observations will contribute to a clearer understanding of the relative merits of the technologies.

Other Considerations

Most comparisons of technologies have been based on duplicating a classroom situation and measuring the ability of either radio or television to instruct as well as if students were in the live, traditional setting. I have no quarrel with the findings that radio can, in many of these cases, concentrate the attention of the students to a higher degree and actually produce better retention. These comparisons, however, are structured such that television has been forced into the mold of a more limited medium. In instances, such as "Sesame Street", where the image and motion capabilities of the television have been integrated into the total presentation, results seem to show that television has a clear advantage. (Undoubtedly, the age of the audience is an important variable, as well as the subject matter to be presented.)

In comparing radio and television the statement is often made that television costs five times as much. From this, the conclusion is drawn that unless television is five times better in its ability to instruct, radio is the "best buy" in terms of dollars per unit of retained information. It may still be that radio is more "cost-effective", but the proper comparison must account for the total learning experience and, therefore, the total educational budget, as follows.

Television and radio have been used in conjunction with and largely in support of the total educational infrastructure. The measurements of efficacy using television or radio are, then, measures of the efficacy of the total system (including either radio or television). Suppose that one could (even though one cannot) quantify the output of the total system-with-television and also the output of the total system-with-radio. Let the output of the system-with-television be represented by $O_{tv,s}$, the output of the system-with-radio by $O_{r,s}$, and the output of the system without either radio or television, i.e., with purely tra-

ditional inputs to education, be represented by O_s. If the cost of the systems are then represented, respectively, by $C_{tv,s}$, $C_{r,s}$, and C_s then the correct and fair comparison to determine whether television is worth the extra cost is not whether

$$\frac{O_{tv,s} - O_s}{C_{tv,s} - C_s} \text{ is larger than } \frac{O_{r,s} - O_s}{C_{r,s} - C_s},$$

which is, essentially, a marginal revenue to marginal cost ratio,* but rather is whether

$$\frac{O_{tv,s}}{C_{tv,s}} \text{ is larger than } \frac{O_{r,s}}{C_{r,s}}.$$

An illustration of the above will help convey the meaning. A proposal of the executive secretary of the National Education Association, Sam Lamberg, reported in the Palo Alto Times of May 4, 1972, suggested that a national average cost standard for education (elementary and secondary) of $1200 per pupil per year be established. This would correspond to C_s. Cost figures for one hour of programming per day of "Sesame Street" averaged over the estimated audience of 7 million preschool children came to $0.65 per child for the first year.[16] Part of this cost is undoubtedly due to distribution costs, nevertheless, let us suppose that in addition to these mostly software costs there is a 10% increase in cost to provide the hardware (as if one were required to purchase the television sets and install the means of distributing the program signals)** and that the programming is increased to eight hours a day. The cost per pupil would then be $(1.10)(0.65)(8) = $5.72. Further, assume, very conservatively, that radio would cost only one-tenth as much as television, or $0.57 per pupil per year.

The correct comparison should not be

$$\frac{O_{tv,s} - O_s}{O_{r,s} - O_s} \overset{?}{>} \frac{10}{1},$$

---

* An individual firm in a purely competitive market will not produce at a level of output such that the ratio of marginal revenue to marginal cost is a maximum. It will maximize instead, the ratio of total revenue to total cost. This principle, I believe, applies in the present case of comparing the desirability of using one technology in preference to another.

** The Brazilian education project involving a satellite estimates that their hardware costs are less than 10% of the total cost of the experiment.[17]

but rather should be

$$\frac{O_{tv,s}}{O_{r,s}} \overset{?}{>} \frac{\$1200.00 + \$5.72}{\$1200.00 + \$0.57} .$$

It is easily seen that very different results may come from the two comparisons. In the first case, it is likely that radio would be used in the majority of cases. In the second comparions, television would be able to prove in, and rightly so, for only small increases in total output over the system with radio. Also, a nation's total budget for education becomes a direct factor in determining which technology to use, as well it should.

Application

In the light of these findings and discussion the design and analysis of alternative national telecommunications systems should proceed on the basis that they will re required to carry several channels of television. Full-action television, at least so far, is the largest single bandwidth item to be encountered for transmission over the system. Any other educational technology may, therefore, be accommodated once bandwidths sufficient for television have been reserved.

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Section B

SATELLITE SYSTEM OPTIMIZATIO

The potential applications of telecommunications technology are limited only by man's ingenuity. The telecommunications satellite holds great promise of permitting this technology to reach into even the most remote parts of a country. For sufficiently large scale applications it is the least-cost method for high penetration.[1,2]

The task is to be able to determine the least-cost satellite system for particular applications. The development of an appropriate model is well underway.

The Long Range Goal

The final model of the essential parts of a national joint telephony/ educational technology satellity system, as now perceived, will be able to answer the following questions:

1. At a given point in time, characterized by a) the number of cities, towns and villages to be served by the system, and b) the demand for service (the number of channels into and out of each city, town or village), what is the least-cost combination of satellite power and earth station sensitivities and powers that will provide the service?
2. Taking into account economies of scale in the purchase of components, what is the least-cost schedule for increasing the capacity of the earth stations as the demand at their locations increases?
3. As the demand between any two cities increases, for what combinations, in terms of the number of channels and the separation distance between the cities, may it become less expensive to serve the communications needs by terrestrial facilities rather than by satellite (this will be a function of the satellite fill as well as of component costs)?
4. In the long-run, what is the proper role of the telecommunications satellite in serving the demand for communications? Will it eventually serve as the link among only light traffic centers or can it be cost-effective in serving overflow traffic between large traffic centers?

The answers to all these questions together constitute the necessary information with which to determine the long range implementation of national telecommunications facilities to serve given projected needs.

Present Model Capability

The model in its present form is a first step toward the realization of the final model. It has been devised primarily with the educational part of the system in mind. The implementation of the model as a computer program enables a least-cost system to be determined that will provide television program reception at any number of small "slave" stations (earth stations) as broadcast from a few "master" origination stations and separate voice or digital communication from the slave stations to the master stations. (At present the program will not accommodate different sizes of slave stations, nor communications among slave stations. When these rather significant additions are made, the answer to question one will have been given.)

Within the model, the cost of the satellite is entered as a charge per watt of satellite power used. This approach permits the selection of the satellite as a separate component of the model. During this selection the costs and capacities of the various satellites that have been described in the domestic satellite filings before the FCC were compared (although the methodology is completely general and can be used with any set of satellites) under several plausible demand conditions to determine the satellite (including replacements, spares and increases in number as demand grows) with the smallest cost per watt of power.

A typical output of this present model is shown in Figure 1, where

$$C_{lds}(c,N) = C_s(c,N) + C_b(c,N) + NC_e(c,N)$$

and

$C_{lds}(c,N)$ is the cost of the total satellite system

c is the number of video channels carried by the satellite

N is the minimum number of video-receive earth stations in the system

$C_s(c,N)$ is the cost of that part of the space segment (i.e., the satellite power) actually used by the educational system

Satellite System Cost Parameters with $C_{w/y}$ = \$15,000 and c = 4

N	$C_e(c, N)$	$C_b(c, N)$	$C_s(c, N)$	$C_{lds}(c, N)$
100	13, 277	190, 453	1, 719, 027	3, 237, 180
250	11, 404	244, 954	1, 969, 774	5, 065, 735
500	9, 437	263, 594	2, 626, 464	7, 608, 640
1, 000	8, 115	295, 771	3, 515, 082	11, 925, 760
2, 500	6, 999	427, 823	5, 101, 800	23, 027, 488
5, 000	6, 459	520, 435	6, 886, 546	39, 700, 528
10, 000	6, 085	697, 998	9, 391, 256	70, 938, 144

Satellite System Cost Parameters with $C_{w/y}$ = \$30,000 and c = 4

N	$C_e(c, N)$	$C_b(c, N)$	$C_s(c, N)$	$C_{lds}(c, N)$
100	21, 118	244, 623	2, 025, 320	4, 318, 709
250	12, 392	264, 884	3, 407, 118	6, 770, 074
500	11, 101	293, 152	3, 828, 800	9, 672, 456
1, 000	9, 218	400, 766	5, 044, 458	14, 663, 023
2, 500	7, 638	492, 540	7, 430, 076	27, 016, 832
5, 000	6, 881	623, 697	10, 014, 704	45, 045, 536
10, 000	6, 365	860, 615	13, 600, 203	78, 108, 272

Satellite System Cost Parameters with $C_{w/y}$ = \$50,000 and c = 4

N	$C_e(c, N)$	$C_b(c, N)$	$C_s(c, N)$	$C_{lds}(c, N)$
100	34, 185	258, 583	1, 890, 907	5, 568, 063
250	19, 415	287, 412	3, 418, 220	8, 559, 295
500	11, 785	389, 192	5, 663, 671	11, 945, 315
1, 000	10, 338	439, 389	6, 659, 990	17, 437, 072
2, 500	8, 287	564, 274	9, 812, 110	31, 093, 520
5, 000	7, 311	739, 032	13, 221, 370	50, 516, 352
10, 000	6, 649	1, 045, 246	17, 928, 640	85, 466, 640

Figure 1. Representative Output of the Present Model.

$C_b(c,N)$ is the cost of the master station(s)

$C_c(c,N)$ is the cost of a slave station

$C_{w/y}$ is the cost of the use of one watt-year of satellite power

The program minimizes the cost of the overall system. It does not minimize the cost of the earth stations alone. Conceivably, other pricing policies for satellite power could be used that would alter this strategy. The model can easily accommodate these changes by varying the cost per watt of satellite power.

Future Work

As work has progressed toward the final model (one that will include the effect on costs of handling a nation's regular commercial telephone and telegraph traffic over the same satellite system that is used to transmit the educational programming), it has become apparent that before modifications to the present computer program can be made some knowledge must be obtained about the least-cost schedule for increasing the capacity of a given earth station facing a given demand profile (question 2). The following model has been proposed and its feasibility will be investigated within the next two weeks as contacts at Philco-Ford and GTE Lenkurt allow the pertinent cost information to be assembled.

Let $F(n)$ be the cost of an earth station with a capacity of n channels working through a particular satellite (identical earth stations are assumed for transmit and for receive). $F(n)$ will be a function of N because of economies of scale. Let $f(n,n_i)$ be the cost of upgrading the earth station's capacity from n channels to $n + n_i$ channels. Assume a linear increase in demand for channels through the earth station such that $n_e(t) = a + bt$ where t is the number of years since time zero, a is the demand at time zero, and b is the number of channels per year increase in demand. Suppose that when $t = T$ the end of the planning period will have arrived.

The present worth of the costs of meeting the increasing demand out to time $t = T$ is:

$$PWC(k') = F(a + n_i) + \sum_{k=1}^{k' = \frac{Th - n_i}{n_i}} pwf'(i', kn_i/b) \times f(a + kn_i, n_i)$$

Because $F(n)$ and $f(n,n_i)$ are not susceptible to mathematical expression (they are not continuous functions, and they depend on N and on the charge per watt of satellite power, $C_{w/y}$) it is not possible to find the minimum of $FWC(k')$ by differentiation. It will be necessary to proceed by direct evaluation for several values of k' with each set of values for a,b, and i%. The probable outcome will be as shown in Figure 2.

The parameter k' is the number of times during the planning period of length T that the station will undergo upgrading, if there were only one size station in the system. With more than one size the effect of economies of scale must be included. All the stations' schedules will interact to produce the overall schedule. As an example, Brazil has about 4,700 towns and villages of less than 2,000 population and 1,000 towns of between 2,000 and 5,000 population. Suppose that there and N_1 towns and villages that will require n_1 channels at first ($a_1 = n_1$) and N_2 towns that will require n_2 channels ($a_2 = n_2$). If $d(N)$ represents the discount factor that accounts for economies of scale, then the cost of meeting the demand for n_1 and for n_2 channels with different equipment is:

$$C_{N_1,N_2} = N_1 d(N_1)F(n_1) + N_2 d(N_2)F(n_2)$$

and the cost of meeting the demand using the larger capacity equipment throughout is:

$$C_{N_1+N_2} = (N_1 + N_2)d(N_1 + N_2)F(n_2).$$

It may be that $C_{N_1+N_2}$ is less than C_{N_1,N_2} in which case, only the larger capacity station would be installed. It may also be that even if $C_{N_1+N_2}$ is larger than C_{N_1,N_2} it would still be more economical to use only the larger capacity station.

Suppose, for instance, that the larger capacity station would at some time be needed at the N_1 locations which have an initial demand for only n_1 channels. Then, if $C_{N_1+N_2}$ is larger than C_{N_1,N_2} but

$$C_{N_1+N_2} < C_{N_1,N_2} + \left\{\min_{k'}\left[FWC(k') - F(n_1)\right]\right\}N_1 d(N_1)$$

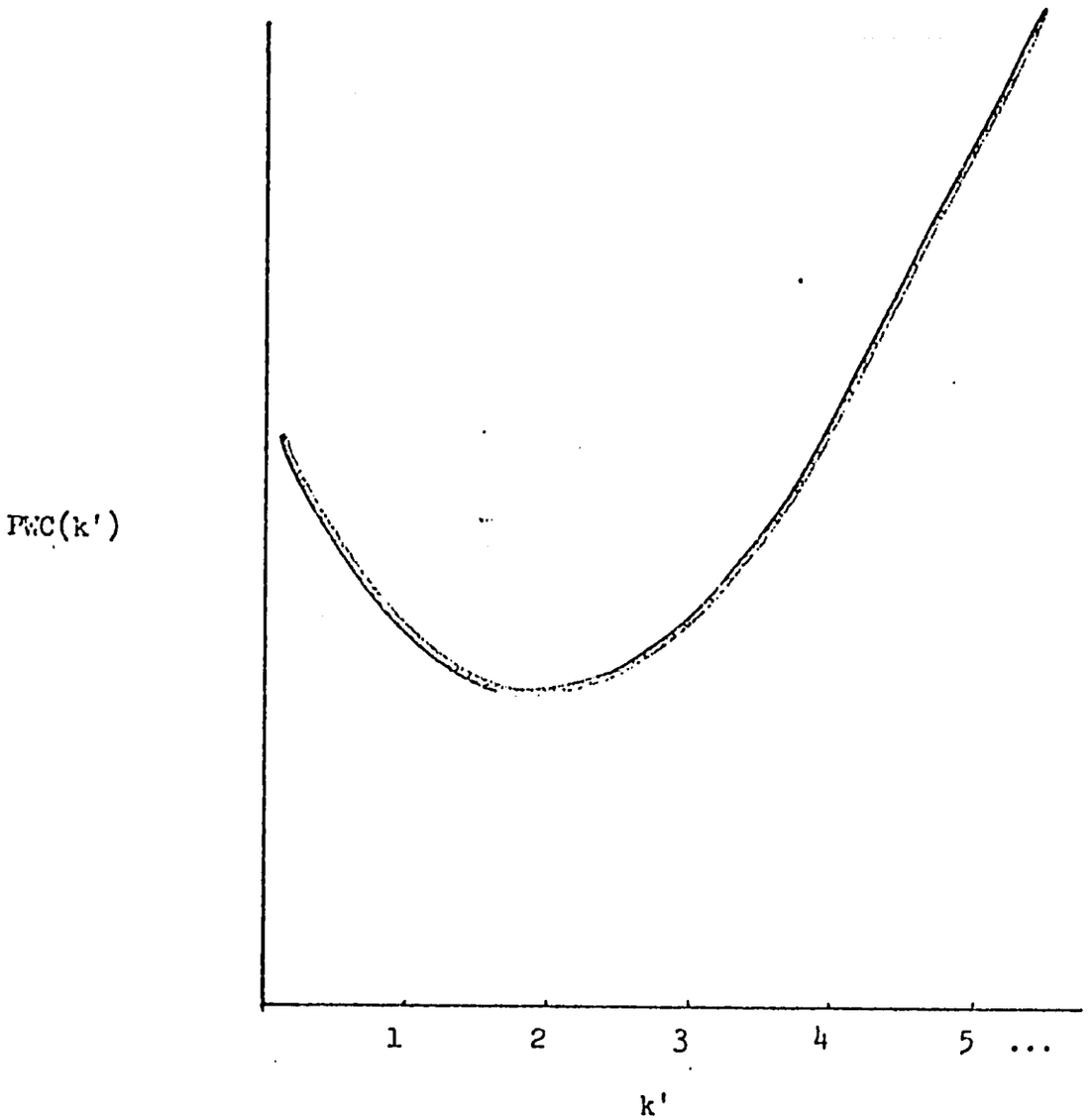

Figure 2. The Present Worth of the Cost of Upgrading the Capacity of an Earth Station over the Planning Period of length T, as a Function of the number of Upgradings.

or

$$C_{N_1 + N_2} < C_{N_1,N_2} + \min_{k'} \left\{ \sum_{k=1}^{k' = \frac{n_2 - n_1}{n_i}} pwf'(i\%, kn_i/b) \times f(n_1 + kn_i, n_i) \right\} N_1 d(N$$

it would still be less expensive to install only the larger capacity station. In words: economies of scale and station upgrading schedules can be such that it is less expensive to install only one size station than to install two different sizes and later upgrade the smaller size to the same capacity as the larger size.

From considerations such as the above, it will be possible to construct a light-route growth strategy. The objective of this model is to determine the cross-over point (in distance-channel space) for various terrestrial technologies. That is, at any given distance and channel requirement, it is less expensive to serve the link using the satellite (and if so, what size earth station is required for this link as well as to serve the other satellite-linked cities) or should terrestrial facilities be used, and which one (open wire, cable pairs, microwave, coaxial cable, etc.). Combining this type of information from all routes will be a necessary step in determining the total requirements on satellite capability and thus help to determine which satellite is used.

This is an iterative process since the cross-over points will be determined by the optimum size stations and the optimum schedule for station upgradings. These will be determined by the number of stations and the required initial capacity of the stations and the cost per watt of satellite power, which, in turn will depend on the optimum size of the stations and the optimum schedule for upgradings. It will be necessary to make initial estiamtes for some paramcters, run through all the programs of the total model and then adjust the initial estimates to more nearly match the final outcome on succeeding runs.

References

1. ASCEND (Advanced System for Communications and Education in National Development), Stanford University School of Engineering Report, June 1967.

2. Teleconferencing: Cost Optimization of Satellite and Ground Systems for Continuing Professional Education and Medical Services, Stanford University Institute for Public Policy Analysis Report, May 1972.

SECOND PERIOD REPORT TO AED

by Carl Mitchell,

I. Introduction

It has been noted in the literature that a very simple relationship exists between a nation's gross domestic product (GDP) and its telephone density (the number of telephones per 1000 population).[1, 2] It should not be inferred from this that the demand for telephone service can be characterized by the same simple relationship to GDP. Only in the more developed countries is the investment in telephone plant sufficient to produce a demand-limited market. The budget constraints of less developed countries (LDC's) produce a very definitely supply-limited market. That is, at current prices for services, there is more demand than there is facility to satisfy the demand.[3] Especially in such a supply-limited situation, there is impetus to determine the least-cost method of providing service, since the target for the communications entities of these LDC's is a development plan to upgrade the present telecommunications system to make it compatible with the socioeconomic level of the country, and to do so within the telecommunications budget.

We feel that the telecommunications satellite can significantly reduce the costs of service to dispersed populations or subscribers (e.g., interconnection of CATV companies) while maintaining the same standard of performance as obtained with terrestrial systems. In fact, we believe that the satellite makes economically feasible some services that otherwise could not be supported by LDC's, and that further experience with telecommunications via satellite will improve its economic advantage for these services. *

This advantage, however, may not be realizable unless the large cost of the satellite, and, to a much lesser extent, the costs of the earth stations, are shared in a multipurpose venture. Such a venture is, of course, entirely possible from a technical standpoint, since a satellite can simultaneously receive and retransmit several dissimilar signals (be they telephone, telegraph, television, analog or digital). We, therefore, strongly recommend that coordinated inter-

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* An indication of the continuing trend to lower costs for satellite services is the dramatic reduction in space-segment per-year costs of a telephone circuit. Using figures generally available, the graph in Fig. 1 was plotted. (see also reference 4) (It should be emphasized that these costs do not include the ground segment of the system. They are shown only to draw attention to the declining costs currently being experienced in satellite technology.)

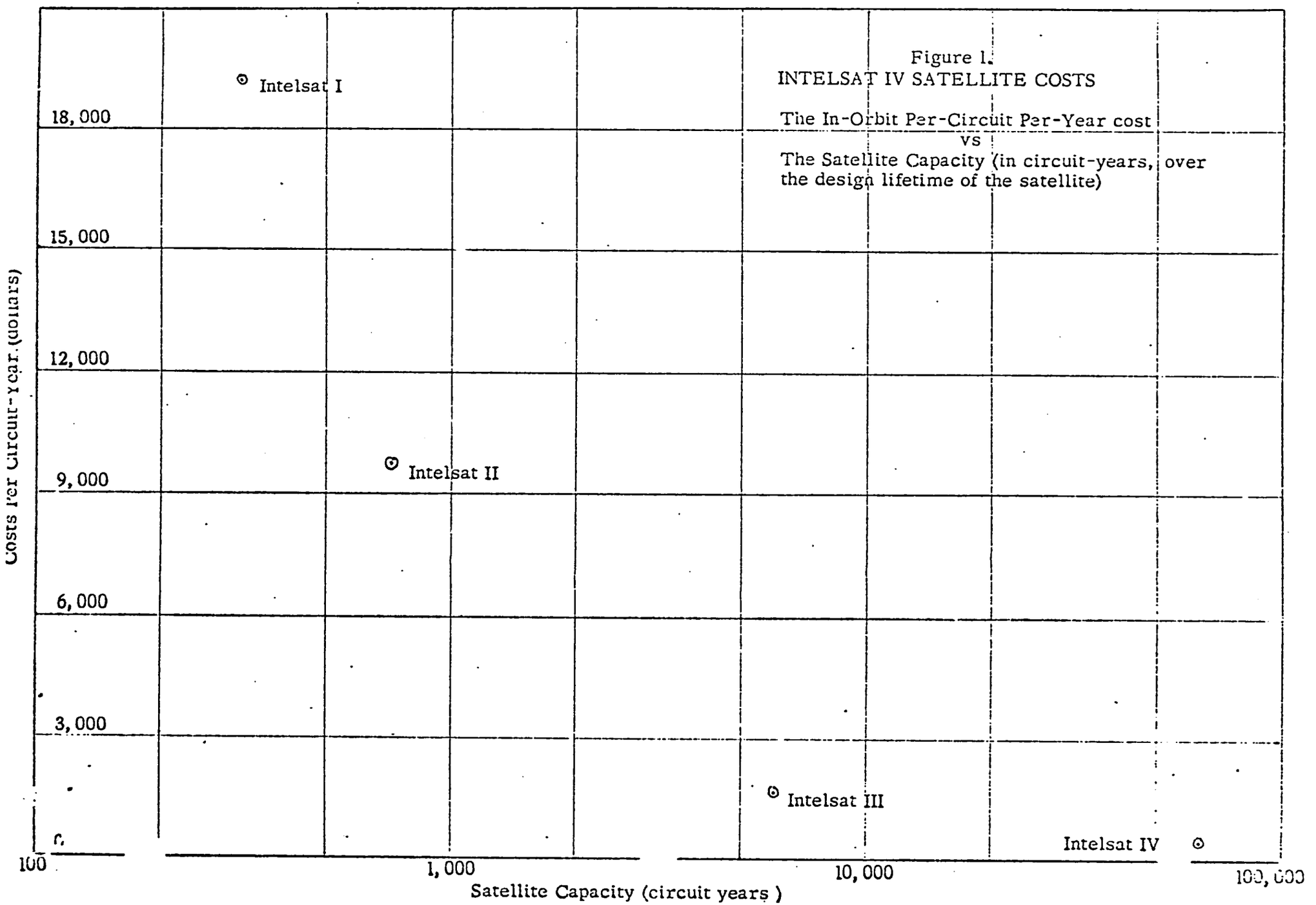


Figure 1.
INTELSAT IV SATELLITE COSTS

The In-Orbit Per-Circuit Per-Year cost
vs
The Satellite Capacity (in circuit-years, over the design lifetime of the satellite)

agency planning be encouraged where a national satellite is being considered.

A prime candidate, in addition to commercial telephony, for a share in a multipurpose system is educational programming. It has received widespread attention over the past few years,[6] especially in LDC applications. In part, this is because of its potential for reducing costs. Traditional approaches to education have always been labor intensive. In fact, it is largely for this reason that the present cost squeeze in education has become so accute. Other "industries" have benefitted from technological innovations and improvements to increase the productivity of their employees. This increase in efficiency permitted higher wages. Although no corresponding increase in efficiency occurred in education, teachers and administrators participated in the upward wage trends. As Baumol states, "...(this) suggests that, as productivity in the remainder of the economy continues to increase, costs of running the educational organizations will mount correspondingly, so that whatever the magnitude of the funds they need today we can be reasonably certain that they will require more tomorrow, and even more on the day after that."[5]

Reducing the labor-intensive nature of the educational enterprise can, of course, help to open the way for technologically motivated reductions in cost. With low-cost earth stations, the distribution of educational materials via television, with or without a voice talk-back capability, becomes a very attractive alternative to the slow and costly process of specialized training of teachers and the subsequent continual problem of motivating teachers to work in rural areas. Due care must be exercised so that the affective component of education does not suffer as the instructional component is being helped with remote programming expertise.

This report will present results of our work and give several examples of the capability of programs developed here at Stanford to determine the least-cost system suitable for educational television program distribution with audio feedback. It will also outline the work in progress toward a model to determine a least-cost configuration of a multipurpose system to provide both television distribution (commercial or educational or both) and regular telephone service.

II. Least-Cost TV/Return Audio System

A. Terrestrial Systems

An investigation of terrestrial technologies revealed that only coaxial cable and microwave radio facilities have sufficient bandwidth to carry television programming. Except for relatively short distances, microwave radio is the less expensive of the two. A typical radio link consists of the transmit terminal, several repeaters and the destination terminal. These are shown schematically in Fig. 2. The average distance between repeaters (called the hop distance) is 30 miles.

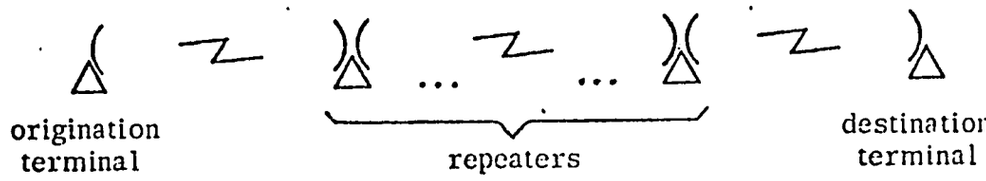


Figure 2. A Microwave Radio Relay Link

Each origin and destination terminal requires the following equipment:

transmitter or receiver (per TV channel)	$4,500
antenna and feed	1,900
standby batteries and charger - first channel	1,600
each add'l channel	200
tower (150', guyed)	6,000
installation and alignment - first channel	1,000
each add'l channel	500
voice feedback equipment	
transmitter or receiver	4,500
antenna and feed	1,900
batteries and charger	200
multiplex equipment - heavy route, per channel (voice)	2,000
light route, per channel (voice)	1,000
installation and alignment - first channel (voice)	900
each add'l channel (voice)	200

These costs can be represented in equation form by

$$C_{mt}(c) = \$24,500 + \$7,400(c - 1) \quad \text{for heavy routes (voice)}$$

$$C_{mt}(c) = \$23,500 + \$6,400(c - 1) \quad \text{for light routes (voice)}$$

where $C_{mt}(c)$ is the cost of microwave terminal-station equipment and c is the number of television channels being distributed.

Each repeater station requires the following equipment:

transmitter and receiver (per TV channel)	$7,000
antennas and feed	3,800
standby batteries and charger - first channel	2,000
each add'l channe	200
tower (150', guyed)	6,000
installation and alignment - first channel	1,300
each add'l channel	500
voice feedback equipment	
transmitter and receiver	7,000
antennas and feed	3,800
batteries and charger	200
installation and alignment	1,100

or, in equation form,

$$C_{mr}(c) = \$32,200 + \$7,700(c - 1)$$

An important simplification was made at this point. A microwave terminal station (no retransmission of the video signal is required) would only be used in the distribution network at the ends of branches where a final destination has been reached and the particular city in question is not serving, simultaneously, as a repeater link for other cities. Nevertheless, each terminal station will have its video transmit counterpart somewhere upstream towards the origination station. This is significant in that it allows the costs of the microwave system to be modeled (on the low side) as the total number of stations used, whether terminal or repeater, times the cost of a repeater station: or, in equation form,

$$C_{ms}(c, N) = (1 + \eta(N))NC_{mr}(c)$$

where $C_{ms}(c, N)$ is the cost of the microwave system

N is the number of cities being served by the system,

c is the number of TV channels being distributed.

$\eta(N)$ is the ratio of the number of microwave repeater stations between cities to the number of cities connected by the network.

To make the cost-components of a repeater station comparable to those included later on for satellite earth stations, the equipment costs of a repeater station were modified to reflect the costs of land (land, grading, roads, and tower foundation) and maintenance. Maintenance was assumed to be 15 per cent of first cost (an average figure used by Pacific Telephone and Telegraph Co.) over a 25-year period (PTT uses 15.99 years), and land costs were assumed to be $8,000 (this allows for the fact that not all sites will require land or towers).

The other costs incident to the design and implementation of the system (such as transportation, documentation, spare parts, engineering, commercial power connection, etc.) were broadly assumed to be common to any other telecommunications system being considered, and were not, therefore, explicitly included. (Another reason is that one comparison of the cost of a microwave system to the cost of a satellite system was done on the supposition favorable to the microwave system that no intermediate repeater stations would be required, i.e., $\eta(N) = 0$. Thus each station would be located at or near a city to be served, similar to the placement of satellite earth stations if a satellite system were used, and support costs for either type of installation would be fairly comparable.)

The addition of these costs to $C_{mr}(c)$ gives:

$$C_{mr}(c) = \$72,600 + \$17,500(c - 1)$$

and

$$C_{ms}(c, N) = (1 + \eta(N))N(\$72,600 + \$17,500(c - 1))$$

The values of N and c are known in any given situation. $\eta(N)$, on the other hand, can be known accurately only after a preliminary route survey with topographic maps and path profiles has been completed. It was sufficient for our purposes, however, to derive a rough estimate of the functional dependence of η on N. A uniform distribution of cities throughout the entire area to be served was assumed. Although not a very likely distribution for an actual system, it might be argued that the number of repeaters required to serve such a distribution could be considered as an upper bound since any departure from uniformity would allow advantage to be taken of the clustering that would appear. It was further assumed that the origination station was located at one of the N cities to be served. The straight-forward derivation of $\eta(N)$ is as follows.

Consider a region of rectangular shape L miles long by W miles wide. For a uniform distribution, each city will be at the center of a smaller rectangle that is $L/N^{1/2}$ miles long by $W/N^{1/2}$ miles wide (see Fig. 3). The intercity separation distance is thus either $L/N^{1/2}$ miles (long link) or $W/N^{1/2}$ miles (short link) depending on whether the direction of travel is parallel to the length or to the width of the rectangle. If, insofar as possible, cities are connected to their neighbors using short links fewer intercity repeaters will be required than with any other link patter. With this pattern, the network will consist of $(N^{1/2} - 1)N^{1/2}$ short links and $(N^{1/2} - 1)$ long links.

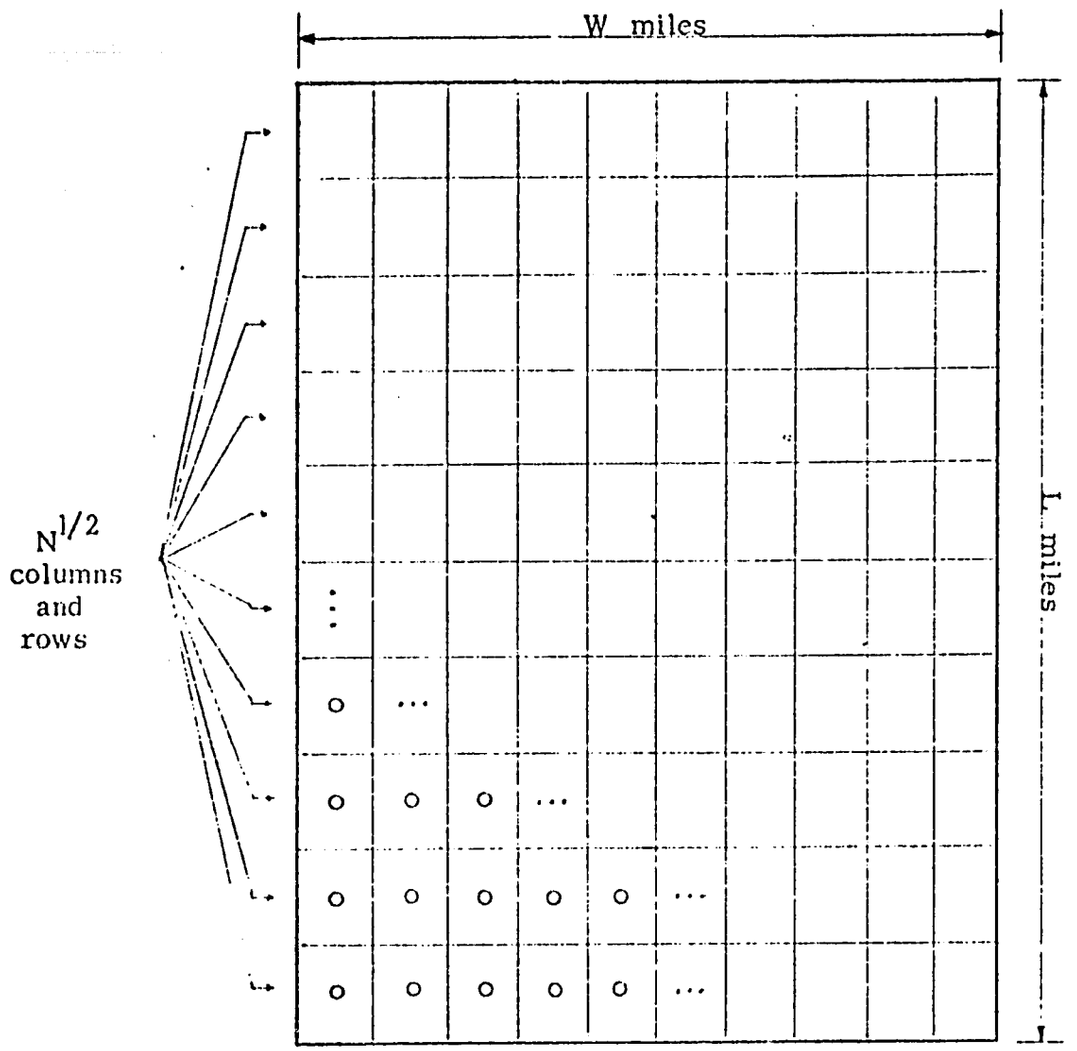


Figure 3. A Rectangular Educational Satellite Region Containing N Uniformly Distributed Cities.

In calculating the total number of intercity repeaters implied by this pattern, we let h represent the average inter-repeater (hop) distance and D represent the distance between cities, or the link length. Because h is the average hop distance and not the maximum, and because of the large numbers of equal length links involved, a reasonable approximation for the average number of repeaters per intercity link as a function of link length is taken to be $n = (D/h - 1)$. This number will generally not be an integer.

An equation for the total number of intercity repeaters, $N\eta$, may now be written.

$$N\eta = N^{1/2}(N^{1/2} - 1) \times \text{(the average number of repeaters in a short link)}$$
$$+ (N^{1/2} - 1) \times \text{(the average number of repeaters in a long link)}$$

$$= N^{1/2}(N^{1/2} - 1)(W/hN^{1/2} - 1) + (N^{1/2} - 1)(L/hN^{1/2} - 1)$$

or

$$\eta = (N^{1/2} - 1)(W/h - N^{1/2})/N + (N^{1/2} - 1)(L/hN^{1/2} - 1)/N$$

For very large N, this equation would yield a negative value for η. To prevent this, η was defined as the larger of the value given by the above equation and zero. For L = 1,500 miles, W = 1,000 miles (corresponding roughly to the size of the Rocky Mountain region), and h = 30 miles, Table 1 gives some representative values of N and the corresponding η.

TABLE 1

$\eta(N)$ for representative values of N

N	η
100	2.46
250	1.16
500	.52
1,000	.07
1,140	.00
10,000	.00

B. Satellite System

A satellite long-distance transmission system consists of the following components: 1) a video-transmit, audio-receive up-link earth station at each television origination point; 2) a satellite; and 3) a video-receive, audio-transmit earth station at each local receive point. (The number of local receive points will generally be greater than the number of cities being served. In any event, it cannot be less.)

Two types of video-receive earth stations might be distinguished according to their received output signal-to-noise ratio. Earth stations that feed local distribution subsystems would need a higher output ratio than would earth stations that serve isolated subscribers (no further distribution is necessary). For simplicity, our analysis assumed that all earth stations provide the same higher quality signal as that required for redistribution. A slight cost savings could be realized in any actual implementation by limiting use of the higher quality station to receiving points that actually require the higher quality signal.

The cost of the satellite distribution system may be expressed as:

$$C_{ss}(c, N) = C_s(c, N) + C_b(c, N) + NC_e(c, N)$$

where

$C_{ss}(c, N)$ is the cost of the satellite system (in $)

c is again, the number of video channels carried by the satellite

N is the minimum number of video-receive earth stations in the network

$C_s(c, N)$ is the cost of that part of the space segment of the system actually used by the educational system (here is an implicit assumption of a multipurpose system and the consequent cost saving through sharing) (in $)

$C_b(c, N)$ is the cost of the master video-transmit, audio-receive station(s) (in $)

$C_e(c, N)$ is the cost of a video-receive, audio-transmit earth station (in $)

The earth station costs include the following:

1) equipment costs

2) site costs (assumed to be 40 per cent of the antenna costs)

3) installation costs (assumed to be 10 per cent of the equipment costs)

4) the present worth of maintenance costs over an assumed 25-year lifetime using a discount rate of 10 per cent. Annual maintenance costs are assumed to be 15 per cent of equipment costs.

5) the cost of channel separation and demodulation to baseband for each video channel received. On a per-channel basis, this cost has been estimated to be near $1,200, as follows. A lower bound may be established by looking at the function and cost of an ITFS (instructional television fixed service) down converter. The down converter, used with an ITFS receive-station, does no more than shift the frequency of the incoming rf signal down to the proper TV carrier frequency, using a double conversion process, and then amplifies the result. The cost of the down converter is $800. Demodulation is not included (it, of course, is not necessary in ITFS transmissions). An upper bound may be taken to be $1,500. This is the cost of the equipment needed at a cable headend site to prepare a TV signal, received from a microwave link, for transmission on the cable. This $1,500 does not include demodulation either, but does include AM modulation, frequency translation to the proper cable channel, and power amplification. Insofar as demodulation can be considered to require equipment of lower cost than does modulation, the compromise figure of $1,200 is reasonable.

The computer program developed here at Stanford uses extensive cost information that we gathered on earth station components together with a value for the cost per-watt per-year of satellite rf power to calculate earth station costs and configurations for the criterion of minimum overall satellite system cost. Thus, if the cost per watt-of-space-segment-use increases, minimizing total system cost would require that the earth stations be made more sensitive, and consequently, more costly so that less satellite power need be used. Similarly, if only a few earth stations are to be constructed, their unit cost should be much higher than if many are needed.

The range of per-watt space-segment charges that is used in the following printouts is based on matching in-orbit satellite capacity with various assumed demand curves over time for that capacity. The present worths of the costs that would be incurred in providing sufficient satellite capacity to just meet these demands are calculated using the costs of currently proposed satellites. Then the amount that must be charged for a watt-year of satellite capacity is determined such that the present worths of the revenue streams associated with each demand curve are equal to the present worths of the costs, respectively, of satisfying the demand. The range of charges runs from $C_{w/y}$ = $15,000 per watt-year to

$C_{w/y}$ = \$50,000 per watt-year. $C_{w/y}$ is the cost to the education system of one watt of satellite rf power for one year.

The costs shown in Tables 2 through 7 are representative of those obtaining for a country whose area may be covered by a satellite antenna of 10' equivalent diameter and for which the slant range to the satellite at the furthest 3-dB beam edge is comparable to any location in Northern Montana.

C. Cost Comparison

The cost comparison between the satellite system and the terrestrial system as portrayed above is shown in Figures 4 and 5. It is based on the equations for C_{ms} and C_{ss} developed in the last two sections. Figure 4 gives the costs for systems that carry four video channels and Figure 5 presents the costs for 12-channel systems. Each figure also includes a plot of what the microwave network would cost if $\eta(N) = 0$. This approximates the case where the cities involved are not spread throughout an entire region but are, in fact, so situated that very few intercity repeaters would be needed.

It may be seen that for any regional network serving even as few as 100 cities the satellite system is dramatically less expensive than the terrestrial system. In fact, providing 12 channels via the satellite is less costly than providing 4 channels with the microwave network, even though to provide 12 channels through the satellite involves stacking the TV channels so close together in frequency that adjacent channels must be transmitted on carriers that are cross-polarized with respect to each other (permitting some overlapping occupancy of the available frequency spectrum) and the earth stations must be equipped with two antennas and two preamplifiers.

In view of this cost dependency on the number of cities involved, one is led to ask now many cities might require service in a typical regional system. An example of a region that might actually be served by such an education system is the Rocky Mountain region. In the eight states of this region there are 1168 cities. There are 361 cities of greater than 2,000 population and 100 cities of greater than 10,000 population. An education system transmitting to this area would be of most use in the smaller cities where large or specialized curriculum aids are not readily available. Thus, most of the 361 cities of greater than 2,000 population would probably wish service. This is an obvious case, then, of where the satellite system would be less expensive.

TABLE

Satellite System Cost Parameters with $C_{w/y}$ = \$15,000 and c = 4

N	$C_e(c, N)$	$C_b(c, N)$	$C_s(c, N)$	$C_{lds}(c, N)$
100	13,277	190,453	1,719,027	3,237,180
250	11,404	244,954	1,969,774	5,065,735
500	9,437	263,594	2,626,464	7,608,640
1,000	8,115	295,771	3,515,082	11,925,763
2,500	6,999	427,823	5,101,800	23,027,488
5,000	6,459	520,435	6,886,546	39,700,528
10,000	6,085	697,998	9,391,256	70,938,144

TABLE 3

Satellite System Cost Parameters with $C_{w/y}$ = \$30,000 and c = 4

N	$C_e(c, N)$	$C_b(c, N)$	$C_s(c, N)$	$C_{lds}(c, N)$
100	21,118	244,623	2,025,320	4,318,709
250	12,392	264,884	3,407,118	6,770,074
500	11,101	293,152	3,828,800	9,672,456
1,000	9,218	400,766	5,044,458	14,663,023
2,500	7,638	492,540	7,430,076	27,016,832
5,000	6,881	623,697	10,014,704	45,045,536
10,000	6,365	860,615	13,600,203	78,108,272

TABLE 4

Satellite System Cost Parameters with $C_{w/y}$ = \$50,000 and c = 4

N	$C_e(c, N)$	$C_b(c, N)$	$C_s(c, N)$	$C_{lds}(c, N)$
100	34,185	258,583	1,890,907	5,568,063
250	19,415	287,412	3,418,220	8,559,295
500	11,785	389,192	5,663,671	11,945,315
1,000	10,338	439,389	6,659,990	17,437,072
2,500	8,287	564,274	9,812,110	31,093,520
5,000	7,311	739,032	13,221,370	50,516,352
10,000	6,649	1,045,246	17,928,640	85,466,640

TABLE 5

Satellite System Cost Parameters with $C_{w/y}$ = \$15,000 and c = 12

N	$C_e(c, N)$	$C_b(c, N)$	$C_s(c, N)$	$C_{lds}(c, N)$
100	44, 205	328, 056	3, 083, 475	7, 832, 028
250	28, 173	3541861	5, 168, 194	12, 566, 348
500	24, 865	457, 012	6, 227, 586	19, 117, 216
1, 000	21, 722	506, 487	8, 287, 900	30, 516, 720
2, 500	19, 078	739, 824	12, 093, 080	60, 527, 104
5, 000	17, 832	919, 098	16, 257, 658	106, 335, 184
10, 000	16, 980	1, 248, 249	22, 008, 800	193, 059, 920

TABLE 6

Satellite System Cost Parameters with $C_{w/y}$ = \$30,000 and c = 12

N	$C_e(c, N)$	$C_b(c, N)$	$C_s(c, N)$	$C_{lds}(c, N)$
100	68, 250	354, 861	3, 418, 916	10, 598, 739
250	41, 094	460, 870	6, 113, 468	16, 847, 920
500	27, 071	614, 462	10, 116, 378	24, 266, 496
1, 000	24, 318	689, 948	11, 992, 616	37, 000, 112
2, 500	20, 606	877, 653	17, 622, 336	70, 051, 760
5, 000	18, 844	1, 140, 515	23, 679, 872	119, 038, 928
10, 000	17, 650	1, 601, 609	31, 992, 640	210, 097, 520

TABLE 7

Satellite System Cost Parameters with $C_{w/y}$ = \$50,000 and c = 12

N	$C_e(c, N)$	$C_b(c, N)$	$C_s(c, N)$	$C_{lds}(c, N)$
100	81, 443	450, 293	5, 082, 237	13, 676, 797
250	41, 094	606, 186	9, 968, 821	20, 848, 576
500	38, 959	669, 417	10, 121, 574	30, 270, 368
1, 000	26, 058	773, 462	17, 017, 984	43, 849, 040
2, 500	22, 161	1, 030, 177	23, 275, 408	79, 706, 912
5, 000	19, 873	1, 386, 146	31, 278, 336	132, 027, 904
10, 000	18, 332	1, 997, 533	42, 237, 200	227, 550, 608

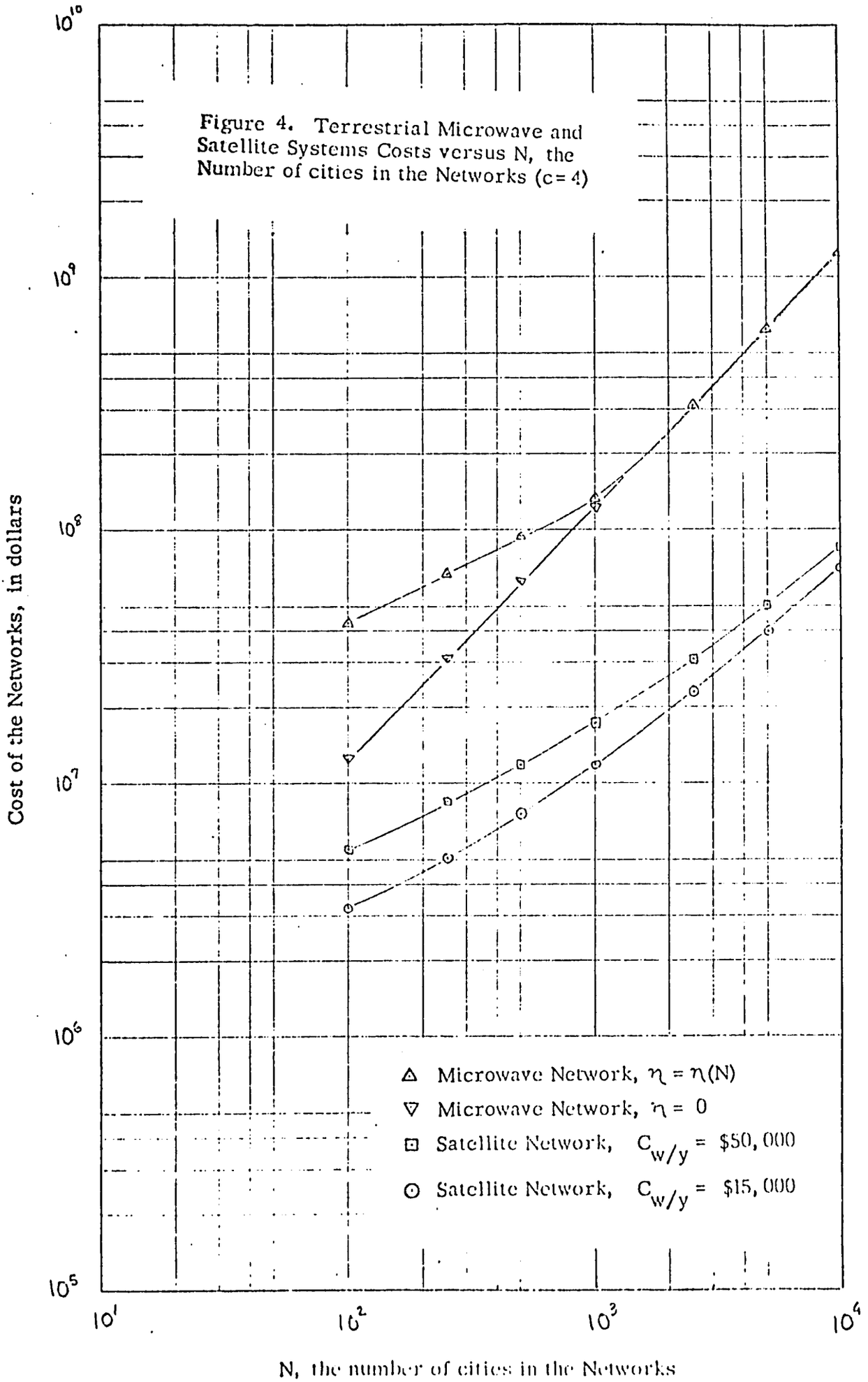


Figure 4. Terrestrial Microwave and Satellite Systems Costs versus N, the Number of cities in the Networks (c = 4)
Cost of the Networks, in dollars
N, the number of cities in the Networks
10^{10}
10^{9}
10^{8}
10^{7}
10^{6}
10^{5}
10^{1}
10^{2}
10^{3}
10^{4}
Microwave Network, $\eta = \eta(N)$
Microwave Network, $\eta = 0$
Satellite Network, $C_{w/y} = \$50,000$
Satellite Network, $C_{w/y} = \$15,000$

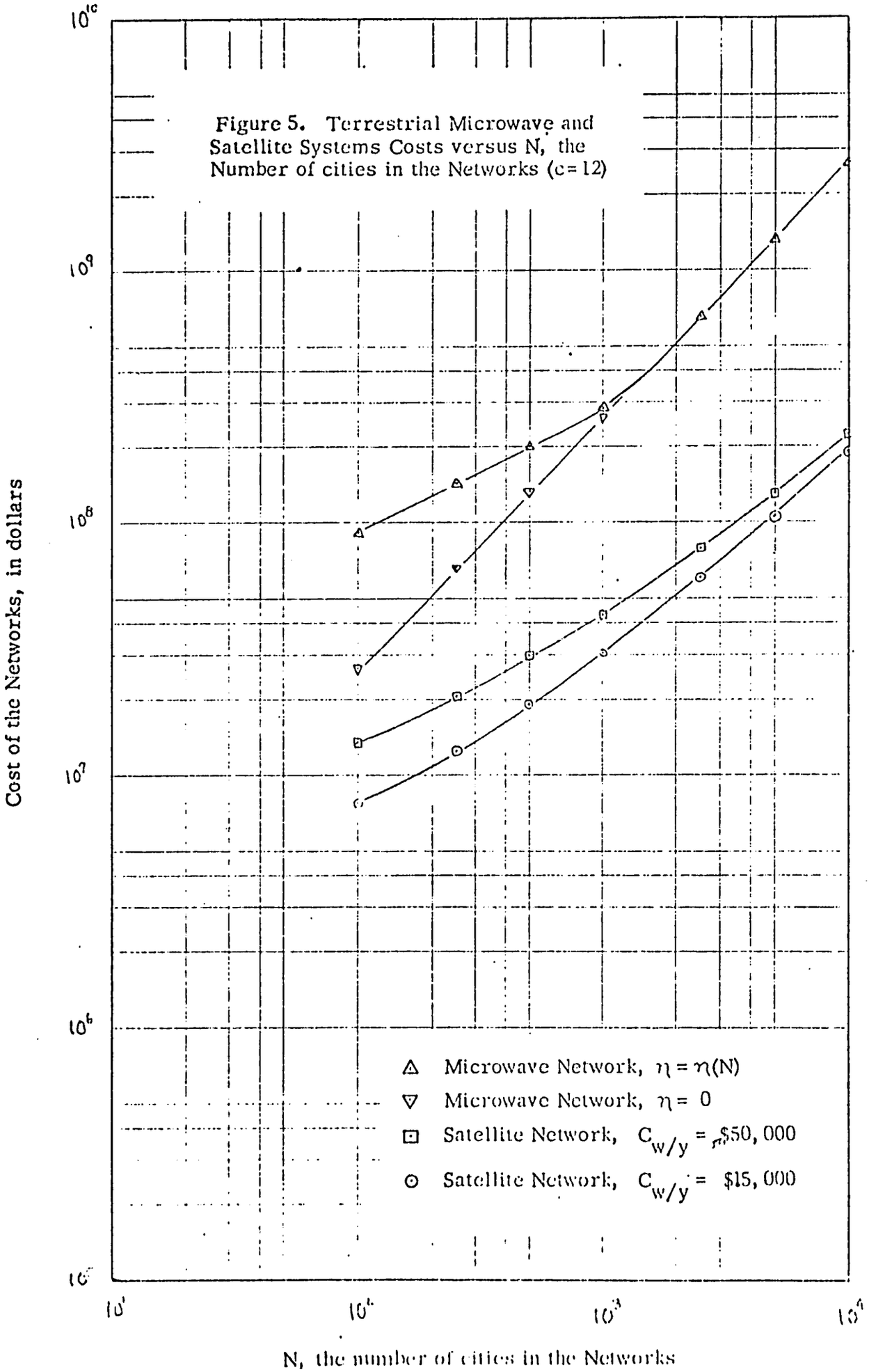


Figure 5. Terrestrial Microwave and Satellite Systems Costs versus N, the Number of cities in the Networks (c = 12)
Cost of the Networks, in dollars
N, the number of cities in the Networks
Microwave Network, η = η(N)
Microwave Network, η = 0
Satellite Network, C_w/y = $50,000
Satellite Network, C_w/y = $15,000

III. Examples of Program Capability

Since the printouts of satellite system costs given in section II-B were obtained some modifications of the program have been made -- mostly format, although some were substantive. With these modifications in force, representative calculations of the costs of satellite service for four Latin American countries were made. The program accepts as input parameters the values of the variables shown on the printouts under INPUT PARAMETERS, as well as the following variables.

1. The longitude of the country's geographical center
2. The latitude of the country's northernmost boundary
3. The latitude of the country's southernmost boundary
4. The longitude of the westernmost boundary
5. The longitude of the easternmost boundary
6. The latitude for the maximum slant range calculation
7. The longitude for the maximum slant range calculation

Two cases were considered for each country (Brazil, Peru, Mexico, and Colombia). First, it was assumed that only one TV origination station would be provided and that it would be at the capital of the country. It would transmit to receive stations located at every city of 2,000 or more inhabitants. Second, it was assumed that there would be a TV origination station at all state capitals and at any large population center (these places are shown on the accompanying maps). With only one TV origination station, the number of channels carried for educational purposes was specified as 4. When more than one TV origination station is permitted, each is assumed to be capable of transmitting two channels to every village (any size) with the satellite carrying a maximum of 12 channels at any one time. The number of villages was determined by looking at either the latest census of population for the given country if available in the Government Documents Section of the Stanford Library, or in the 1966 edition of the Hammond World Atlas if no census was available.

Brazil

case 1. Brazil"s 1960 census of population lists 1,797 cities, towns, above 2,000 population. We used 1,800.

case 2. Brazil's 1960 census of population lists 6,535 cities, towns, and villages (total). There are 28 cities on the accompanying map that were used as origination stations, and the number of receive stations will be rounded to 6,500. (By way of contrast, the Hammond World Atlas lists only some 746 cities, towns, and villages with only three of these having populations lower than 1,000)

Peru

case 2. Peru's Anuario Estadistico Del Peru, 1966 shows 24,908 places of greater than 50 inhabitants. However, only 7,969 of these have more than 200 inhabitants. We used the figure of 7,950 in the program. (Hammond lists only 363 for the total number of towns and villages and cities) The number of origination stations is equal to 12.

case 1. Peru's Anuario Estadistico Del Peru, 1966 lists 355 cities and towns larger than 2,000 population. (Hammond lists only 148)

Mexico

case 1. The Anuario Estadistico de los Estados Unidos Mexicanos, 1966-1967 has nine categories of localities: ciudades, villas, pueblos, congregaciones, haciendas y fincas, ejidos, ranchos, rancherias, and otras. In running this program the arbitrary choice was made to assume that the first three categories include all cities and towns larger than 2,000 population. This number is (362 + 528 + 5,189) = 6,079. We used 6,050.

case 2. To the above number was added the number of congregaciones to bring the total to about 11,000. There are 22 cities at which origination stations are situated.

Colombia

case 1. There are 193 cities and towns listed in Hammond as larger than 2,000 population.

case 2. Hammond shows 306 as the total number of cities, towns, and villages. There are 18 sites for origination stations.

BRAZIL
Area: 3,286,170 sq. mi.
Population: 83,900,000 (1966)
Rural 59.7 per cent (1960)
46.0 per cent (1980 projected)
BOA VISTA
MACAPA
BELEM
SAO LUIS
MANAUS
FORTALEZA
SINA
NATAL
JOAO PESSOA
RECIFE
MACEIO
ARACAJU
SALVADOR
CUIABA
BRASILIA
GOIANIA
BELO HORIZONTE
VITORIA
CAMPINAS
SAO PAULO
NITEROI
RIO DE JANEIRO
SANTOS
CURITIBA
FLORIANOPOLIS
PORTE ALEGRE
RIO BRANCO
PORTO VELHO

*** BRAZIL ***

INPUT PARAMETERS

AND AREA	3286170 SQ MI
LATITUDE OF COUNTRY'S GEOGRAPHICAL CENTER	-14" **** DEG
ASSUMED COST OF SATELLITE POWER ($/WATT-YEAR)	$50000.
DISCOUNT FACTOR	10.0%
NO. OF TV-TRANSMIT/AUDIO-RECEIVE (MASTER) STATIONS	1
NO. OF TV-RECEIVE/AUDIO-TRANSMIT (SLAVE) STATIONS	1800
NO. OF TV CHANNELS PER MASTER STATION	4
NO. OF TV CHANNELS PER SLAVE STATION	4
SIGNAL-TO-NOISE RATIO REQUIRED FOR TV	43 DB
SIGNAL-TO-NOISE RATIO REQUIRED FOR AUDIO	43 DB

OUTPUT PARAMETERS

MASTER STATION

ANTENNA:	DIAMETER	49.6 FT	UNIT COST	$ 554768.
RCVR PRE-AMP:	NOISE TEMP	20. DEG K	UNIT COST	$ 60000
TXMTR PWR AMP:	OUTPUT PWR	350.0 W	UNIT COST	$ 17000
INITIAL CAPITAL COST PER STATION				$ 960956
PRESENT WORTH OF TEN-YEAR ANNUAL COST STREAM				$ 2112689

SLAVE STATION

ANTENNA:	DIAMETER	11.8 FT	UNIT COST	$ 6466.
RCVR PRE-AMP:	NOISE TEMP	180. DEG K	UNIT COST	$ 7000
TXMTR PWR AMP	OUTPUT PWR	30.0 W	UNIT COST	$ 6000
INITIAL CAPITAL COST PER STATION				$ 14411
PRESENT WORTH OF TEN-YEAR ANNUAL COST STREAM				$ 25337

SATELLITE

SATELLITE ANTENNA N-S DIAMETER	4.3'	**** FT
SATELLITE ANTENNA E-W DIAMETER	4.2'	-0.0 FT
MAXIMUM SLANT RANGE FOR TRANSMISSION		23081.7 MI
POWER CHARGED PER TV CHANNEL		17.13 W
POWER CHARGED PER AUDIO CHANNEL		0.0124572 W
TOTAL COST PER YEAR OF SATELLITE POWER		$ 3519270
PRESENT WORTH OF TEN-YEAR ANNUAL COST STREAM		$ 21622384

TOTAL INITIAL CAPITAL COST (NOT INCLUDING SATELLITE COSTS)	$ 18280752.
PRESENT WORTH OF TOTAL-SYSTEM TEN-YEAR COST	$ 69342720.
ANNUAL COST OF TOTAL SYSTEM PER SLAVE STATION	$ 6241.
ANNUAL COST OF TOTAL SYSTEM PER SLAVE STATION PER TV CHANNEL	$ 1560.

BRAZIL (CONT'D)

LINK CALCULATIONS

TV UP-LINK (2.5 GHZ)	
OUTPUT PWR PER CHANNEL OF MASTER STATION PWR AMP	23.4 DB
MASTER STATION ANTENNA GAIN	49.4 DB
PATH LOSS	-191.6 DB
SATELLITE ANTENNA GAIN	27.6 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT SAT. RCVR	196.6 DB
NOISE BANDWIDTH (25.1 MHZ)	-74.0 DB
UP-LINK CNR	31.4 DB
TV DOWN-LINK (2.5 GHZ)	
OUTPUT POWER OF SATELLITE TRANSPONDER	12.3 DB
SATELLITE ANTENNA GAIN	24.6 DB
PATH LOSS	-191.8 DB
SLAVE STATION ANTENNA GAIN	36.9 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT SLAVE STATION RCVR	205.0 DB
NOISE BANDWIDTH	-74.0 DB
DOWN-LINK CNR	13.1 DB
TV TOTAL CNR	13.0 DB
TV TOTAL SNR (=6*(((B/2F)-1)**2)*(C/N)*(B/F)*KP)	42.9 DB
WHERE B = RF BANDWIDTH; F = HIGHEST BASEBAND FREQUENCY; C/N = TV TOTAL CNR; KP = A NOISE WEIGHTING FACTOR	
AUDIO UP-LINK (2.5 GHZ)	
OUTPUT POWER PER CHANNEL AT SLAVE STA. PWR. AMP.	13.8 DB
SLAVE STATION ANTENNA GAIN	36.9 DB
PATH LOSS	-191.8 DB
SATELLITE ANTENNA GAIN	24.6 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT SAT. RCVR	196.6 DB
NOISE BANDWIDTH (0.100 MHZ)	-50.0 DB
UP-LINK CNR	30.1 DB
BACK-OFF OF SATELLITE TRANSPONDER	10.0 DB
CNR FROM INTERMODULATION IN SATELLITE TWT	16.9 DB
AUDIO DOWN-LINK (2.5 GHZ)	
OUTPUT PWR PER CHANNEL AT SAT. TRANSPONDER	-29.0 DB
SATELLITE ANTENNA GAIN	24.6 DB
PATH LOSS	-191.6 DB
MASTER STATION ANTENNA GAIN	49.4 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT MASTER STA.RCVR	212.1 DB
NOISE BANDWIDTH	-50.0 DB
DOWN-LINK CNR	15.4 DB
AUDIO TOTAL CNR	13.0 DB
AUDIO TOTAL SNR (=3*(((B/2F)-1)**2)*(C/N)*(B/F)*(1/KP'))	43.5 DB
WHERE KP' IS THE PEAK-TO-AVERAGE POWER RATIO FOR A SINGLE VOICE SIGNAL; OTHER PARAMETERS AS ABOVE	

*** BRAZIL ***

'PUT PARAMETERS

LAND AREA	3286170 SQ MI
LATITUDE OF COUNTRY'S GEOGRAPHICAL CENTER	-14° **** DEG
ASSUMED COST OF SATELLITE POWER ($/WATT-YEAR)	$50000.
DISCOUNT FACTOR	10.0%
NO. OF TV-TRANSMIT/AUDIO-RECEIVE (MASTER) STATIONS	28
NO. OF TV-RECEIVE/AUDIO-TRANSMIT (SLAVE) STATIONS	6500
NO. OF TV CHANNELS PER MASTER STATION	2
NO. OF TV CHANNELS PER SLAVE STATION	12
SIGNAL-TO-NOISE RATIO REQUIRED FOR TV	43 DB
SIGNAL-TO-NOISE RATIO REQUIRED FOR AUDIO	43 DB

OUTPUT PARAMETERS

MASTER STATION

ANTENNA:	DIAMETER	45.4 FT	UNIT COST	$ 526790.
RCVR PRE-AMP:	NOISE TEMP	20. DEG K	UNIT COST	$ 80000
TXMTR PWR AMP:	OUTPUT PWR	350.0 W	UNIT COST	$ 17000
INITIAL CAPITAL COST PER STATION				$ 610302
PRESENT WORTH OF TEN-YEAR ANNUAL COST STREAM				$ 1313421

SLAVE STATION

ANTENNA:	DIAMETER	12.0 FT	UNIT COST	$ 2606.
RCVR PRE-AMP:	NOISE TEMP	130. DEG K	UNIT COST	$ 7000
TXMTR PWR AMP	OUTPUT PWR	30.0 W	UNIT COST	$ 6000
INITIAL CAPITAL COST PER STATION				$ 24119
PRESENT WORTH OF TEN-YEAR ANNUAL COST STREAM				$ 35741

SATELLITE

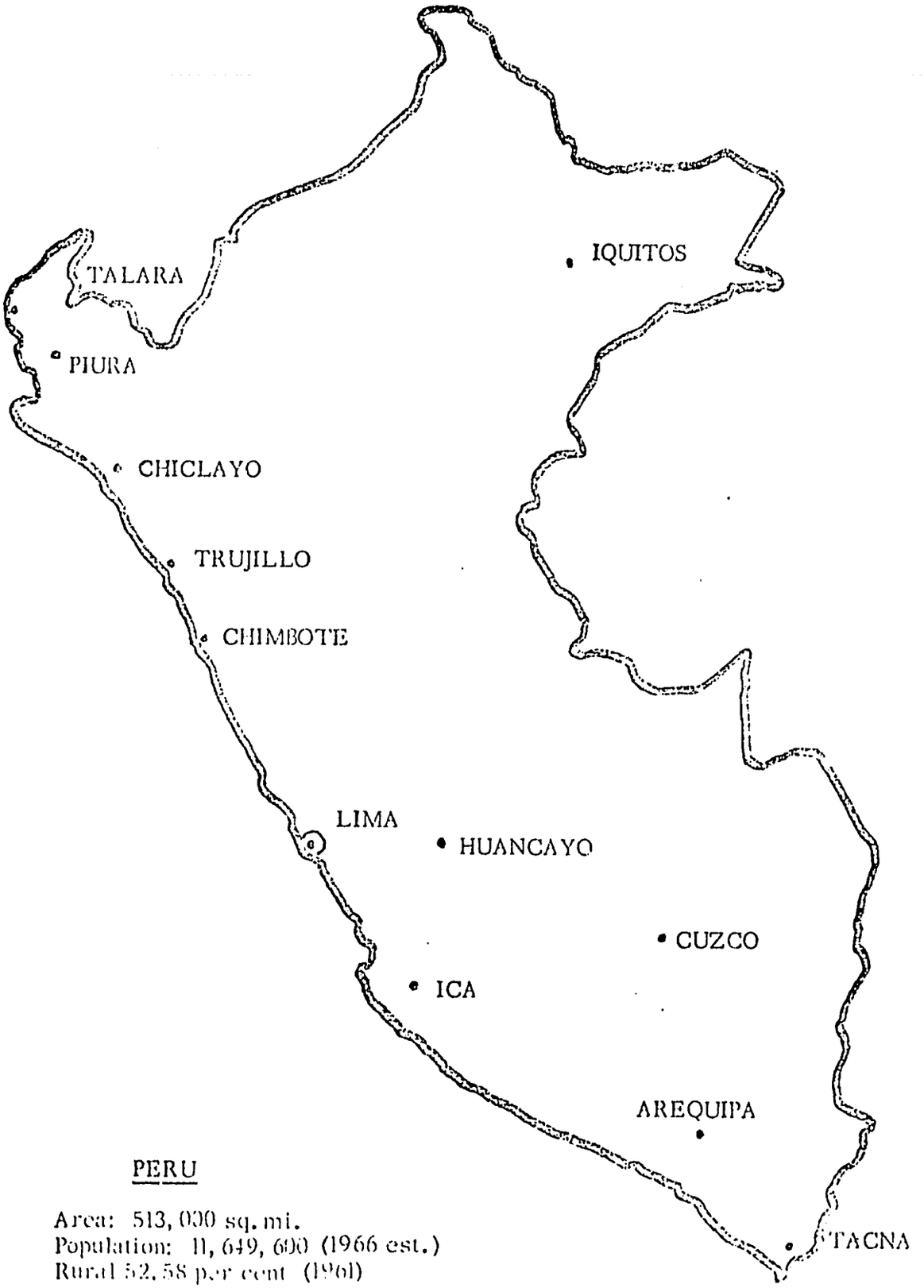
SATELLITE ANTENNA N-S DIAMETER	4.3'	**** FT
SATELLITE ANTENNA E-W DIAMETER	4.2'	-0.0 FT
MAXIMUM SLANT RANGE FOR TRANSMISSION		23081.7 MI
POWER CHARGED PER TV CHANNEL		18.38 W
POWER CHARGED PER AUDIO CHANNEL		0.0149460 W
TOTAL COST PER YEAR OF SATELLITE POWER		$ 1.2200186
PRESENT WORTH OF TEN-YEAR ANNUAL COST STREAM		$ 74957920

TOTAL INITIAL CAPITAL COST (NOT INCLUDING SATELLITE COSTS)	$ 80262352.
PRESENT WORTH OF TOTAL-SYSTEM TEN-YEAR COST	$ 344055296.
ANNUAL COST OF TOTAL SYSTEM PER SLAVE STATION	$ 8575.
ANNUAL COST OF TOTAL SYSTEM PER SLAVE STATION PER TV CHANNEL	$ 715.

BRAZIL (CON'T)

LINK CALCULATIONS

TV UP-LINK (2.5 GHZ)	
OUTPUT PWR PER CHANNEL OF MASTER STATION PWR AMP	24.2 DB
MASTER STATION ANTENNA GAIN	48.6 DB
PATH LOSS	-191.6 DB
SATELLITE ANTENNA GAIN	27.6 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT SAT. RCVR	196.6 DB
NOISE BANDWIDTH (25.1 MHZ)	-74.0 DB
UP-LINK CNR	31.4 DB
TV DOWN-LINK (2.5 GHZ)	
OUTPUT POWER OF SATELLITE TRANSPONDER	12.6 DB
SATELLITE ANTENNA GAIN	24.6 DB
PATH LOSS	-191.8 DB
SLAVE STATION ANTENNA GAIN	36.6 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT SLAVE STATION RCVR	205.0 DB
NOISE BANDWIDTH	-74.0 DB
DOWN-LINK CNR	13.1 DB
TV TOTAL CNR	13.0 DB
TV TOTAL SNR (=6*(((B/2F)-1)**2)*(C/N)*(B/F)*KP)	42.9 DB
WHERE B = RF BANDWIDTH; F = HIGHEST BASEBAND FREQUENCY; C/N = TV TOTAL CNR; KP = A NOISE WEIGHTING FACTOR	
AUDIO UP-LINK (2.5 GHZ)	
OUTPUT POWER PER CHANNEL AT SLAVE STA. PWR. AMP.	13.8 DB
SLAVE STATION ANTENNA GAIN	36.6 DB
PATH LOSS	-191.8 DB
SATELLITE ANTENNA GAIN	24.6 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT SAT. RCVR	196.6 DB
NOISE BANDWIDTH (0.100 MHZ)	-50.0 DB
UP-LINK CNR	29.8 DB
BACK-OFF OF SATELLITE TRANSPONDER	10.0 DB
CNR FROM INTERMODULATION IN SATELLITE TWT	16.9 DB
AUDIO DOWN-LINK (2.5 GHZ)	
OUTPUT PWR PER CHANNEL AT SAT. TRANSPONDER	-28.3 DB
SATELLITE ANTENNA GAIN	24.6 DB
PATH LOSS	-191.6 DB
MASTER STATION ANTENNA GAIN	48.6 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT MASTER STA.RCVR	212.1 DB
NOISE BANDWIDTH	-50.0 DB
DOWN-LINK CNR	15.4 DB
AUDIO TOTAL CNR	13.0 DB
AUDIO TOTAL SNR (=3*(((B/2F)-1)**2)*(C/N)*(B/F)*(1/KP'))	43.5 DB
WHERE KP' IS THE PEAK-TO-AVERAGE POWER RATIO FOR A SINGLE VOICE SIGNAL; OTHER PARAMETERS AS ABOVE	



PERU

Area: 513,000 sq. mi.
Population: 11,649,600 (1966 est.)
Rural 52.58 per cent (1961)
47.2 per cent (1985 projected)

*** PERU ***

IN T PARAMETERS

ANC AREA	115000 SQ MI
LATITUDE OF COUNTRY'S GEOGRAPHICAL CENTER	-9.0 DEG
ASSUMED COST OF SATELLITE POWER ($/WATT-YEAR)	$50000.
DISCOUNT FACTOR	10.0%
NO. OF TV-TRANSMIT/AUDIO-RECEIVE (MASTER) STATIONS	1
NO. OF TV-RECEIVE/AUDIO-TRANSMIT (SLAVE) STATIONS	355
NO. OF TV CHANNELS PER MASTER STATION	4
NO. OF TV CHANNELS PER SLAVE STATION	4
SIGNAL-TO-NOISE RATIO REQUIRED FOR TV	43 DB
SIGNAL-TO-NOISE RATIO REQUIRED FOR AUDIO	43 DB

IOUTPUT PARAMETERS

MASTER STATION

ANTENNA:	DIAMETER	24.2 FT	UNIT COST	$ 47542.
RCVR PRE-AMP:	NOISE TEMP	40. DEG K	UNIT COST	$ 40000
TXMTR PWR AMP:	OUTPUT PWR	100.0 W	UNIT COST	$ 10000
INITIAL CAPITAL COST PER STATION				$ 161559
PRESENT WORTH OF TEN-YEAR ANNUAL COST STREAM				$ 361574

SLAVE STATION

ANTENNA:	DIAMETER	12.0 FT	UNIT COST	$ 2600.
RCVR PRE-AMP:	NOISE TEMP	180. DEG K	UNIT COST	$ 7000
TXMTR PWR AMP	OUTPUT PWR	5.0 W	UNIT COST	$ 2000
INITIAL CAPITAL COST PER STATION				$ 11578
PRESENT WORTH OF TEN-YEAR ANNUAL COST STREAM				$ 18577

SATELLITE

SATELLITE ANTENNA N-S DIAMETER	9.0'	**** FT
SATELLITE ANTENNA E-W DIAMETER	16.5'	-0.0 FT
MAXIMUM SLANT RANGE FOR TRANSMISSION		22532.4 MI
POWER CHARGED PER TV CHANNEL		3.12 W
POWER CHARGED PER AUDIO CHANNEL		0.0136906 W
TOTAL COST PER YEAR OF SATELLITE POWER		$ 646446
PRESENT WORTH OF TEN-YEAR ANNUAL COST STREAM		$ 3971767

TOTAL INITIAL CAPITAL COST $ 2567055.
(NOT INCLUDING SATELLITE COSTS)

PRESENT WORTH OF TOTAL-SYSTEM TEN-YEAR COST	$ 11070911.
ANNUAL COST OF TOTAL SYSTEM PER SLAVE STATION	$ 5052.
ANNUAL COST OF TOTAL SYSTEM PER SLAVE STATION PER TV CHANNEL	$ 1263.

PERU (CON'T)

L' " CALCULATIONS

TV UP-LINK (2.5 GHZ)	
OUTPUT PWR PER CHANNEL OF MASTER STATION PWR AMP	18.0 DB
MASTER STATION ANTENNA GAIN	43.2 DB
PATH LOSS	-191.5 DB
SATELLITE ANTENNA GAIN	35.2 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT SAT. RCVR	196.6 DB
NOISE BANDWIDTH (25.1 MHZ)	-74.0 DB
UP-LINK CNR	27.4 DB
TV DOWN-LINK (2.5 GHZ)	
OUTPUT POWER OF SATELLITE TRANSPONDER	4.9 DB
SATELLITE ANTENNA GAIN	32.2 DB
PATH LOSS	-191.6 DB
SLAVE STATION ANTENNA GAIN	36.6 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT SLAVE STATION RCVR	205.0 DB
NOISE BANDWIDTH	-74.0 DB
DOWN-LINK CNR	15.2 DB
TV TOTAL CNR	13.0 DB
TV TOTAL SNR (=6*(((B/2F)-1)**2)*(C/N)*(B/F)*KP)	42.9 DB
WHERE B = RF BANDWIDTH; F = HIGHEST BASEBAND FREQUENCY; C/N = TV TOTAL CNR; KP = A NOISE WEIGHTING FACTOR	
AUDIO UP-LINK (2.5 GHZ)	
OUTPUT POWER PER CHANNEL AT SLAVE STA. PWR. AMP.	6.0 DB
SLAVE STATION ANTENNA GAIN	36.6 DB
PATH LOSS	-191.6 DB
SATELLITE ANTENNA GAIN	32.2 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT SAT. RCVR	196.6 DB
NOISE BANDWIDTH (0.100 MHZ)	-50.0 DB
UP-LINK CNR	29.8 DB
BACK-OFF OF SATELLITE TRANSPONDER	10.0 DB
CNR FROM INTERMODULATION IN SATELLITE TWT	16.9 DB
AUDIO DOWN-LINK (2.5 GHZ)	
OUTPUT PWR PER CHANNEL AT SAT. TRANSPONDER	-28.6 DB
SATELLITE ANTENNA GAIN	32.2 DB
PATH LOSS	-191.5 DB
MASTER STATION ANTENNA GAIN	43.2 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT MASTER STA.RCVR	210.3 DB
NOISE BANDWIDTH	-50.0 DB
DOWN-LINK CNR	15.4 DB
AUDIO TOTAL CNR	13.0 DB
AUDIO TOTAL SNR (=3*(((B/2F)-1)**2)*(C/N)*(B/F)*(1/KP'))	43.5 DB
WHERE KP' IS THE PEAK-TO-AVERAGE POWER RATIO FOR A SINGLE VOICE SIGNAL; OTHER PARAMETERS AS ABOVE	

*** PERU ***

I. IT PARAMETERS

LAND AREA	115000 SQ MI
LATITUDE OF COUNTRY'S GEOGRAPHICAL CENTER	-9.0 DEG
ASSUMED COST OF SATELLITE POWER ($/WATT-YEAR)	$50000.
DISCOUNT FACTOR	10.0%
NO. OF TV-TRANSMIT/AUDIO-RECEIVE (MASTER) STATIONS	12
NO. OF TV-RECEIVE/AUDIO-TRANSMIT (SLAVE) STATIONS	7950
NO. OF TV CHANNELS PER MASTER STATION	2
NO. OF TV CHANNELS PER SLAVE STATION	12
SIGNAL-TO-NOISE RATIO REQUIRED FOR TV	43 DB
SIGNAL-TO-NOISE RATIO REQUIRED FOR AUDIO	43 DB

OUTPUT PARAMETERS

MASTER STATION

ANTENNA:	DIAMETER	39.8 FT	UNIT COST	$ 145436.
RCVR PRE-AMP:	NOISE TEMP	40. DEG K	UNIT COST	$ 40000
TXMTR PWR AMP:	OUTPUT PWR	30.0 W	UNIT COST	$ 6000
INITIAL CAPITAL COST PER STATION				$ 196140
PRESENT WORTH OF TEN-YEAR ANNUAL COST STREAM				$ 393866

SLAVE STATION

ANTENNA:	DIAMETER	10.8 FT	UNIT COST	$ 1475.
RCVR PRE-AMP:	NOISE TEMP	320. DEG K	UNIT COST	$ 1000
TXMTR PWR AMP	OUTPUT PWR	5.0 W	UNIT COST	$ 2000
INITIAL CAPITAL COST PER STATION				$ 17097
PRESENT WORTH OF TEN-YEAR ANNUAL COST STREAM				$ 19147

SATELLITE

SATELLITE ANTENNA N-S DIAMETER	9.0'	**** FT
SATELLITE ANTENNA E-W DIAMETER	11.5'	-0.0 FT
MAXIMUM SLANT RANGE FOR TRANSMISSION		22532.4 MI
POWER CHARGED PER TV CHANNEL		6.55 W
POWER CHARGED PER AUDIO CHANNEL		0.0055486 W
TOTAL COST PER YEAR OF SATELLITE POWER		$ 4463622
PRESENT WORTH OF TEN-YEAR ANNUAL COST STREAM		$ 27424480

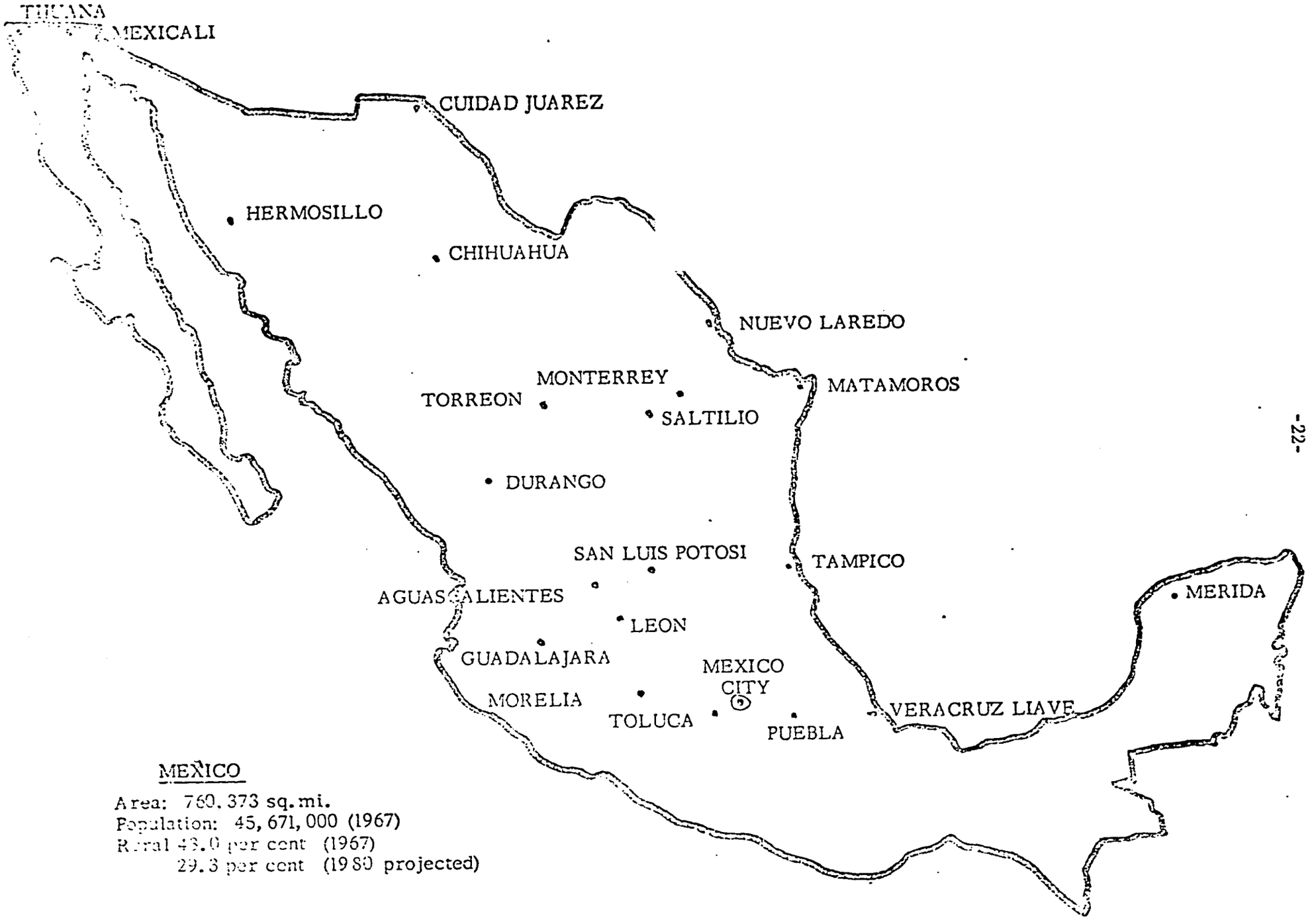
TOTAL INITIAL CAPITAL COST $ 23795872.
(NOT INCLUDING SATELLITE COSTS)

PRESENT WORTH OF TOTAL-SYSTEM TEN-YEAR COST	$ 184375936.
ANNUAL COST OF TOTAL SYSTEM PER SLAVE STATION	$ 3757.
ANNUAL COST OF TOTAL SYSTEM PER SLAVE STATION PER TV CHANNEL	$ 313.

PERU (CON'T)

LINK CALCULATIONS

TV UP-LINK (2.5 GHZ)	
OUTPUT PWR PER CHANNEL OF MASTER STATION PWR AMP	13.5 DB
MASTER STATION ANTENNA GAIN	47.5 DB
PATH LOSS	-191.5 DB
SATELLITE ANTENNA GAIN	35.2 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT SAT. RCVR	196.6 DB
NOISE BANDWIDTH (25.1 MHZ)	-74.0 DB
UP-LINK CNR	27.2 DB
TV DOWN-LINK (2.5 GHZ)	
OUTPUT POWER OF SATELLITE TRANSPONDER	8.2 DB
SATELLITE ANTENNA GAIN	32.2 DB
PATH LOSS	-191.6 DB
SLAVE STATION ANTENNA GAIN	35.7 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT SLAVE STATION RCVR	202.7 DB
NOISE BANDWIDTH	-74.0 DB
DOWN-LINK CNR	13.2 DB
TV TOTAL CNR	13.0 DB
TV TOTAL SNR (=6*(((B/2F)-1)**2)*(C/N)*(B/F)*KP)	42.9 DB
WHERE B = RF BANDWIDTH; F = HIGHEST BASEBAND FREQUENCY; C/N = TV TOTAL CNR; KP = A NOISE WEIGHTING FACTOR	
AUDIO UP-LINK (2.5 GHZ)	
OUTPUT POWER PER CHANNEL AT SLAVE STA. PWR. AMP.	6.0 DB
SLAVE STATION ANTENNA GAIN	35.7 DB
PATH LOSS	-191.6 DB
SATELLITE ANTENNA GAIN	32.2 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT SAT. RCVR	196.6 DB
NOISE BANDWIDTH (0.100 MHZ)	-50.0 DB
UP-LINK CNR	28.9 DB
BACK-OFF OF SATELLITE TRANSPONDER	11.0 DB
CNR FROM INTERMODULATION IN SATELLITE TWT	18.0 DB
AUDIO DOWN-LINK (2.5 GHZ)	
OUTPUT PWR PER CHANNEL AT SAT. TRANSPONDER	-33.6 DB
SATELLITE ANTENNA GAIN	32.2 DB
PATH LOSS	-191.5 DB
MASTER STATION ANTENNA GAIN	47.5 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT MASTER STA.RCVR	210.3 DB
NOISE BANDWIDTH	-50.0 DB
DOWN-LINK CNR	14.8 DB
AUDIO TOTAL CNR	13.0 DB
AUDIO TOTAL SNR (=3*(((B/2F)-1)**2)*(C/N)*(B/F)*(1/KP'))	43.5 DB
WHERE KP' IS THE PEAK-TO-AVERAGE POWER RATIO FOR A SINGLE VOICE SIGNAL; OTHER PARAMETERS AS ABOVE	



MEXICO

Area: 760,373 sq.mi.
Population: 45,671,000 (1967)
Rural 43.0 per cent (1967)
29.3 per cent (1980 projected)

*** MEXICO ***

INPUT PARAMETERS

LAND AREA	760373 SQ MI
LATITUDE OF COUNTRY'S GEOGRAPHICAL CENTER	24.0 DEG
ASSUMED COST OF SATELLITE POWER ($/WATT-YEAR)	$50000.
DISCOUNT FACTOR	10.0%
NO. OF TV-TRANSMIT/AUDIO-RECEIVE (MASTER) STATIONS	1
NO. OF TV-RECEIVE/AUDIO-TRANSMIT (SLAVE) STATIONS	6050
NO. OF TV CHANNELS PER MASTER STATION	4
NO. OF TV CHANNELS PER SLAVE STATION	4
SIGNAL-TO-NOISE RATIO REQUIRED FOR TV	43 DB
SIGNAL-TO-NOISE RATIO REQUIRED FOR AUDIO	43 DB

OUTPUT PARAMETERS

MASTER STATION

ANTENNA:	DIAMETER	51.1 FT	UNIT COST	$ 566922.
RCVR PRE-AMP:	NOISE TEMP	20. DEG K	UNIT COST	$ 80000
TXMTR PWR AMP:	OUTPUT PWR	100.0 W	UNIT COST	$ 10000
INITIAL CAPITAL COST PER STATION				$ 965415
PRESENT WORTH OF TEN-YEAR ANNUAL COST STREAM				$ 2071519

SLAVE STATION

ANTENNA:	DIAMETER	10.8 FT	UNIT COST	$ 1472.
RCVR PRE-AMP:	NOISE TEMP	320. DEG K	UNIT COST	$ 1000
TXMTR PWR AMP	OUTPUT PWR	10.0 W	UNIT COST	$ 3500
INITIAL CAPITAL COST PER STATION				$ 7286
PRESENT WORTH OF TEN-YEAR ANNUAL COST STREAM				$ 9217

SATELLITE

SATELLITE ANTENNA N-S DIAMETER	**** FT
SATELLITE ANTENNA E-W DIAMETER	-0.0 FT
MAXIMUM SLANT RANGE FOR TRANSMISSION	23166.1 MI
POWER CHARGED PER TV CHANNEL	12.81 W
POWER CHARGED PER AUDIO CHANNEL	0.0043461 W
TOTAL COST PER YEAR OF SATELLITE POWER	$ 2667778
PRESENT WORTH OF TEN-YEAR ANNUAL COST STREAM	$ 16390825

TOTAL INITIAL CAPITAL COST $ 16010013.
(NOT INCLUDING SATELLITE COSTS)

PRESENT WORTH OF TOTAL-SYSTEM TEN-YEAR COST	$ 74227984.
ANNUAL COST OF TOTAL SYSTEM PER SLAVE STATION	$ 1988.
ANNUAL COST OF TOTAL SYSTEM PER SLAVE STATION PER TV CHANNEL	$ 497.

MEXICO (CON'T)

LINK CALCULATIONS

TV UP-LINK (2.5 GHZ)	
OUTPUT PWR PER CHANNEL OF MASTER STATION PWR AMP	18.0 DB
MASTER STATION ANTENNA GAIN	49.6 DB
PATH LOSS	-191.7 DB
SATELLITE ANTENNA GAIN	32.4 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT SAT. RCVR	196.6 DB
NOISE BANDWIDTH (25.1 MHZ)	-74.0 DB
UP-LINK CNR	31.0 DB
TV DOWN-LINK (2.5 GHZ)	
OUTPUT POWER OF SATELLITE TRANSPONDER	11.1 DB
SATELLITE ANTENNA GAIN	29.4 DB
PATH LOSS	-191.8 DB
SLAVE STATION ANTENNA GAIN	35.7 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT SLAVE STATION RCVR	202.7 DB
NOISE BANDWIDTH	-74.0 DB
DOWN-LINK CNR	13.1 DB
TV TOTAL CNR	13.0 DB
TV TOTAL SNR (=6*(((B/2F)-1)**2)*(C/N)*(B/F)*KP)	42.9 DB

WHERE B = RF BANDWIDTH; F = HIGHEST BASEBAND FREQUENCY;
C/N = TV TOTAL CNR; KP = A NOISE WEIGHTING FACTOR

AUDIO UP-LINK (2.5 GHZ)	
OUTPUT POWER PER CHANNEL AT SLAVE STA. PWR. AMP.	9.0 DB
SLAVE STATION ANTENNA GAIN	35.7 DB
PATH LOSS	-191.8 DB
SATELLITE ANTENNA GAIN	29.4 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT SAT. RCVR	196.6 DB
NOISE BANDWIDTH (0.100 MHZ)	-50.0 DB
UP-LINK CNR	28.9 DB
BACK-OFF OF SATELLITE TRANSPONDER	11.0 DB
CNR FROM INTERMODULATION IN SATELLITE TWT	18.0 DB
AUDIO DOWN-LINK (2.5 GHZ)	
OUTPUT PWR PER CHANNEL AT SAT. TRANSPONDER	-34.6 DB
SATELLITE ANTENNA GAIN	29.4 DB
PATH LOSS	-191.7 DB
MASTER STATION ANTENNA GAIN	49.6 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT MASTER STA.RCVR	212.1 DB
NOISE BANDWIDTH	-50.0 DB
DOWN-LINK CNR	14.8 DB
AUDIO TOTAL CNR	13.0 DB
AUDIO TOTAL SNR (=3*(((B/2F)-1)**2)*(C/N)*(B/F)*(1/KP'))	43.5 DB

WHERE KP' IS THE PEAK-TO-AVERAGE POWER RATIO FOR A
SINGLE VOICE SIGNAL; OTHER PARAMETERS AS ABOVE

*** MEXICO ***

INPUT PARAMETERS

LAND AREA	760373 SQ MI
LATITUDE OF COUNTRY'S GEOGRAPHICAL CENTER	24.0 DEG
ASSUMED COST OF SATELLITE POWER ($/WATT-YEAR)	$50000.
DISCOUNT FACTOR	10.0%
NO. OF TV-TRANSMIT/AUDIO-RECEIVE (MASTER) STATIONS	22
NO. OF TV-RECEIVE/AUDIO-TRANSMIT (SLAVE) STATIONS	11000
NO. OF TV CHANNELS PER MASTER STATION	2
NO. OF TV CHANNELS PER SLAVE STATION	12
SIGNAL-TO-NOISE RATIO REQUIRED FOR TV	43 DB
SIGNAL-TO-NOISE RATIO REQUIRED FOR AUDIO	43 DB

OUTPUT PARAMETERS

MASTER STATION

ANTENNA:	DIAMETER	44.7 FT	UNIT COST	$ 523045.
RCVR PRE-AMP:	NOISE TEMP	20. DEG K	UNIT COST	$ 80000
TXMTR PWR AMP:	OUTPUT PWR	10.0 W	UNIT COST	$ 3500
INITIAL CAPITAL COST PER STATION				$ 596386
PRESENT WORTH OF TEN-YEAR ANNUAL COST STREAM				$ 1274759

SLAVE STATION

ANTENNA:	DIAMETER	10.7 FT	UNIT COST	$ 1400.
RCVR PRE-AMP:	NOISE TEMP	320. DEG K	UNIT COST	$ 1000
TXMTR PWR AMP	OUTPUT PWR	5.0 W	UNIT COST	$ 2000
INITIAL CAPITAL COST PER STATION				$ 16935
PRESENT WORTH OF TEN-YEAR ANNUAL COST STREAM				$ 18865

SATELLITE

SATELLITE ANTENNA N-S DIAMETER	9.6 FT
SATELLITE ANTENNA E-W DIAMETER	5.7 FT
MAXIMUM SLANT RANGE FOR TRANSMISSION	23166.1 MI
POWER CHARGED PER TV CHANNEL	13.27 W
POWER CHARGED PER AUDIO CHANNEL	0.0065686 W
TOTAL COST PER YEAR OF SATELLITE POWER	$ 8834034
PRESENT WORTH OF TEN-YEAR ANNUAL COST STREAM	$ 54276288

TOTAL INITIAL CAPITAL COST $ 41007328.
(NOT INCLUDING SATELLITE COSTS)

PRESENT WORTH OF TOTAL-SYSTEM TEN-YEAR COST	$ 289843712.
ANNUAL COST OF TOTAL SYSTEM PER SLAVE STATION	$ 4269.
ANNUAL COST OF TOTAL SYSTEM PER SLAVE STATION PER TV CHANNEL	$ 356.

MEXICO (CON'T)

LINK CALCULATIONS

TV UP-LINK (6.0 GHZ)	
OUTPUT PWR PER CHANNEL OF MASTER STATION PWR AMP	8.7 DB
MASTER STATION ANTENNA GAIN	56.1 DB
PATH LOSS	-199.3 DB
SATELLITE ANTENNA GAIN	40.0 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT SAT. RCVR	196.6 DB
NOISE BANDWIDTH (25.1 MHZ)	-74.0 DB
UP-LINK CNR	28.2 DB
TV DOWN-LINK (2.5 GHZ)	
OUTPUT POWER OF SATELLITE TRANSPONDER	11.2 DB
SATELLITE ANTENNA GAIN	29.4 DB
PATH LOSS	-191.8 DB
SLAVE STATION ANTENNA GAIN	35.6 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT SLAVE STATION RCVR	202.7 DB
NOISE BANDWIDTH	-74.0 DB
DOWN-LINK CNR	13.1 DB
TV TOTAL CNR	13.0 DB
TV TOTAL SNR (=6*(((B/2F)-1)**2)*(C/N)*(B/F)*KP)	42.9 DB
WHERE B = RF BANDWIDTH; F = HIGHEST BASEBAND FREQUENCY; C/N = TV TOTAL CNR; KP = A NOISE WEIGHTING FACTOR	
AUDIO UP-LINK (6.0 GHZ)	
OUTPUT POWER PER CHANNEL AT SLAVE STA. PWR. AMP.	6.0 DB
SLAVE STATION ANTENNA GAIN	43.2 DB
PATH LOSS	-199.5 DB
SATELLITE ANTENNA GAIN	37.0 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT SAT. RCVR	196.6 DB
NOISE BANDWIDTH (0.100 MHZ)	-50.0 DB
UP-LINK CNR	33.4 DB
BACK-OFF OF SATELLITE TRANSPONDER	10.0 DB
CNR FROM INTERMODULATION IN SATELLITE TWT	16.9 DB
AUDIO DOWN-LINK (2.2 GHZ)	
OUTPUT PWR PER CHANNEL AT SAT. TRANSPONDER	-31.8 DB
SATELLITE ANTENNA GAIN	28.3 DB
PATH LOSS	-190.6 DB
MASTER STATION ANTENNA GAIN	47.4 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT MASTER STA.RCVR	212.1 DB
NOISE BANDWIDTH	-50.0 DB
DOWN-LINK CNR	15.3 DB
AUDIO TOTAL CNR	13.0 DB
AUDIO TOTAL SNR (=3*(((B/2F)-1)**2)*(C/N)*(B/F)*(1/KP'))	43.5 DB
WHERE KP' IS THE PEAK-TO-AVERAGE POWER RATIO FOR A SINGLE VOICE SIGNAL; OTHER PARAMETERS AS ABOVE	

COLOMBIA

Area: 439,828 sq. mi.
Population: 18,100,000 (1965)
Rural 53.9 per cent (1960)
37.9 per cent (1980 projected)

*** COLOMBIA ***

INPUT PARAMETERS

LAND AREA	439828 SQ MI
LATITUDE OF COUNTRY'S GEOGRAPHICAL CENTER	5.0 DEG
ASSUMED COST OF SATELLITE POWER ($/WATT-YEAR)	$50000.
DISCOUNT FACTOR	10.0%
NO. OF TV-TRANSMIT/AUDIO-RECEIVE (MASTER) STATIONS	1
NO. OF TV-RECEIVE/AUDIO-TRANSMIT (SLAVE) STATIONS	193
NO. OF TV CHANNELS PER MASTER STATION	4
NO. OF TV CHANNELS PER SLAVE STATION	4
SIGNAL-TO-NOISE RATIO REQUIRED FOR TV	43 DB
SIGNAL-TO-NOISE RATIO REQUIRED FOR AUDIO	43 DB

OUTPUT PARAMETERS

MASTER STATION

ANTENNA:	DIAMETER	28.4 FT	UNIT COST	$ 68476.
RCVR PRE-AMP:	NOISE TEMP	90. DEG K	UNIT COST	$ 17000
TXMTR PWR AMP:	OUTPUT PWR	10.0 W	UNIT COST	$ 3500
INITIAL CAPITAL COST PER STATION				$ 132574
PRESENT WORTH OF TEN-YEAR ANNUAL COST STREAM				$ 245601

SLAVE STATION

ANTENNA:	DIAMETER	12.2 FT	UNIT COST	$ 7276.
RCVR PRE-AMP:	NOISE TEMP	180. DEG K	UNIT COST	$ 7000
TXMTR PWR AMP	OUTPUT PWR	0.5 W	UNIT COST	$ 500
INITIAL CAPITAL COST PER STATION				$ 14595
PRESENT WORTH OF TEN-YEAR ANNUAL COST STREAM				$ 24702

SATELLITE

SATELLITE ANTENNA N-S DIAMETER	9.4 FT
SATELLITE ANTENNA E-W DIAMETER	13.3 FT
MAXIMUM SLANT RANGE FOR TRANSMISSION	22419.5 MI
POWER CHARGED PER TV CHANNEL	2.24 W
POWER CHARGED PER AUDIO CHANNEL	0.0212644 W
TOTAL COST PER YEAR OF SATELLITE POWER	$ 468389
PRESENT WORTH OF TEN-YEAR ANNUAL COST STREAM	$ 2877787

TOTAL INITIAL CAPITAL COST (NOT INCLUDING SATELLITE COSTS)	$ 2023046.
PRESENT WORTH OF TOTAL-SYSTEM TEN-YEAR COST	$ 7891011.
ANNUAL COST OF TOTAL SYSTEM PER SLAVE STATION	$ 6624.
ANNUAL COST OF TOTAL SYSTEM PER SLAVE STATION PER TV CHANNEL	$ 1656.

COLOMBIA(CON'T)

LINK CALCULATIONS

TV UP-LINK (6.0 GHZ)	
OUTPUT PWR PER CHANNEL OF MASTER STATION PWR AMP	8.0 DB
MASTER STATION ANTENNA GAIN	52.1 DB
PATH LOSS	-199.1 DB
SATELLITE ANTENNA GAIN	43.6 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT SAT. RCVR	196.6 DB
NOISE BANDWIDTH (25.1 MHZ)	-74.0 DB
UP-LINK CNR	27.2 DB
TV DOWN-LINK (2.5 GHZ)	
OUTPUT POWER OF SATELLITE TRANSPONDER	3.5 DB
SATELLITE ANTENNA GAIN	33.0 DB
PATH LOSS	-191.6 DB
SLAVE STATION ANTENNA GAIN	37.2 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT SLAVE STATION RCVR	205.0 DB
NOISE BANDWIDTH	-74.0 DB
DOWN-LINK CNR	13.2 DB
TV TOTAL CNR	13.0 DB
TV TOTAL SNR (=6*(((B/2F)-1)**2)*(C/N)*(B/F)*KP)	42.9 DB
WHERE B = RF BANDWIDTH; F = HIGHEST BASEBAND FREQUENCY; C/N = TV TOTAL CNR; KP = A NOISE WEIGHTING FACTOR	
AUDIO UP-LINK (6.0 GHZ)	
OUTPUT POWER PER CHANNEL AT SLAVE STA. PWR. AMP.	-4.0 DB
SLAVE STATION ANTENNA GAIN	44.8 DB
PATH LOSS	-199.2 DB
SATELLITE ANTENNA GAIN	40.6 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT SAT. RCVR	196.6 DB
NOISE BANDWIDTH (0.100 MHZ)	-50.0 DB
UP-LINK CNR	28.8 DB
BACK-OFF OF SATELLITE TRANSPONDER	11.0 DB
CNR FROM INTERMODULATION IN SATELLITE TWT	18.0 DB
AUDIO DOWN-LINK (2.2 GHZ)	
OUTPUT PWR PER CHANNEL AT SAT. TRANSPONDER	-27.7 DB
SATELLITE ANTENNA GAIN	31.9 DB
PATH LOSS	-190.4 DB
MASTER STATION ANTENNA GAIN	43.4 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT MASTER STA.RCVR	207.6 DB
NOISE BANDWIDTH	-50.0 DB
DOWN-LINK CNR	14.8 DB
AUDIO TOTAL CNR	13.0 DB
AUDIO TOTAL SNR (=3*(((B/2F)-1)**2)*(C/N)*(B/F)*(1/KP'))	43.5 DB
WHERE KP' IS THE PEAK-TO-AVERAGE POWER RATIO FOR A SINGLE VOICE SIGNAL; OTHER PARAMETERS AS ABOVE	

*** COLOMBIA ***

INPUT PARAMETERS

LAND AREA	439828 SQ MI
LATITUDE OF COUNTRY'S GEOGRAPHICAL CENTER	5.0 DEG
ASSUMED COST OF SATELLITE POWER ($/WATT-YEAR)	$50000.
DISCOUNT FACTOR	10.0%
NO. OF TV-TRANSMIT/AUDIO-RECEIVE (MASTER) STATIONS	18
NO. OF TV-RECEIVE/AUDIO-TRANSMIT (SLAVE) STATIONS	306
NO. OF TV CHANNELS PER MASTER STATION	2
NO. OF TV CHANNELS PER SLAVE STATION	12
SIGNAL-TO-NOISE RATIO REQUIRED FOR TV	43 DB
SIGNAL-TO-NOISE RATIO REQUIRED FOR AUDIO	43 DB

OUTPUT PARAMETERS

MASTER STATION

ANTENNA:	DIAMETER	19.5 FT	UNIT COST	$ 27903.
RCVR PRE-AMP:	NOISE TEMP	90. DEG K	UNIT COST	$ 17000
TXMTR PWR AMP:	OUTPUT PWR	30.0 W	UNIT COST	$ 6000
INITIAL CAPITAL COST PER STATION				$ 56050
PRESENT WORTH OF TEN-YEAR ANNUAL COST STREAM				$ 112794

SLAVE STATION

ANTENNA:	DIAMETER	12.0 FT	UNIT COST	$ 6771.
RCVR PRE-AMP:	NOISE TEMP	180. DEG K	UNIT COST	$ 7000
TXMTR PWR AMP	OUTPUT PWR	1.0 W	UNIT COST	$ 850
INITIAL CAPITAL COST PER STATION				$ 30779
PRESENT WORTH OF TEN-YEAR ANNUAL COST STREAM				$ 47839

SATELLITE

SATELLITE ANTENNA N-S DIAMETER	9.4 FT
SATELLITE ANTENNA E-W DIAMETER	13.3 FT
MAXIMUM SLANT RANGE FOR TRANSMISSION	22419.5 MI
POWER CHARGED PER TV CHANNEL	2.29 W
POWER CHARGED PER AUDIO CHANNEL	0.0410046 W
TOTAL COST PER YEAR OF SATELLITE POWER	$ 1545591
PRESENT WORTH OF TEN-YEAR ANNUAL COST STREAM	$ 9496109

TOTAL INITIAL CAPITAL COST (NOT INCLUDING SATELLITE COSTS)	$ 6021167.
PRESENT WORTH OF TOTAL-SYSTEM TEN-YEAR COST	$ 26165440.
ANNUAL COST OF TOTAL SYSTEM PER SLAVE STATION	$ 13852.
ANNUAL COST OF TOTAL SYSTEM PER SLAVE STATION PER TV CHANNEL	$ 1154.

COLOMBIA(CON'T)

LINK CALCULATIONS

TV UP-LINK (6.0 GHZ)	
OUTPUT PWR PER CHANNEL OF MASTER STATION PWR AMP	13.5 DB
MASTER STATION ANTENNA GAIN	48.8 DB
PATH LOSS	-199.1 DB
SATELLITE ANTENNA GAIN	43.6 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT SAT. RCVR	196.6 DB
NOISE BANDWIDTH (25.1 MHZ)	-74.0 DB
UP-LINK CNR	29.4 DB
TV DOWN-LINK (2.5 GHZ)	
OUTPUT POWER OF SATELLITE TRANSPONDER	3.6 DB
SATELLITE ANTENNA GAIN	33.0 DB
PATH LOSS	-191.6 DB
SLAVE STATION ANTENNA GAIN	37.0 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT SLAVE STATION RCVR	205.0 DB
NOISE BANDWIDTH	-74.0 DB
DOWN-LINK CNR	13.1 DB
TV TOTAL CNR	13.0 DB
TV TOTAL SNR (=6*(((B/2F)-1)**2)*(C/N)*(B/F)*KP)	42.9 DB
WHERE B = RF BANDWIDTH; F = HIGHEST BASEBAND FREQUENCY; C/N = TV TOTAL CNR; KP = A NOISE WEIGHTING FACTOR	
AUDIO UP-LINK (6.0 GHZ)	
OUTPUT POWER PER CHANNEL AT SLAVE STA. PWR. AMP.	-1.0 DB
SLAVE STATION ANTENNA GAIN	44.6 DB
PATH LOSS	-199.2 DB
SATELLITE ANTENNA GAIN	40.6 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT SAT. RCVR	196.6 DB
NOISE BANDWIDTH (0.100 MHZ)	-50.0 DB
UP-LINK CNR	31.7 DB
BACK-OFF OF SATELLITE TRANSPONDER	10.0 DB
CNR FROM INTERMODULATION IN SATELLITE TWT	16.9 DB
AUDIO DOWN-LINK (2.2 GHZ)	
OUTPUT PWR PER CHANNEL AT SAT. TRANSPONDER	-23.9 DB
SATELLITE ANTENNA GAIN	31.9 DB
PATH LOSS	-190.4 DB
MASTER STATION ANTENNA GAIN	40.1 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT MASTER STA.RCVR	207.6 DB
NOISE BANDWIDTH	-50.0 DB
DOWN-LINK CNR	15.4 DB
AUDIO TOTAL CNR	13.0 DB
AUDIO TOTAL SNR (=3*(((B/2F)-1)**2)*(C/N)*(B/F)*(1/KP'))	43.5 DB
WHERE KP' IS THE PEAK-TO-AVERAGE POWER RATIO FOR A SINGLE VOICE SIGNAL; OTHER PARAMETERS AS ABOVE	

IV. Sketch of Progress

Several parts of the final model are presently being constructed. For the terrestrial systems costs needed for comparison with the satellite system costs I have been working closely with Pacific Telephone and Telegraph Co. of San Jose. Two parts of the overall program of six parts have been written. These parts deal with costs for T Carrier equipment on cable-pairs and N Carrier equipment on cable-pairs. Each is appropriate for a different cross-section and total link length. The other parts to the program will deal with microwave radio, open-wire lines, the determination of the least-cost cable-pair size to serve in a given situation, and the coupler program that will take the output from these separate parts and provide answers in the following matrix format. The length, L, of the telecommunications link under study will be given along the abscissa of the output graph. The increase in channel demand per year that must be satisfied by the link, YID, will be given along the ordinate. The matrix element designated by any pair of values (L, YID) will contain the least-cost type of terrestrial telecommunications facility that will satisfy these requirements and the present worth of the facility for the whole period of study.

In considering the time element in a satellite system it is necessary to know the costs of upgrading earth stations. This cost has been difficult to obtain from industry inasmuch as the type of station with which we are dealing (very low cost) is not in widespread use. Nevertheless, some handle on these costs will be obtained from data gathered for the teleconferencing report. The cost will be taken to be the replacement cost of the component (either antenna, preamplifier, or power amplifier) or components whose upgrading will render the required increase in earth station channel capacity.

A step toward the completion of the integration of educational requirements and telephony requirements into one system has been made with the completion of a version of the original least-cost satellite system program that treats the case where only telephony service is desired. The system is simple in configuration in that each earth station is assumed to have the same G/T and the same power amplifier. Further work will allow perhaps three different sizes of earth station to be determined, according to the demand requirements.

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MASTER

DETERMINATION OF THE COMPARATIVE ENGINEERING COST-EFFECTIVENESS OF TERRESTRIAL, CELESTIAL, AND MIXED TERRESTRIAL-CELESTIAL INSTRUCTIONAL TECHNOLOGY SYSTEMS

by

Carl Mitchell

for

Academy for Educational Development, Inc.
1424 Sixteenth Street, N.W.
Washington, D.C. 20036

~~IN-HOUSE WORKING DOCUMENT~~

MASTER

INTRODUCTION

In the United States and throughout much of the Western world there is a growing awareness of the enormity of the task that has been defined for the various national education systems. Educators, for several reasons, are referring to the situation as the "crisis in education".[1,2] The principal reason being given is the lack of funds to provide a basic education by traditional methods to the burgeoning numbers of people for whom such an education may well mean the difference between living and merely subsisting.

Because the core of education is communication, it is perhaps only natural that telecommunications technology is being investigated as an ingredient of both more efficient and possibly, at the same time, more effective educational systems. Surely, the potential is there. Yet, it is being tapped, with few exceptions, in a piecemeal fashion that nullifies the one clear advantage it has, in terms of efficiency, over traditional classroom-teacher situations -- that of being capable of reducing the student-teacher ratio. The importance of this advantage was pointed out by the Academy for Educational Development following a study to investigate the new instructional technologies with regard to school finances. In a summary statement before the President's Commission of School Finance, the Academy's Executive Vice President, Sidney G. Tickton, said "The only way to reduce unit costs substantially is to increase the pupil-teacher ratio dramatically."[3]

The advantage of transmitting educational programs by radio-waves using a geo-stationary satellite is immediately apparent. A satellite offers to a large country or group of countries lacking adequate ground communications (and this is almost always the case, as far as educational technologies are concerned, for some regions of every country) a system that can cover a geographic area of a million square kilometers. The satellite signals can reach isolated, mobile, and dispersed populations with ease, and recent studies show that the cost of the distribution system for television programming can be significantly less by satellite than for comparable terrestrial facilities.[4]

In the case of a less developed country (LDC) it is inconceivable that an undertaking of such magnitude as to provide educational television by satellite for the whole country would not be joined, if not

controlled, by the national ministry (department, bureau, etc.) of telecommunications or a comparable entity. In any event, it would be very desirable from an economic standpoint. For little additional cost, a revenue producing service could be provided using the same satellite and slightly enlarged earth stations.

Section B of this report describes progress toward the development of a model to determine the least-cost joint system.

Inasmuch as a telecommunications system may be used to carry a variety of technological approaches designed to enhance the educational process, some evaluation as to which approach or approaches to use would be desirable. Section A of this report presents the progress to-date in this effort as given in the literature.

Section A

EDUCATIONAL TECHNOLOGY
A Summary Of Recent Evaluations

> "The forms of society we shall see in the twenty-first, century in my judgement, will depend less upon our relationship as workers to the means of production of goods and services and more -- much more -- upon our relationship as total social beings to the means of production of information, ideas and images."
>
> -- Rose K. Goldsen
> Cornell University

Education, as contrasted with instruction, is seen as "a preparation for life through more adequate adaptation to one's environment." [1] It is regarded as being concerned with the "whole student" and as relating to "his mental, emotional, physical, social, cultural, and technological adjustments." [2] Or, put another way: "In the broadest sense the aims of education include the transmission of knowledge, the installation of values and the development of intellectual, physical, social, and artistic skills and competencies." [3]

It may be argued that attempting to evaluate the effectiveness of any particular educational system or process in contributing to the above implied objectives is tantamount to measuring (quantifying) the whole individual and the "usefulness" he is imputed by society. Surely, there is no more herculean task!

Most people are well aware of this problem. For instance, Jamison and Suppes in discussing alternatives for improving productivity and efficiency in education state their belief that "clearly categorizing and measuring the outputs of an educational system is presently an impossible task." [4] In their view, "much of the work that would be required in such an endeavor would involve assessment of values, not facts, and even if...(one) were to reach a concensus, both the desirability and capability of...(a government's) acting on this concensus are dubious."

As a result, most evaluations of alternative educational processes are based largely on the ability of these processes to perform the instructional part of education and are, thereby, implying that the affective component of education is invariant under the several alternative processes. Thus, Jamison and Suppes adopt as their definition of the output of educational systems, with susceptibility to measurement clearly

in mind, two types of proxy measures: "1) enrollments weighted by time and type of exposure, and 2) distributions of scores on achievement tests."

In and of itself, this approach biases the educational reformer toward methods and systems alternatives that reportedly maximize this "objectively" determined transference of information -- with little overt regard to other aspects. I would agree with Miller that such a bias, although understandable, creates the possibility of our "neglecting important variables in the educational systems we are evaluating because we do not have adequate ways to measure them." [5] I feel it appropriate to reiterate the following caveat of Bruner and Olson. [6]

> The assumption that knowledge was central to the educational enterprise and that it was independent from the form of experience from which it derived and the goals for which it was used has had several important and persisting effects on educational thought. First it has led to a certain blindness to the effects of the medium of instruction as opposed to the content, a blindness which McLuhan has alerted us to, and secondly, it has led to an unsatisfactory and restricted conception of ability. As the effects of experience were completely assimilated to the account of the acquisition of knowledge, experience was considered less and less central to the acquisition of ability. Since knowledge was all, ability could be taken for granted -- one had abilities which may be used to acquire knowledge. Abilities were then projected rather directly into the mind in the form of genetic traits (Jensen,) while the culture and experience were both ignored as possible candidates to account for their development. The effects of this strange turn has been to obscure the importance of developing abilities, often thereby making schooling irrelevent.

Of course, technology is but an instrument and in the strict sense of the word is neutral. The final judgement on the effectiveness of various technologies will depend almost entirely on the software, on the programs which they are used to disseminate. With this view, the educational technologies are seen as tools to be used in the educational process much as a textbook -- i.e., that they are not capable in and of themselves of more than imparting information, nor were they ever intended to do more. [7] To the extent that this is true, it is quite sensible that evaluations of technologies deal only with the cognitive, not the affective, component of education.

Nevertheless, it would be hoped that the current trend in some schools of education toward an emphasis on the recipient of education, on learning theories and away from an emphasis on the dispenser of information, on teaching methods will be furthered by the introduction of technology. Certainly the potential for encouraging this shift in emphasis is inherent in much of the recent technology. Especially designed curriculae can place the major burden of the informational, cognitive aspects of education on the technology and free the teacher to improve the affective content of the interaction with and among students.

The point of view adopted here in reviewing the findings to-date of educational effectiveness studies is that it is rational to suppose that telecommunications technology is neutral. The context in which such technology is used will determine the effects of its use in the affective domain. If evaluation of the learned-information capability of various technologies shows differences among them, it is fitting to use them when the ratio of this capability to the corresponding cost if implementation is larger than when conventional methods are employed.

Findings

Now, what have the various studies of and experiments with educational technology shown? The results which seem of most relevance here are that: 1) remote television instruction can teach at least as well as a conventional classroom lecture situation if some form of feedback to the instructor is provided; [8,9,10] 2) instructional radio and radio-vision (aural material supplemented with still pictures provided by one of several means such as facsimile, slow-scan TV, pre-distributed handouts, predistributed film strips, etc.) can be , in some instances as effective in teaching as television (sometimes it can be even more effective); 3) a balanced approach to using the technology will produce the most learning. That is, in general, "use the simplest, barest, clearest, and least distracting presentation possible." This result, coupled with the previous one, indicates that television as presently used may be optimal only a small percentage of the time; 4) "considering 'dollars alone' and 'measurable results' no one knows whether instructional technology is worth the cost." [11,12] (It is probable that this statement

was focused on the American scene where only a few "experiments" in ETV have sufficient audience to benefit to any extent from economies of scale, since, in the same report, it is noted, with implied enthusiasm, that El Salvador's present systematic approach to improving education never could have been possible without advanced instructional technology.) However, when other effects are included, most practitioners are enthusiastic about the results and the low cost levels being achieved.

A word regarding some experiments that are now in the planning stage may be indicative of the perceived value of one technology in comparison to the others. Of the several being given attention in the current literature, there are none which involve purely radio. All are using television! This may be due, in part, to the recognition that most people, given a choice between radio or television, will choose television. Also, the effectiveness of radio may not be known and the entertainment aspects of television are probably not seen as a possible deterrent to learning. Strong pressure is thus created for "keeping up with the Joneses." ETV is clearly the newer medium and will attract its share of proponents if for no other reason. As Forsythe points out, "If present circumstances were the product of systematic planning and convincing evidence, few would resist them, but that, unfortunately, is not the case. On the contrary, it is more reasonable today than ever before to regard radio as a versatile, a practical, and an effective instructional medium." [13]

The probable outcome of all this is that television will continue to be provided in the educational context not only because there are some applications in which it is more effective than other technologies, but also because of its popular image. (As Skorhia puts it, "It has been generally assumed that communication through more than one sense is better than communication through only one: For example, that television teaches better than radio, sound-film better than silent film, movies better than still pictures, color TV more effectively than monochrome, and so on.") [14] Whether in these applications the added benefits of television exceed its added cost is moot

because we are accustomed to thinking of education in terms of the classroom setting and are trying to duplicate

the classroom at the remote location. As one technologist said, "I consider the optimum system as one that establishes an environment for the off-campus student which, as closely as possible, approximates the situation of the regular full-time student on campus." [15]

In this same light, I believe that the following observations will contribute to a clearer understanding of the relative merits of the technologies.

Other Considerations

Most comparisons of technologies have been based on duplicating a classroom situation and measuring the ability of either radio or television to instruct as well as if students were in the live, traditional setting. I have no quarrel with the findings that radio can, in many of these cases, concentrate the attention of the students to a higher degree and actually produce better retention. These comparisons, however, are structured such that television has been forced into the mold of a more limited medium. In instances, such as "Sesame Street", where the image and motion capabilities of the television have been integrated into the total presentation, results seem to show that television has a clear advantage. (Undoubtedly, the age of the audience is an important variable, as well as the subject matter to be presented.)

In comparing radio and television the statement is often made that television costs five times as much. From this, the conclusion is drawn that unless television is five times better in its ability to instruct, radio is the "best buy" in terms of dollars per unit of retained information. It may still be that radio is more "cost-effective", but the proper comparison must account for the total learning experience and, therefore, the total educational budget, as follows.

Television and radio have been used in conjunction with and largely in support of the total educational infrastructure. The measurements of efficacy using television or radio are, then, measures of the efficacy of the total system (including either radio or television). Suppose that one could (even though one cannot) quantify the output of the total system-with-television and also the output of the total system-with-radio. Let the output of the system-with-television be represented by $O_{tv,s}$, the output of the system-with-radio by $O_{r,s}$, and the output of the system without either radio or television, i.e., with purely tra-

ditional inputs to education, be represented by O_s. If the cost of the systems are then represented, respectively, by $C_{tv,s}$, $C_{r,s}$, and C_s then the correct and fair comparison to determine whether television is worth the extra cost is not whether

$$\frac{O_{tv,s} - O_s}{C_{tv,s} - C_s} \text{ is larger than } \frac{O_{r,s} - O_s}{C_{r,s} - C_s},$$

which is, essentially, a marginal revenue to marginal cost ratio,* but rather is whether

$$\frac{O_{tv,s}}{C_{tv,s}} \text{ is larger than } \frac{O_{r,s}}{C_{r,s}}.$$

An illustration of the above will help convey the meaning. A proposal of the executive secretary of the National Education Association, Sam Lamberg, reported in the Palo Alto Times of May 4, 1972, suggested that a national average cost standard for education (elementary and secondary) of $1200 per pupil per year be established. This would correspond to C_s. Cost figures for one hour of programming per day of "Sesame Street" averaged over the estimated audience of 7 million preschool children came to $0.65 per child for the first year.[16] Part of this cost is undoubtedly due to distribution costs, nevertheless, let us suppose that in addition to these mostly software costs there is a 10% increase in cost to provide the hardware (as if one were required to purchase the television sets and install the means of distributing the program signals)** and that the programming is increased to eight hours a day. The cost per pupil would then be $(1.10)(0.65)(8) = $5.72. Further, assume, very conservatively, that radio would cost only one-tenth as much as television, or $0.57 per pupil per year.

The correct comparison should not be

$$\frac{O_{tv,s} - O_s}{O_{r,s} - O_s} \overset{?}{>} \frac{10}{1},$$

---

* An individual firm in a purely competitive market will not produce at a level of output such that the ratio of marginal revenue to marginal cost is a maximum. It will maximize instead, the ratio of total revenue to total cost. This principle, I believe, applies in the present case of comparing the desirability of using one technology in preference to another.

** The Brazilian education project involving a satellite estimates that their hardware costs are less than 10% of the total cost of the experiment.[17]

but rather should be

$$\frac{O_{tv,s}}{O_{r,s}} \overset{?}{>} \frac{\$1200.00 + \$5.72}{\$1200.00 + \$0.57} .$$

It is easily seen that very different results may come from the two comparisons. In the first case, it is likely that radio would be used in the majority of cases. In the second comparions, television would be able to prove in, and rightly so, for only small increases in total output over the system with radio. Also, a nation's total budget for education becomes a direct factor in determining which technology to use, as well it should.

Application

In the light of these findings and discussion the design and analysis of alternative national telecommunications systems should proceed on the basis that they will re required to carry several channels of television. Full-action television, at least so far, is the largest single bandwidth item to be encountered for transmission over the system. Any other educational technology may, therefore, be accommodated once bandwidths sufficient for television have been reserved.

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Section B

SATELLITE SYSTEM OPTIMIZATION

The potential applications of telecommunications technology are limited only by man's ingenuity. The telecommunications satellite holds great promise of permitting this technology to reach into even the most remote parts of a country. For sufficiently large scale applications it is the least-cost method for high penetration.[1,2]

The task is to be able to determine the least-cost satellite system for particular applications. The development of an appropriate model is well underway.

The Long Range Goal

The final model of the essential parts of a national joint telephony/ educational technology satellite system, as now perceived, will be able to answer the following questions:

1. At a given point in time, characterized by a) the number of cities, towns and villages to be served by the system, and b) the demand for service (the number of channels into and out of each city, town or village), what is the least-cost combination of satellite power and earth station sensitivities and powers that will provide the service?
2. Taking into account economies of scale in the purchase of components, what is the least-cost schedule for increasing the capacity of the earth stations as the demand at their locations increases?
3. As the demand between any two cities increases, for what combinations, in terms of the number of channels and the separation distance between the cities, may it become less expensive to serve the communications needs by terrestrial facilities rather than by satellite (this will be a function of the satellite fill as well as of component costs)?
4. In the long-run, what is the proper role of the telecommunications satellite in serving the demand for communications? Will it eventually serve as the link among only light traffic centers or can it be cost-effective in serving overflow traffic between large traffic centers?

The answers to all these questions together constitute the necessary information with which to determine the long range implementation of national telecommunications facilities to serve given projected needs.

Present Model Capability

The model in its present form is a first step toward the realization of the final model. It has been devised primarily with the educational part of the system in mind. The implementation of the model as a computer program enables a least-cost system to be determined that will provide television program reception at any number of small "slave" stations (earth stations) as broadcast from a few "master" origination stations and separate voice or digital communication from the slave stations to the master stations. (At present the program will not accommodate different sizes of slave stations, nor communications among slave stations. When these rather significant additions are made, the answer to question one will have been given.)

Within the model, the cost of the satellite is entered as a charge per watt of satellite power used. This approach permits the selection of the satellite as a separate component of the model. During this selection the costs and capacities of the various satellites that have been described in the domestic satellite filings before the FCC were compared (although the methodology is completely general and can be used with any set of satellites) under several plausible demand conditions to determine the satellite (including replacements, spares and increases in number as demand grows) with the smallest cost per watt of power.

A typical output of this present model is shown in Figure 1, where

$$C_{lds}(c,N) = C_s(c,N) + C_b(c,N) + NC_e(c,N)$$

and

$C_{lds}(c,N)$ is the cost of the total satellite system

c is the number of video channels carried by the satellite

N is the minimum number of video-receive earth stations in the system

$C_s(c,N)$ is the cost of that part of the space segment (i.e., the satellite power) actually used by the educational system

Satellite System Cost Parameters with $C_{w/y}$ = \$15,000 and c = 4

N	$C_e(c, N)$	$C_b(c, N)$	$C_s(c, N)$	$C_{lds}(c, N)$
100	13, 277	190, 453	1, 719, 027	3, 237, 180
250	11, 404	244, 954	1, 969, 774	5, 065, 735
500	9, 437	263, 594	2, 626, 464	7, 608, 640
1, 000	8, 115	295, 771	3, 515, 082	11, 925, 760
2, 500	6, 999	427, 823	5, 101, 800	23, 027, 488
5, 000	6, 459	520, 435	6, 886, 546	39, 700, 528
10, 000	6, 085	697, 998	9, 391, 256	70, 938, 144

Satellite System Cost Parameters with $C_{w/y}$ = \$30,000 and c = 4

N	$C_e(c, N)$	$C_b(c, N)$	$C_s(c, N)$	$C_{lds}(c, N)$
100	21, 118	244, 623	2, 025, 320	4, 318, 709
250	12, 392	264, 884	3, 407, 118	6, 770, 074
500	11, 101	293, 152	3, 828, 800	9, 672, 456
1, 000	9, 218	400, 766	5, 044, 458	14, 663, 023
2, 500	7, 638	492, 540	7, 430, 076	27, 016, 832
5, 000	6, 881	623, 697	10, 014, 704	45, 045, 536
10, 000	6, 365	860, 615	13, 600, 203	78, 108, 272

Satellite System Cost Parameters with $C_{w/y}$ = \$50,000 and c = 4

N	$C_e(c, N)$	$C_b(c, N)$	$C_s(c, N)$	$C_{lds}(c, N)$
100	34, 185	258, 583	1, 890, 907	5, 568, 063
250	19, 415	287, 412	3, 418, 220	8, 559, 295
500	11, 785	389, 192	5, 663, 671	11, 945, 315
1, 000	10, 338	439, 389	6, 659, 990	17, 437, 072
2, 500	8, 287	564, 274	9, 812, 110	31, 093, 520
5, 000	7, 311	739, 032	13, 221, 370	50, 516, 352
10, 000	6, 649	1, 045, 246	17, 928, 640	85, 466, 640

Figure 1. Representative Output of the Present Model.

$C_b(c,N)$ is the cost of the master station(s)

$C_c(c,N)$ is the cost of a slave station

$C_{w/y}$ is the cost of the use of one watt-year of satellite power

The program minimizes the cost of the overall system. It does not minimize the cost of the earth stations alone. Conceivably, other pricing policies for satellite power could be used that would alter this strategy. The model can easily accommodate these changes by varying the cost per watt of satellite power.

Future Work

As work has progressed toward the final model (one that will include the effect on costs of handling a nation's regular commercial telephone and telegraph traffic over the same satellite system that is used to transmit the educational programming), it has become apparent that before modifications to the present computer program can be made some knowledge must be obtained about the least-cost schedule for increasing the capacity of a given earth station facing a given demand profile (question 2). The following model has been proposed and its feasibility will be investigated within the next two weeks as contacts at Philco-Ford and GTE Lenkurt allow the pertinent cost information to be assembled.

Let $F(n)$ be the cost of an earth station with a capacity of n channels working through a particular satellite (identical earth stations are assumed for transmit and for receive). $F(n)$ will be a function of N because of economies of scale. Let $f(n,n_i)$ be the cost of upgrading the earth station's capacity from n channels to $n + n_i$ channels. Assume a linear increase in demand for channels through the earth station such that $n_e(t) = a + bt$ where t is the number of years since time zero, a is the demand at time zero, and b is the number of channels per year increase in demand. Suppose that when $t = T$ the end of the planning period will have arrived.

The present worth of the costs of meeting the increasing demand out to time $t = T$ is:

$$PWC(k') = F(a + n_i) + \sum_{k=1}^{k' = \frac{Th - n_i}{n_i}} pwf'(i', kn_i/b) \times f(a + kn_i, n_i)$$

Because $F(n)$ and $f(n,n_i)$ are not susceptible to mathematical expression (they are not continuous functions, and they depend on N and on the charge per watt of satellite power, $C_{w/y}$) it is not possible to find the minimum of $FWC(k')$ by differentiation. It will be necessary to proceed by direct evaluation for several values of k' with each set of values for a,b, and i%. The probable outcome will be as shown in Figure 2.

The parameter k' is the number of times during the planning period of length T that the station will undergo upgrading, if there were only one size station in the system. With more than one size the effec of economics of scale must be included. All the stations' schedules will interact to produce the overall schedule. As an example, Brazil has about 4,700 towns and villages of less than 2,000 population and 1,000 towns of between 2,000 and 5,000 population. Suppose that there and N_1 towns and villages that will require n_1 channels at first ($a_1 = n_1$) and N_2 towns that will require n_2 channels ($a_2 = n_2$). If $d(N)$ represents the discount factor that accounts for economics of scale, then the cost of meeting the demand for n_1 and for n_2 channels with different equipment is:

$$C_{N_1,N_2} = N_1 d(N_1)F(n_1) + N_2 d(N_2)F(n_2)$$

and the cost of meeting the demand using the larger capacity equipment throughout is:

$$C_{N_1+N_2} = (N_1 + N_2)d(N_1 + N_2)F(n_2).$$

It may be that $C_{N_1+N_2}$ is less than C_{N_1,N_2} in which case, only the larger capacity station would be installed. It may also be that even if $C_{N_1+N_2}$ is larger than C_{N_1,N_2} it would still be more economical to use only the larger capacity station.

Suppose, for instance, that the larger capacity station would at some time be needed at the N_1 locations which have an initial demand for only n_1 channels. Then, if $C_{N_1+N_2}$ is larger than C_{N_1,N_2} but

$$C_{N_1+N_2} < C_{N_1,N_2} + \left\{\min_{k'}\left[FWC(k') - F(n_1)\right]\right\}N_1 d(N_1)$$

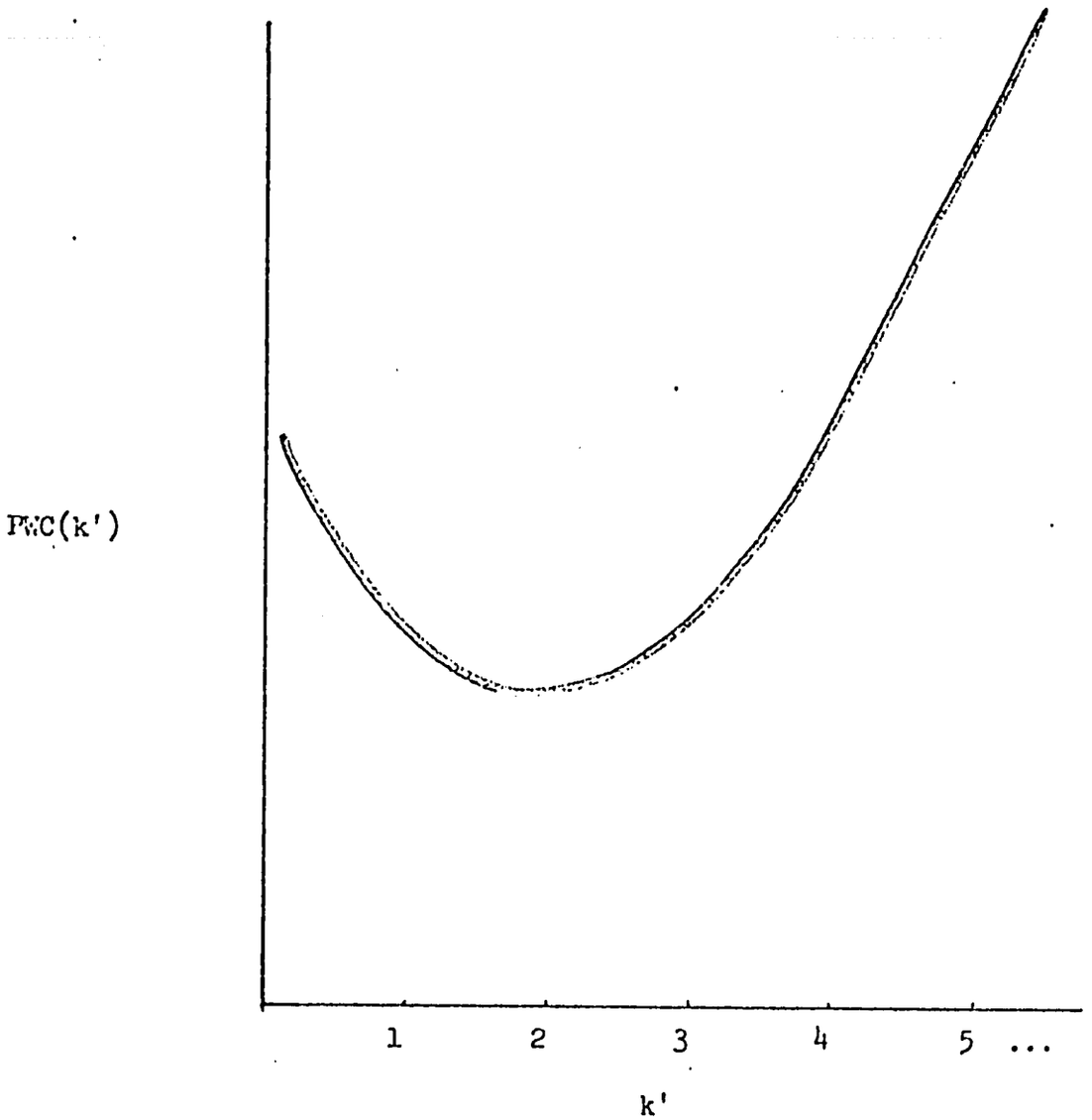

Figure 2. The Present Worth of the Cost of Upgrading the Capacity of an Earth Station over the Planning Period of length T, as a Function of the number of Upgradings.

or

$$C_{N_1 + N_2} < C_{N_1,N_2} + \min_{k'} \left\{ \sum_{k=1}^{k' = \frac{n_2 - n_1}{n_i}} pwf'(i\%, kn_i/b) \times f(n_1 + kn_i, n_i) \right\} N_1 d(N$$

it would still be less expensive to install only the larger capacity station. In words: economies of scale and station upgrading schedules can be such that it is less expensive to install only one size station than to install two different sizes and later upgrade the smaller size to the same capacity as the larger size.

From considerations such as the above, it will be possible to construct a light-route growth strategy. The objective of this model is to determine the cross-over point (in distance-channel space) for various terrestrial technologies. That is, at any given distance and channel requirement, it is less expensive to serve the link using the satellite (and if so, what size earth station is required for this link as well as to serve the other satellite-linked cities) or should terrestrial facilities be used, and which one (open wire, cable pairs, microwave, coaxial cable, etc.). Combining this type of information from all routes will be a necessary step in determining the total requirements on satellite capability and thus help to determine which satellite is used.

This is an iterative process since the cross-over points will be determined by the optimum size stations and the optimum schedule for station upgradings. These will be determined by the number of stations and the required initial capacity of the stations and the cost per watt of satellite power, which, in turn will depend on the optimum size of the stations and the optimum schedule for upgradings. It will be necessary to make initial estiamtes for some paramcters, run through all the programs of the total model and then adjust the initial estimates to more nearly match the final outcome on succeeding runs.

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SECOND PERIOD REPORT TO AED

by Carl Mitchell,

I. Introduction

It has been noted in the literature that a very simple relationship exists between a nation's gross domestic product (GDP) and its telephone density (the number of telephones per 1000 population).[1, 2] It should not be inferred from this that the demand for telephone service can be characterized by the same simple relationship to GDP. Only in the more developed countries is the investment in telephone plant sufficient to produce a demand-limited market. The budget constraints of less developed countries (LDC's) produce a very definitely supply-limited market. That is, at current prices for services, there is more demand than there is facility to satisfy the demand.[3] Especially in such a supply-limited situation, there is impetus to determine the least-cost method of providing service, since the target for the communications entities of these LDC's is a development plan to upgrade the present telecommunications system to make it compatible with the socioeconomic level of the country, and to do so within the telecommunications budget.

We feel that the telecommunications satellite can significantly reduce the costs of service to dispersed populations or subscribers (e.g., interconnection of CATV companies) while maintaining the same standard of performance as obtained with terrestrial systems. In fact, we believe that the satellite makes economically feasible some services that otherwise could not be supported by LDC's, and that further experience with telecommunications via satellite will improve its economic advantage for these services. *

This advantage, however, may not be realizable unless the large cost of the satellite, and, to a much lesser extent, the costs of the earth stations, are shared in a multipurpose venture. Such a venture is, of course, entirely possible from a technical standpoint, since a satellite can simultaneously receive and retransmit several dissimilar signals (be they telephone, telegraph, television, analog or digital). We, therefore, strongly recommend that coordinated inter-

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* An indication of the continuing trend to lower costs for satellite services is the dramatic reduction in space-segment per-year costs of a telephone circuit. Using figures generally available, the graph in Fig. 1 was plotted. (see also reference 4) (It should be emphasized that these costs do not include the ground segment of the system. They are shown only to draw attention to the declining costs currently being experienced in satellite technology.)

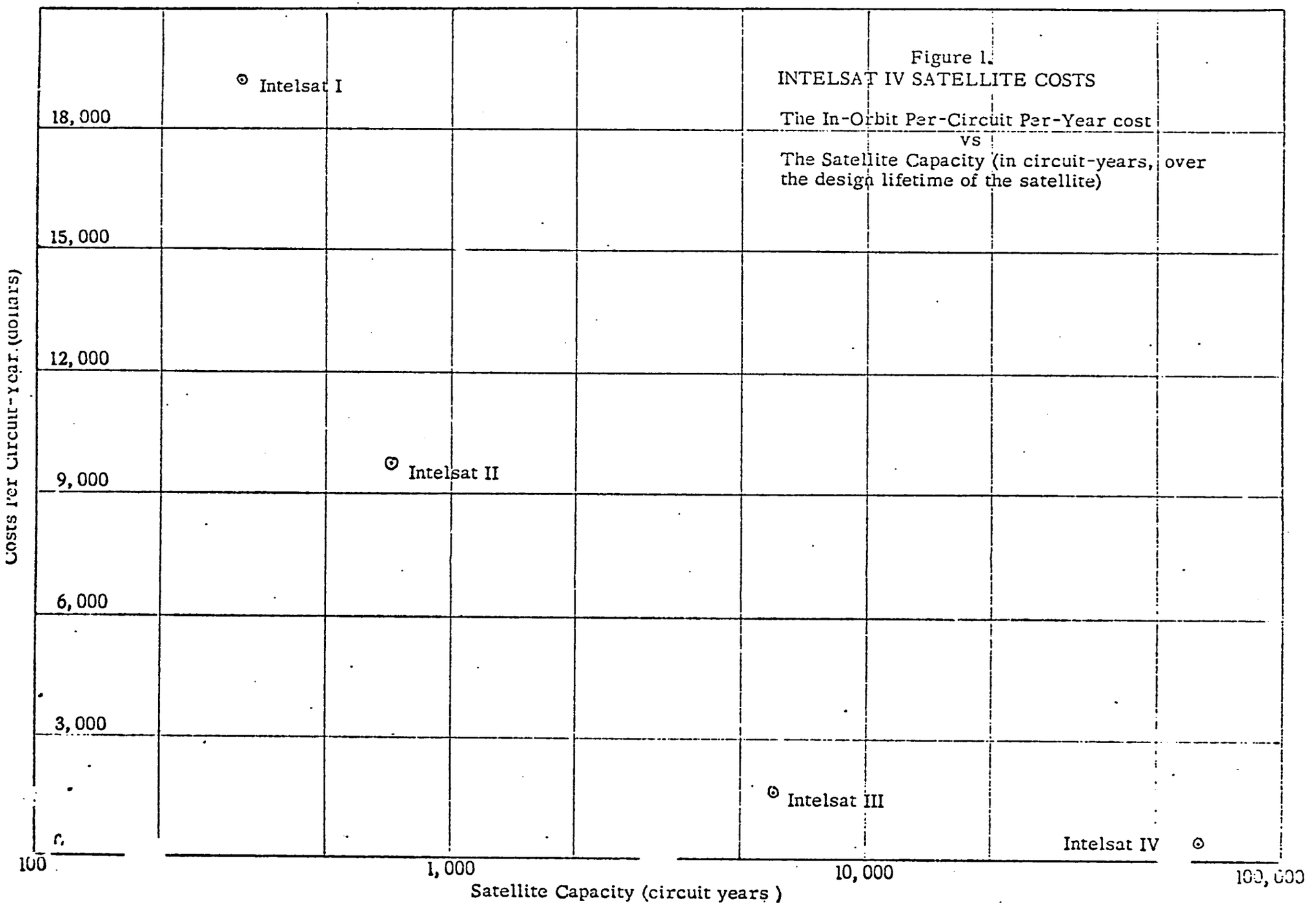


Figure 1.
INTELSAT IV SATELLITE COSTS

The In-Orbit Per-Circuit Per-Year cost
vs
The Satellite Capacity (in circuit-years, over the design lifetime of the satellite)

agency planning be encouraged where a national satellite is being considered.

A prime candidate, in addition to commercial telephony, for a share in a multipurpose system is educational programming. It has received widespread attention over the past few years,[6] especially in LDC applications. In part, this is because of its potential for reducing costs. Traditional approaches to education have always been labor intensive. In fact, it is largely for this reason that the present cost squeeze in education has become so accute. Other "industries" have benefitted from technological innovations and improvements to increase the productivity of their employees. This increase in efficiency permitted higher wages. Although no corresponding increase in efficiency occurred in education, teachers and administrators participated in the upward wage trends. As Baumol states, "...(this) suggests that, as productivity in the remainder of the economy continues to increase, costs of running the educational organizations will mount correspondingly, so that whatever the magnitude of the funds they need today we can be reasonably certain that they will require more tomorrow, and even more on the day after that."[5]

Reducing the labor-intensive nature of the educational enterprise can, of course, help to open the way for technologically motivated reductions in cost. With low-cost earth stations, the distribution of educational materials via television, with or without a voice talk-back capability, becomes a very attractive alternative to the slow and costly process of specialized training of teachers and the subsequent continual problem of motivating teachers to work in rural areas. Due care must be exercised so that the affective component of education does not suffer as the instructional component is being helped with remote programming expertise.

This report will present results of our work and give several examples of the capability of programs developed here at Stanford to determine the least-cost system suitable for educational television program distribution with audio feedback. It will also outline the work in progress toward a model to determine a least-cost configuration of a multipurpose system to provide both television distribution (commercial or educational or both) and regular telephone service.

II. Least-Cost TV/Return Audio System

A. Terrestrial Systems

An investigation of terrestrial technologies revealed that only coaxial cable and microwave radio facilities have sufficient bandwidth to carry television programming. Except for relatively short distances, microwave radio is the less expensive of the two. A typical radio link consists of the transmit terminal, several repeaters and the destination terminal. These are shown schematically in Fig. 2. The average distance between repeaters (called the hop distance) is 30 miles.

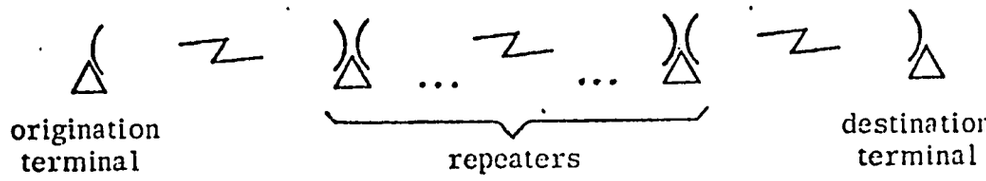


Figure 2. A Microwave Radio Relay Link

Each origin and destination terminal requires the following equipment:

transmitter or receiver (per TV channel)	$4,500
antenna and feed	1,900
standby batteries and charger - first channel	1,600
each add'l channel	200
tower (150', guyed)	6,000
installation and alignment - first channel	1,000
each add'l channel	500
voice feedback equipment	
transmitter or receiver	4,500
antenna and feed	1,900
batteries and charger	200
multiplex equipment - heavy route, per channel (voice)	2,000
light route, per channel (voice)	1,000
installation and alignment - first channel (voice)	900
each add'l channel (voice)	200

These costs can be represented in equation form by

$$C_{mt}(c) = \$24,500 + \$7,400(c - 1) \quad \text{for heavy routes (voice)}$$

$$C_{mt}(c) = \$23,500 + \$6,400(c - 1) \quad \text{for light routes (voice)}$$

where $C_{mt}(c)$ is the cost of microwave terminal-station equipme

and c is the number of television channels being distributed.

Each repeater station requires the following equipment:

transmitter and receiver (per TV channel)	$7,000
antennas and feed	3,800
standby batteries and charger - first channel	2,000
each add'l channel	200
tower (150', guyed)	6,000
installation and alignment - first channel	1,300
each add'l channel	500
voice feedback equipment	
transmitter and receiver	7,000
antennas and feed	3,800
batteries and charger	200
installation and alignment	1,100

or, in equation form,

$$C_{mr}(c) = \$32,200 + \$7,700(c - 1)$$

An important simplification was made at this point. A microwave terminal station (no retransmission of the video signal is required) would only be used in the distribution network at the ends of branches where a final destination has been reached and the particular city in question is not serving, simultaneously, as a repeater link for other cities. Nevertheless, each terminal station will have its video transmit counterpart somewhere upstream towards the origination station. This is significant in that it allows the costs of the microwave system to be modeled (on the low side) as the total number of stations used, whether terminal or repeater, times the cost of a repeater station: or, in equation form,

$$C_{ms}(c, N) = (1 + \eta(N))NC_{mr}(c)$$

where $C_{ms}(c, N)$ is the cost of the microwave system

N is the number of cities being served by the system,

c is the number of TV channels being distributed.

$\eta(N)$ is the ratio of the number of microwave repeater stations between cities to the number of cities connected by the network.

To make the cost-components of a repeater station comparable to those included later on for satellite earth stations, the equipment costs of a repeater station were modified to reflect the costs of land (land, grading, roads, and tower foundation) and maintenance. Maintenance was assumed to be 15 per cent of first cost (an average figure used by Pacific Telephone and Telegraph Co.) over a 25-year period (PTT uses 15.99 years), and land costs were assumed to be $8,000 (this allows for the fact that not all sites will require land or towers).

The other costs incident to the design and implementation of the system (such as transportation, documentation, spare parts, engineering, commercial power connection, etc.) were broadly assumed to be common to any other telecommunications system being considered, and were not, therefore, explicitly included. (Another reason is that one comparison of the cost of a microwave system to the cost of a satellite system was done on the supposition favorable to the microwave syste that no intermediate repeater stations would be required, i.e., $\eta(N) = 0$. Thus each station would be located at or near a city to be served, similar to the placement of satellite earth stations if a satellite system were used, and support costs for either type of installation would be fairly comparable.)

The addition of these costs to $C_{mr}(c)$ gives:

$$C_{mr}(c) = \$72,600 + \$17,500(c - 1)$$

and

$$C_{ms}(c, N) = (1 + \eta(N))N(\$72,600 + \$17,500(c - 1))$$

The values of N and c are known in any given situation. $\eta(N)$, on the other hand, can be known accurately only after a preliminary route survey with topographic maps and path profiles has been completed. It was sufficient for our purposes, however, to derive a rough estimate of the functional dependence of η on N. A uniform distribution of cities throughout the entire area to be served was assumed. Although not a very likely distribution for an actual system, it might be argued that the number of repeaters required to serve such a distribution could be considered as an upper bound since any departure from uniformity would allow advantage to be taken of the clustering that would appear. It was further assumed that the origination station was located at one of the N cities to be served. The straight-forward derivation of $\eta(N)$ is as follows.

Consider a region of rectangular shape L miles long by W miles wide. For a uniform distribution, each city will be at the center of a smaller rectangle that is $L/N^{1/2}$ miles long by $W/N^{1/2}$ miles wide (see Fig. 3). The intercity separation distance is thus either $L/N^{1/2}$ miles (long link) or $W/N^{1/2}$ miles (short link) depending on whether the direction of travel is parallel to the length or to the width of the rectangle. If, insofar as possible, cities are connected to their neighbors using short links fewer intercity repeaters will be required than with any other link patter. With this pattern, the network will consist of $(N^{1/2} - 1)N^{1/2}$ short links and $(N^{1/2} - 1)$ long links.

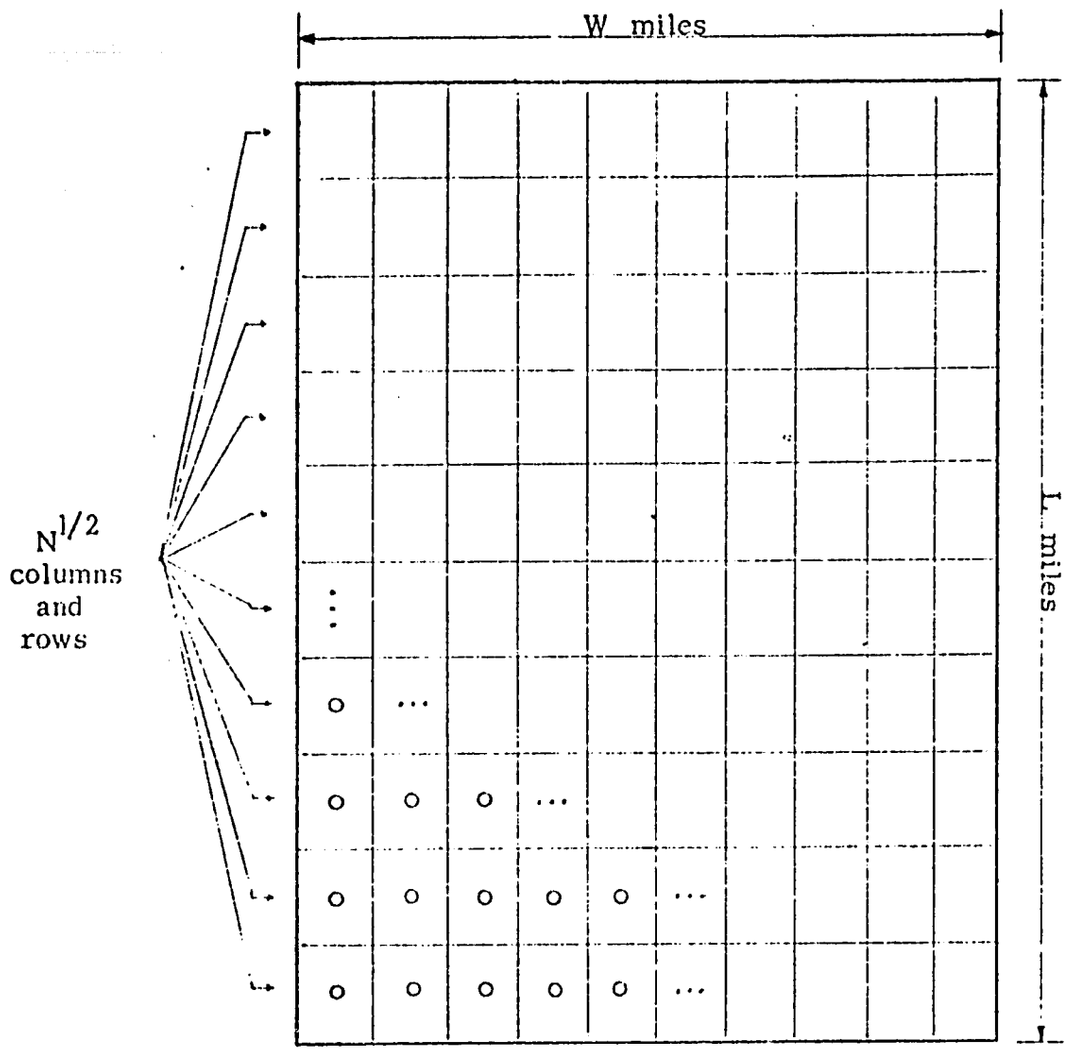


Figure 3. A Rectangular Educational Satellite Region Containing N Uniformly Distributed Cities.

In calculating the total number of intercity repeaters implied by this pattern, we let h represent the average inter-repeater (hop) distance and D represent the distance between cities, or the link length. Because h is the average hop distance and not the maximum, and because of the large numbers of equal length links involved, a reasonable approximation for the average number of repeaters per intercity link as a function of link length is taken to be $n = (D/h - 1)$. This number will generally not be an integer.

An equation for the total number of intercity repeaters, $N\eta$, may now be written.

$$N\eta = N^{1/2}(N^{1/2} - 1) \times \text{(the average number of repeaters in a short link)}$$
$$+ (N^{1/2} - 1) \times \text{(the average number of repeaters in a long link)}$$

$$= N^{1/2}(N^{1/2} - 1)(W/hN^{1/2} - 1) + (N^{1/2} - 1)(L/hN^{1/2} - 1)$$

or

$$\eta = (N^{1/2} - 1)(W/h - N^{1/2})/N + (N^{1/2} - 1)(L/hN^{1/2} - 1)/N$$

For very large N, this equation would yield a negative value for η. To prevent this, η was defined as the larger of the value given by the above equation and zero. For L = 1,500 miles, W = 1,000 miles (corresponding roughly to the size of the Rocky Mountain region), and h = 30 miles, Table 1 gives some representative values of N and the corresponding η.

TABLE 1

$\eta(N)$ for representative values of N

N	η
100	2.46
250	1.16
500	.52
1,000	.07
1,140	.00
10,000	.00

B. Satellite System

A satellite long-distance transmission system consists of the following components: 1) a video-transmit, audio-receive up-link earth station at each television origination point; 2) a satellite; and 3) a video-receive, audio-transmit earth station at each local receive point. (The number of local receive points will generally be greater than the number of cities being served. In any event, it cannot be less.)

Two types of video-receive earth stations might be distinguished according to their received output signal-to-noise ratio. Earth stations that feed local distribution subsystems would need a higher output ratio than would earth stations that serve isolated subscribers (no further distribution is necessary). For simplicity, our analysis assumed that all earth stations provide the same higher quality signal as that required for redistribution. A slight cost savings could be realized in any actual implementation by limiting use of the higher quality station to receiving points that actually require the higher quality signal.

The cost of the satellite distribution system may be expressed as:

$$C_{ss}(c, N) = C_s(c, N) + C_b(c, N) + NC_e(c, N)$$

where

$C_{ss}(c, N)$ is the cost of the satellite system (in $)

c is again, the number of video channels carried by the satellite

N is the minimum number of video-receive earth stations in the network

$C_s(c, N)$ is the cost of that part of the space segment of the system actually used by the educational system (here is an implicit assumption of a multipurpose system and the consequent cost saving through sharing) (in $)

$C_b(c, N)$ is the cost of the master video-transmit, audio-receive station(s) (in $)

$C_e(c, N)$ is the cost of a video-receive, audio-transmit earth station (in $)

The earth station costs include the following:

1) equipment costs

2) site costs (assumed to be 40 per cent of the antenna costs)

3) installation costs (assumed to be 10 per cent of the equipment costs)

4) the present worth of maintenance costs over an assumed 25-year lifetime using a discount rate of 10 per cent. Annual maintenance costs are assumed to be 15 per cent of equipment costs.

5) the cost of channel separation and demodulation to baseband for each video channel received. On a per-channel basis, this cost has been estimated to be near $1,200, as follows. A lower bound may be established by looking at the function and cost of an ITFS (instructional television fixed service) down converter. The down converter, used with an ITFS receive-station, does no more than shift the frequency of the incoming rf signal down to the proper TV carrier frequency, using a double conversion process, and then amplifies the result. The cost of the down converter is $800. Demodulation is not included (it, of course, is not necessary in ITFS transmissions). An upper bound may be taken to be $1,500. This is the cost of the equipment needed at a cable headend site to prepare a TV signal, received from a microwave link, for transmission on the cable. This $1,500 does not include demodulation either, but does include AM modulation, frequency translation to the proper cable channel, and power amplification. Insofar as demodulation can be considered to require equipment of lower cost than does modulation, the compromise figure of $1,200 is reasonable.

The computer program developed here at Stanford uses extensive cost information that we gathered on earth station components together with a value for the cost per-watt per-year of satellite rf power to calculate earth station costs and configurations for the criterion of minimum overall satellite system cost. Thus, if the cost per watt-of-space-segment-use increases, minimizing total system cost would require that the earth stations be made more sensitive, and consequently, more costly so that less satellite power need be used. Similarly, if only a few earth stations are to be constructed, their unit cost should be much higher than if many are needed.

The range of per-watt space-segment charges that is used in the following printouts is based on matching in-orbit satellite capacity with various assumed demand curves over time for that capacity. The present worths of the costs that would be incurred in providing sufficient satellite capacity to just meet these demands are calculated using the costs of currently proposed satellites. Then the amount that must be charged for a watt-year of satellite capacity is determined such that the present worths of the revenue streams associated with each demand curve are equal to the present worths of the costs, respectively, of satisfying the demand. The range of charges runs from $C_{w/y}$ = $15,000 per watt-year to

$C_{w/y}$ = \$50,000 per watt-year. $C_{w/y}$ is the cost to the education system of one watt of satellite rf power for one year.

The costs shown in Tables 2 through 7 are representative of those obtaining for a country whose area may be covered by a satellite antenna of 10' equivalent diameter and for which the slant range to the satellite at the furthest 3-dB beam edge is comparable to any location in Northern Montana.

C. Cost Comparison

The cost comparison between the satellite system and the terrestrial system as portrayed above is shown in Figures 4 and 5. It is based on the equations for C_{ms} and C_{ss} developed in the last two sections. Figure 4 gives the costs for systems that carry four video channels and Figure 5 presents the costs for 12-channel systems. Each figure also includes a plot of what the microwave network would cost if $\eta(N) = 0$. This approximates the case where the cities involved are not spread throughout an entire region but are, in fact, so situated that very few intercity repeaters would be needed.

It may be seen that for any regional network serving even as few as 100 cities the satellite system is dramatically less expensive than the terrestrial system. In fact, providing 12 channels via the satellite is less costly than providing 4 channels with the microwave network, even though to provide 12 channels through the satellite involves stacking the TV channels so close together in frequency that adjacent channels must be transmitted on carriers that are cross-polarized with respect to each other (permitting some overlapping occupancy of the available frequency spectrum) and the earth stations must be equipped with two antennas and two preamplifiers.

In view of this cost dependency on the number of cities involved, one is led to ask now many cities might require service in a typical regional system. An example of a region that might actually be served by such an education system is the Rocky Mountain region. In the eight states of this region there are 1168 cities. There are 361 cities of greater than 2,000 population and 100 cities of greater than 10,000 population. An education system transmitting to this area would be of most use in the smaller cities where large or specialized curriculum aids are not readily available. Thus, most of the 361 cities of greater than 2,000 population would probably wish service. This is an obvious case, then, of where the satellite system would be less expensive.

TABLE 2

Satellite System Cost Parameters with $C_{w/y}$ = \$15,000 and c = 4

N	$C_e(c, N)$	$C_b(c, N)$	$C_s(c, N)$	$C_{lds}(c, N)$
100	13,277	190,453	1,719,027	3,237,180
250	11,404	244,954	1,969,774	5,065,735
500	9,437	263,594	2,626,464	7,608,640
1,000	8,115	295,771	3,515,082	11,925,763
2,500	6,999	427,823	5,101,800	23,027,488
5,000	6,459	520,435	6,886,546	39,700,528
10,000	6,085	697,998	9,391,256	70,938,144

TABLE 3

Satellite System Cost Parameters with $C_{w/y}$ = \$30,000 and c = 4

N	$C_e(c, N)$	$C_b(c, N)$	$C_s(c, N)$	$C_{lds}(c, N)$
100	21,118	244,623	2,025,320	4,318,709
250	12,392	264,884	3,407,118	6,770,074
500	11,101	293,152	3,828,800	9,672,456
1,000	9,218	400,766	5,044,458	14,663,023
2,500	7,638	492,540	7,430,076	27,016,832
5,000	6,881	623,697	10,014,704	45,045,536
10,000	6,365	860,615	13,600,203	78,108,272

TABLE 4

Satellite System Cost Parameters with $C_{w/y}$ = \$50,000 and c = 4

N	$C_e(c, N)$	$C_b(c, N)$	$C_s(c, N)$	$C_{lds}(c, N)$
100	34,185	258,583	1,890,907	5,568,063
250	19,415	287,412	3,418,220	8,559,295
500	11,785	389,192	5,663,671	11,945,315
1,000	10,338	439,389	6,659,990	17,437,072
2,500	8,287	564,274	9,812,110	31,093,520
5,000	7,311	739,032	13,221,370	50,516,352
10,000	6,649	1,045,246	17,928,640	85,466,640

TABLE 5

Satellite System Cost Parameters with $C_{w/y}$ = \$15,000 and c = 12

N	$C_e(c, N)$	$C_b(c, N)$	$C_s(c, N)$	$C_{lds}(c, N)$
100	44, 205	328, 056	3, 083, 475	7, 832, 028
250	28, 173	3541861	5, 168, 194	12, 566, 348
500	24, 865	457, 012	6, 227, 586	19, 117, 216
1, 000	21, 722	506, 487	8, 287, 900	30, 516, 720
2, 500	19, 078	739, 824	12, 093, 080	60, 527, 104
5, 000	17, 832	919, 098	16, 257, 658	106, 335, 184
10, 000	16, 980	1, 248, 249	22, 008, 800	193, 059, 920

TABLE 6

Satellite System Cost Parameters with $C_{w/y}$ = \$30,000 and c = 12

N	$C_e(c, N)$	$C_b(c, N)$	$C_s(c, N)$	$C_{lds}(c, N)$
100	68, 250	354, 861	3, 418, 916	10, 598, 739
250	41, 094	460, 870	6, 113, 468	16, 847, 920
500	27, 071	614, 462	10, 116, 378	24, 266, 496
1, 000	24, 318	689, 948	11, 992, 616	37, 000, 112
2, 500	20, 606	877, 653	17, 622, 336	70, 051, 760
5, 000	18, 844	1, 140, 515	23, 679, 872	119, 038, 928
10, 000	17, 650	1, 601, 609	31, 992, 640	210, 097, 520

TABLE 7

Satellite System Cost Parameters with $C_{w/y}$ = \$50,000 and c = 12

N	$C_e(c, N)$	$C_b(c, N)$	$C_s(c, N)$	$C_{lds}(c, N)$
100	81, 443	450, 293	5, 082, 237	13, 676, 797
250	41, 094	606, 186	9, 968, 821	20, 848, 576
500	38, 959	669, 417	10, 121, 574	30, 270, 368
1, 000	26, 058	773, 462	17, 017, 984	43, 849, 040
2, 500	22, 161	1, 030, 177	23, 275, 408	79, 706, 912
5, 000	19, 873	1, 386, 146	31, 278, 336	132, 027, 904
10, 000	18, 332	1, 997, 533	42, 237, 200	227, 550, 608

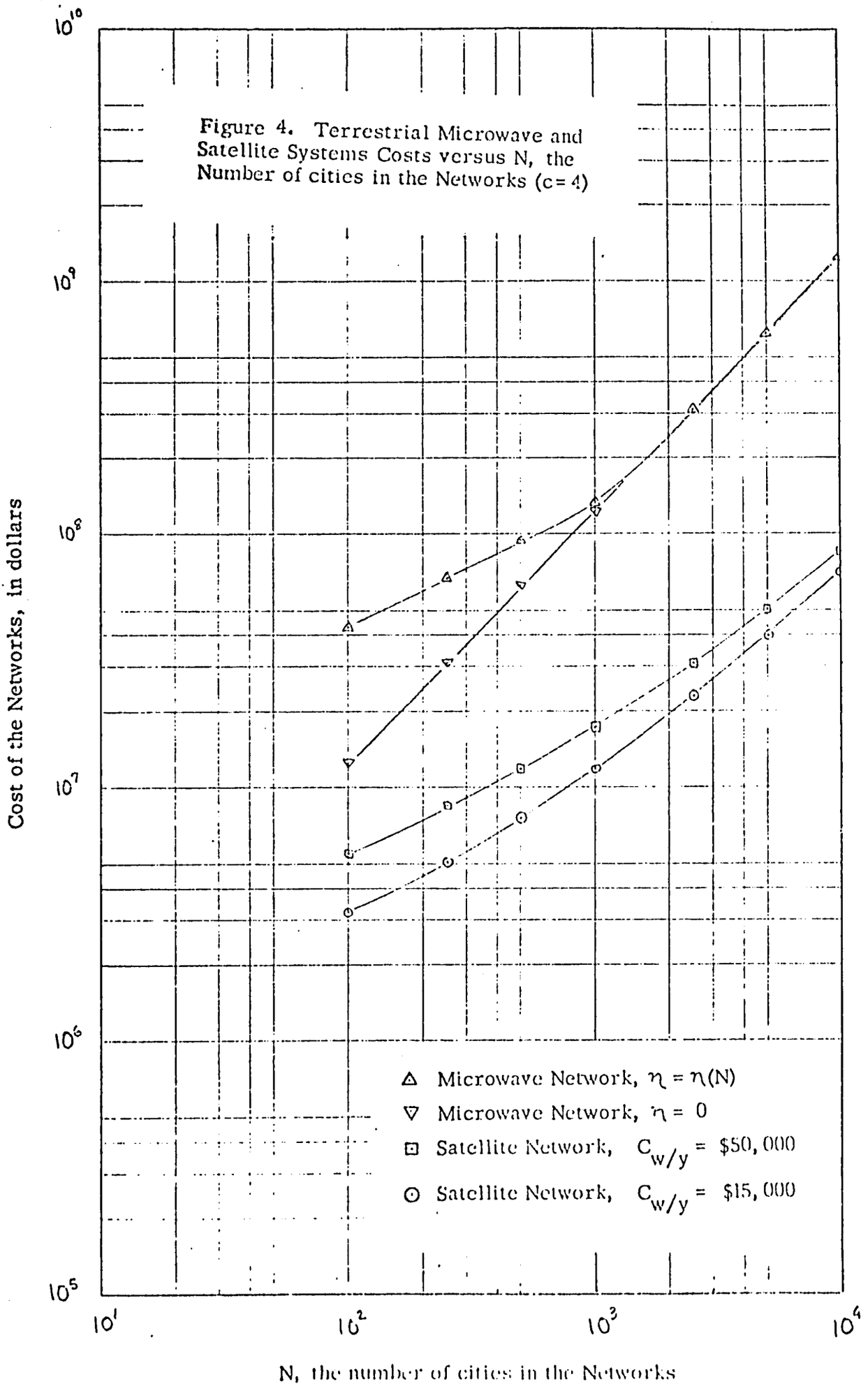


Figure 4. Terrestrial Microwave and Satellite Systems Costs versus N, the Number of cities in the Networks (c = 4)
Cost of the Networks, in dollars
N, the number of cities in the Networks
10^{10}
10^{9}
10^{8}
10^{7}
10^{6}
10^{5}
10^{1}
10^{2}
10^{3}
10^{4}
Microwave Network, $\eta = \eta(N)$
Microwave Network, $\eta = 0$
Satellite Network, $C_{w/y} = \$50,000$
Satellite Network, $C_{w/y} = \$15,000$

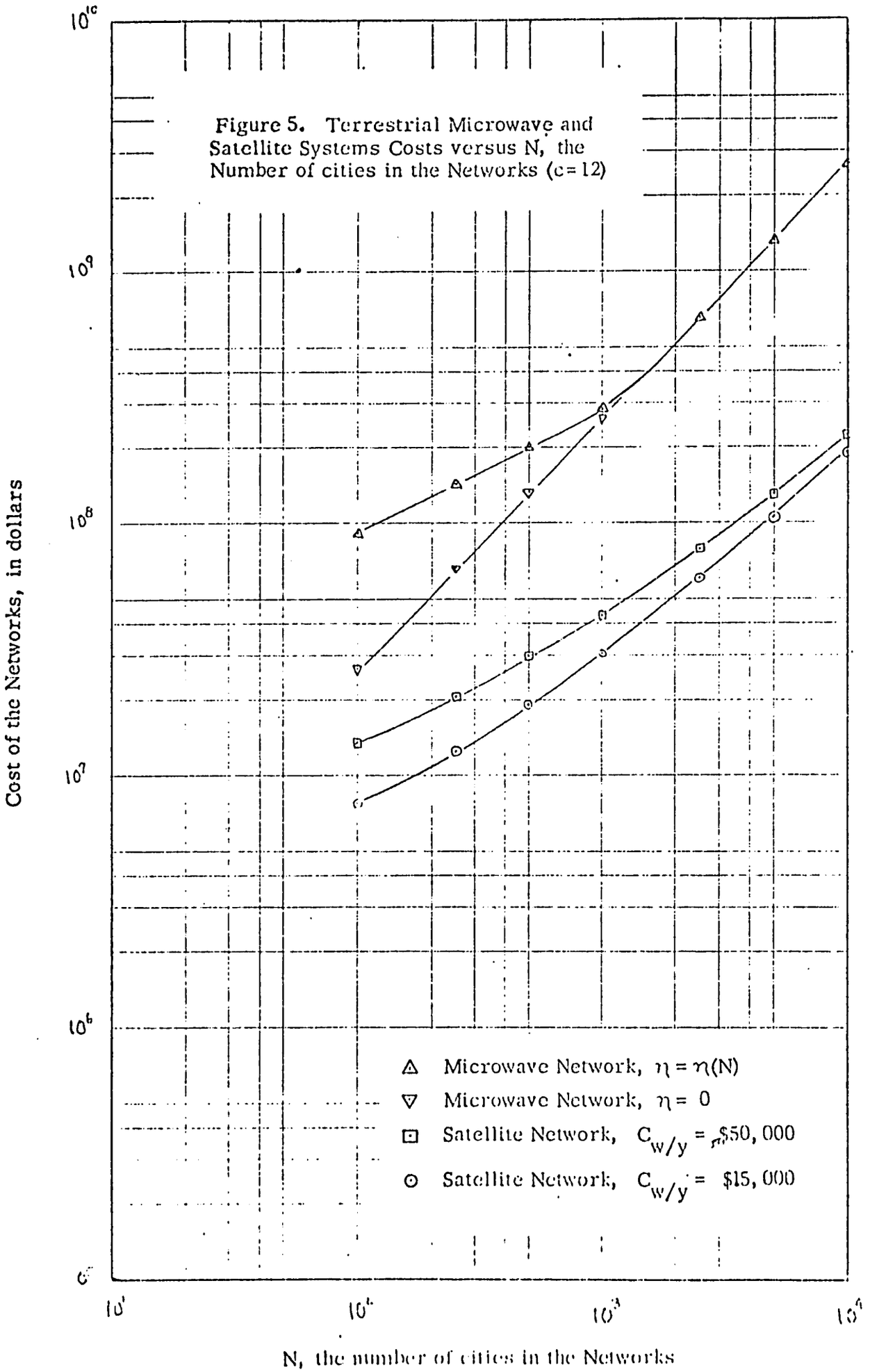


Figure 5. Terrestrial Microwave and Satellite Systems Costs versus N, the Number of cities in the Networks (c = 12)
Cost of the Networks, in dollars
N, the number of cities in the Networks
Microwave Network, η = η(N)
Microwave Network, η = 0
Satellite Network, C_w/y = $50,000
Satellite Network, C_w/y = $15,000

III. Examples of Program Capability

Since the printouts of satellite system costs given in section II-B were obtained some modifications of the program have been made -- mostly format, although some were substantive. With these modifications in force, representative calculations of the costs of satellite service for four Latin American countries were made. The program accepts as input parameters the values of the variables shown on the printouts under INPUT PARAMETERS, as well as the following variables.

1. The longitude of the country's geographical center
2. The latitude of the country's northernmost boundary
3. The latitude of the country's southernmost boundary
4. The longitude of the westernmost boundary
5. The longitude of the easternmost boundary
6. The latitude for the maximum slant range calculation
7. The longitude for the maximum slant range calculation

Two cases were considered for each country (Brazil, Peru, Mexico, and Colombia). First, it was assumed that only one TV origination station would be provided and that it would be at the capital of the country. It would transmit to receive stations located at every city of 2,000 or more inhabitants. Second, it was assumed that there would be a TV origination station at all state capitals and at any large population center (these places are shown on the accompanying maps). With only one TV origination station, the number of channels carried for educational purposes was specified as 4. When more than one TV origination station is permitted, each is assumed to be capable of transmitting two channels to every village (any size) with the satellite carrying a maximum of 12 channels at any one time. The number of villages was determined by looking at either the latest census of population for the given country if available in the Government Documents Section of the Stanford Library, or in the 1966 edition of the Hammond World Atlas if no census was available.

Brazil

case 1. Brazil"s 1960 census of population lists 1,797 cities, towns, above 2,000 population. We used 1,800.

case 2. Brazil's 1960 census of population lists 6,535 cities, towns, and villages (total). There are 28 cities on the accompanying map that were used as origination stations, and the number of receive stations will be rounded to 6,500. (By way of contrast, the Hammond World Atlas lists only some 746 cities, towns, and villages with only three of these having populations lower than 1,000)

Peru

case 2. Peru's Anuario Estadistico Del Peru, 1966 shows 24,908 places of greater than 50 inhabitants. However, only 7,969 of these have more than 200 inhabitants. We used the figure of 7,950 in the program. (Hammond lists only 363 for the total number of towns and villages and cities) The number of origination stations is equal to 12.

case 1. Peru's Anuario Estadistico Del Peru, 1966 lists 355 cities and towns larger than 2,000 population. (Hammond lists only 148)

Mexico

case 1. The Anuario Estadistico de los Estados Unidos Mexicanos, 1966-1967 has nine categories of localities: ciudades, villas, pueblos, congregaciones, haciendas y fincas, ejidos, ranchos, rancherias, and otras. In running this program the arbitrary choice was made to assume that the first three categories include all cities and towns larger than 2,000 population. This number is (362 + 528 + 5,189) = 6,079. We used 6,050.

case 2. To the above number was added the number of congregaciones to bring the total to about 11,000. There are 22 cities at which origination stations are situated.

Colombia

case 1. There are 193 cities and towns listed in Hammond as larger than 2,000 population.

case 2. Hammond shows 306 as the total number of cities, towns, and villages. There are 18 sites for origination stations.

BRAZIL
Area: 3,286,170 sq. mi.
Population: 83,900,000 (1966)
Rural 59.7 per cent (1960)
46.0 per cent (1980 projected)
BOA VISTA
MACAPA
BELEM
SAO LUIS
MANAUS
FORTALEZA
TERESINA
NATAL
JOAO PESSOA
RECIFE
MACEIO
ARACAJU
SALVADOR
CUIABA
BRASILIA
GOIANIA
BELO HORIZONTE
VITORIA
CAMPINAS
NITEROI
SAO PAULO
RIO DE JANEIRO
SANTOS
CURITIBA
FLORIANOPOLIS
PORTE ALEGRE
RIO BRANCO
PORTO VELHO

*** BRAZIL ***

INPUT PARAMETERS

AND AREA	3286170 SQ MI
LATITUDE OF COUNTRY'S GEOGRAPHICAL CENTER	-14° **** DEG
ASSUMED COST OF SATELLITE POWER ($/WATT-YEAR)	$50000.
DISCOUNT FACTOR	10.0%
NO. OF TV-TRANSMIT/AUDIO-RECEIVE (MASTER) STATIONS	1
NO. OF TV-RECEIVE/AUDIO-TRANSMIT (SLAVE) STATIONS	1800
NO. OF TV CHANNELS PER MASTER STATION	4
NO. OF TV CHANNELS PER SLAVE STATION	4
SIGNAL-TO-NOISE RATIO REQUIRED FOR TV	43 DB
SIGNAL-TO-NOISE RATIO REQUIRED FOR AUDIO	43 DB

OUTPUT PARAMETERS

MASTER STATION

ANTENNA:	DIAMETER	49.6 FT	UNIT COST	$ 554768.
RCVR PRE-AMP:	NOISE TEMP	20. DEG K	UNIT COST	$ 60000
TXMTR PWR AMP:	OUTPUT PWR	350.0 W	UNIT COST	$ 17000
INITIAL CAPITAL COST PER STATION				$ 960956
PRESENT WORTH OF TEN-YEAR ANNUAL COST STREAM				$ 2112689

SLAVE STATION

ANTENNA:	DIAMETER	11.8 FT	UNIT COST	$ 6466.
RCVR PRE-AMP:	NOISE TEMP	180. DEG K	UNIT COST	$ 7000
TXMTR PWR AMP	OUTPUT PWR	30.0 W	UNIT COST	$ 6000
INITIAL CAPITAL COST PER STATION				$ 14411
PRESENT WORTH OF TEN-YEAR ANNUAL COST STREAM				$ 25337

SATELLITE

SATELLITE ANTENNA N-S DIAMETER	4.3'	**** FT
SATELLITE ANTENNA E-W DIAMETER	4.2'	-0.0 FT
MAXIMUM SLANT RANGE FOR TRANSMISSION		23081.7 MI
POWER CHARGED PER TV CHANNEL		17.13 W
POWER CHARGED PER AUDIO CHANNEL		0.0124572 W
TOTAL COST PER YEAR OF SATELLITE POWER		$ 3519270
PRESENT WORTH OF TEN-YEAR ANNUAL COST STREAM		$ 21622384

TOTAL INITIAL CAPITAL COST (NOT INCLUDING SATELLITE COSTS)	$ 18280752.
PRESENT WORTH OF TOTAL-SYSTEM TEN-YEAR COST	$ 69342720.
ANNUAL COST OF TOTAL SYSTEM PER SLAVE STATION	$ 6241.
ANNUAL COST OF TOTAL SYSTEM PER SLAVE STATION PER TV CHANNEL	$ 1560.

BRAZIL (CONT'D)

LINK CALCULATIONS

TV UP-LINK (2.5 GHZ)	
OUTPUT PWR PER CHANNEL OF MASTER STATION PWR AMP	23.4 DB
MASTER STATION ANTENNA GAIN	49.4 DB
PATH LOSS	-191.6 DB
SATELLITE ANTENNA GAIN	27.6 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT SAT. RCVR	196.6 DB
NOISE BANDWIDTH (25.1 MHZ)	-74.0 DB
UP-LINK CNR	31.4 DB
TV DOWN-LINK (2.5 GHZ)	
OUTPUT POWER OF SATELLITE TRANSPONDER	12.3 DB
SATELLITE ANTENNA GAIN	24.6 DB
PATH LOSS	-191.8 DB
SLAVE STATION ANTENNA GAIN	36.9 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT SLAVE STATION RCVR	205.0 DB
NOISE BANDWIDTH	-74.0 DB
DOWN-LINK CNR	13.1 DB
TV TOTAL CNR	13.0 DB
TV TOTAL SNR (=6*(((B/2F)-1)**2)*(C/N)*(B/F)*KP)	42.9 DB
WHERE B = RF BANDWIDTH; F = HIGHEST BASEBAND FREQUENCY; C/N = TV TOTAL CNR; KP = A NOISE WEIGHTING FACTOR	
AUDIO UP-LINK (2.5 GHZ)	
OUTPUT POWER PER CHANNEL AT SLAVE STA. PWR. AMP.	13.8 DB
SLAVE STATION ANTENNA GAIN	36.9 DB
PATH LOSS	-191.8 DB
SATELLITE ANTENNA GAIN	24.6 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT SAT. RCVR	196.6 DB
NOISE BANDWIDTH (0.100 MHZ)	-50.0 DB
UP-LINK CNR	30.1 DB
BACK-OFF OF SATELLITE TRANSPONDER	10.0 DB
CNR FROM INTERMODULATION IN SATELLITE TWT	16.9 DB
AUDIO DOWN-LINK (2.5 GHZ)	
OUTPUT PWR PER CHANNEL AT SAT. TRANSPONDER	-29.0 DB
SATELLITE ANTENNA GAIN	24.6 DB
PATH LOSS	-191.6 DB
MASTER STATION ANTENNA GAIN	49.4 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT MASTER STA.RCVR	212.1 DB
NOISE BANDWIDTH	-50.0 DB
DOWN-LINK CNR	15.4 DB
AUDIO TOTAL CNR	13.0 DB
AUDIO TOTAL SNR (=3*(((B/2F)-1)**2)*(C/N)*(B/F)*(1/KP'))	43.5 DB
WHERE KP' IS THE PEAK-TO-AVERAGE POWER RATIO FOR A SINGLE VOICE SIGNAL; OTHER PARAMETERS AS ABOVE	

*** BRAZIL ***

'PUT PARAMETERS

LAND AREA	3286170 SQ MI
LATITUDE OF COUNTRY'S GEOGRAPHICAL CENTER	-14° **** DEG
ASSUMED COST OF SATELLITE POWER ($/WATT-YEAR)	$50000.
DISCOUNT FACTOR	10.0%
NO. OF TV-TRANSMIT/AUDIO-RECEIVE (MASTER) STATIONS	28
NO. OF TV-RECEIVE/AUDIO-TRANSMIT (SLAVE) STATIONS	6500
NO. OF TV CHANNELS PER MASTER STATION	2
NO. OF TV CHANNELS PER SLAVE STATION	12
SIGNAL-TO-NOISE RATIO REQUIRED FOR TV	43 DB
SIGNAL-TO-NOISE RATIO REQUIRED FOR AUDIO	43 DB

OUTPUT PARAMETERS

MASTER STATION

ANTENNA:	DIAMETER	45.4 FT	UNIT COST	$ 526790.
RCVR PRE-AMP:	NOISE TEMP	20. DEG K	UNIT COST	$ 80000
TXMTR PWR AMP:	OUTPUT PWR	350.0 W	UNIT COST	$ 17000
INITIAL CAPITAL COST PER STATION				$ 610302
PRESENT WORTH OF TEN-YEAR ANNUAL COST STREAM				$ 1313421

SLAVE STATION

ANTENNA:	DIAMETER	12.0 FT	UNIT COST	$ 2606.
RCVR PRE-AMP:	NOISE TEMP	130. DEG K	UNIT COST	$ 7000
TXMTR PWR AMP	OUTPUT PWR	30.0 W	UNIT COST	$ 6000
INITIAL CAPITAL COST PER STATION				$ 24119
PRESENT WORTH OF TEN-YEAR ANNUAL COST STREAM				$ 35741

SATELLITE

SATELLITE ANTENNA N-S DIAMETER	4.3' **** FT
SATELLITE ANTENNA E-W DIAMETER	4.2' -0.0 FT
MAXIMUM SLANT RANGE FOR TRANSMISSION	23081.7 MI
POWER CHARGED PER TV CHANNEL	18.38 W
POWER CHARGED PER AUDIO CHANNEL	0.0149460 W
TOTAL COST PER YEAR OF SATELLITE POWER	$ 1.2200186
PRESENT WORTH OF TEN-YEAR ANNUAL COST STREAM	$ 74957920

TOTAL INITIAL CAPITAL COST $ 80262352.
(NOT INCLUDING SATELLITE COSTS)

PRESENT WORTH OF TOTAL-SYSTEM TEN-YEAR COST	$ 344055296.
ANNUAL COST OF TOTAL SYSTEM PER SLAVE STATION	$ 8575.
ANNUAL COST OF TOTAL SYSTEM PER SLAVE STATION PER TV CHANNEL	$ 715.

BRAZIL (CON'T)

LINK CALCULATIONS

TV UP-LINK (2.5 GHZ)	
OUTPUT PWR PER CHANNEL OF MASTER STATION PWR AMP	24.2 DB
MASTER STATION ANTENNA GAIN	48.6 DB
PATH LOSS	-191.6 DB
SATELLITE ANTENNA GAIN	27.6 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT SAT. RCVR	196.6 DB
NOISE BANDWIDTH (25.1 MHZ)	-74.0 DB
UP-LINK CNR	31.4 DB
TV DOWN-LINK (2.5 GHZ)	
OUTPUT POWER OF SATELLITE TRANSPONDER	12.6 DB
SATELLITE ANTENNA GAIN	24.6 DB
PATH LOSS	-191.8 DB
SLAVE STATION ANTENNA GAIN	36.6 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT SLAVE STATION RCVR	205.0 DB
NOISE BANDWIDTH	-74.0 DB
DOWN-LINK CNR	13.1 DB
TV TOTAL CNR	13.0 DB
TV TOTAL SNR (=6*(((B/2F)-1)**2)*(C/N)*(B/F)*KP)	42.9 DB
WHERE B = RF BANDWIDTH; F = HIGHEST BASEBAND FREQUENCY; C/N = TV TOTAL CNR; KP = A NOISE WEIGHTING FACTOR	
AUDIO UP-LINK (2.5 GHZ)	
OUTPUT POWER PER CHANNEL AT SLAVE STA. PWR. AMP.	13.8 DB
SLAVE STATION ANTENNA GAIN	36.6 DB
PATH LOSS	-191.8 DB
SATELLITE ANTENNA GAIN	24.6 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT SAT. RCVR	196.6 DB
NOISE BANDWIDTH (0.100 MHZ)	-50.0 DB
UP-LINK CNR	29.8 DB
BACK-OFF OF SATELLITE TRANSPONDER	10.0 DB
CNR FROM INTERMODULATION IN SATELLITE TWT	16.9 DB
AUDIO DOWN-LINK (2.5 GHZ)	
OUTPUT PWR PER CHANNEL AT SAT. TRANSPONDER	-28.3 DB
SATELLITE ANTENNA GAIN	24.6 DB
PATH LOSS	-191.6 DB
MASTER STATION ANTENNA GAIN	48.6 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT MASTER STA.RCVR	212.1 DB
NOISE BANDWIDTH	-50.0 DB
DOWN-LINK CNR	15.4 DB
AUDIO TOTAL CNR	13.0 DB
AUDIO TOTAL SNR (=3*(((B/2F)-1)**2)*(C/N)*(B/F)*(1/KP'))	43.5 DB
WHERE KP' IS THE PEAK-TO-AVERAGE POWER RATIO FOR A SINGLE VOICE SIGNAL; OTHER PARAMETERS AS ABOVE	

PERU

Area: 513,000 sq. mi.
Population: 11,649,600 (1966 est.)
Rural 52.58 per cent (1961)
47.2 per cent (1985 projected)

*** PERU ***

IN T PARAMETERS

ND AREA	115000 SQ MI
LATITUDE OF COUNTRY'S GEOGRAPHICAL CENTER	-9.0 DEG
ASSUMED COST OF SATELLITE POWER ($/WATT-YEAR)	$50000.
DISCOUNT FACTOR	10.0%
NO. OF TV-TRANSMIT/AUDIO-RECEIVE (MASTER) STATIONS	1
NO. OF TV-RECEIVE/AUDIO-TRANSMIT (SLAVE) STATIONS	355
NO. OF TV CHANNELS PER MASTER STATION	4
NO. OF TV CHANNELS PER SLAVE STATION	4
SIGNAL-TO-NOISE RATIO REQUIRED FOR TV	43 DB
SIGNAL-TO-NOISE RATIO REQUIRED FOR AUDIO	43 DB

OUTPUT PARAMETERS

MASTER STATION

ANTENNA:	DIAMETER	24.2 FT	UNIT COST	$ 47542.
RCVR PRE-AMP:	NOISE TEMP	40. DEG K	UNIT COST	$ 40000
TXMTR PWR AMP:	OUTPUT PWR	100.0 W	UNIT COST	$ 10000
INITIAL CAPITAL COST PER STATION				$ 161559
PRESENT WORTH OF TEN-YEAR ANNUAL COST STREAM				$ 361574

SLAVE STATION

ANTENNA:	DIAMETER	12.0 FT	UNIT COST	$ 2600.
RCVR PRE-AMP:	NOISE TEMP	180. DEG K	UNIT COST	$ 7000
TXMTR PWR AMP	OUTPUT PWR	5.0 W	UNIT COST	$ 2000
INITIAL CAPITAL COST PER STATION				$ 11578
PRESENT WORTH OF TEN-YEAR ANNUAL COST STREAM				$ 18577

SATELLITE

SATELLITE ANTENNA N-S DIAMETER	9.0'	**** FT
SATELLITE ANTENNA E-W DIAMETER	16.5'	-0.0 FT
MAXIMUM SLANT RANGE FOR TRANSMISSION		22532.4 MI
POWER CHARGED PER TV CHANNEL		3.12 W
POWER CHARGED PER AUDIO CHANNEL		0.0136906 W
TOTAL COST PER YEAR OF SATELLITE POWER		$ 646446
PRESENT WORTH OF TEN-YEAR ANNUAL COST STREAM		$ 3971767

TOTAL INITIAL CAPITAL COST (NOT INCLUDING SATELLITE COSTS)	$ 2567055.
PRESENT WORTH OF TOTAL-SYSTEM TEN-YEAR COST	$ 11070911.
ANNUAL COST OF TOTAL SYSTEM PER SLAVE STATION	$ 5052.
ANNUAL COST OF TOTAL SYSTEM PER SLAVE STATION PER TV CHANNEL	$ 1263.

PERU (CON'T)

L' " CALCULATIONS

TV UP-LINK (2.5 GHZ)

OUTPUT PWR PER CHANNEL OF MASTER STATION PWR AMP	18.0 DB
MASTER STATION ANTENNA GAIN	43.2 DB
PATH LOSS	-191.5 DB
SATELLITE ANTENNA GAIN	35.2 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT SAT. RCVR	196.6 DB
NOISE BANDWIDTH (25.1 MHZ)	-74.0 DB
UP-LINK CNR	27.4 DB

TV DOWN-LINK (2.5 GHZ)

OUTPUT POWER OF SATELLITE TRANSPONDER	4.9 DB
SATELLITE ANTENNA GAIN	32.2 DB
PATH LOSS	-191.6 DB
SLAVE STATION ANTENNA GAIN	36.6 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT SLAVE STATION RCVR	205.0 DB
NOISE BANDWIDTH	-74.0 DB
DOWN-LINK CNR	15.2 DB

TV TOTAL CNR	13.0 DB
TV TOTAL SNR (=6*(((B/2F)-1)**2)*(C/N)*(B/F)*KP)	42.9 DB

WHERE B = RF BANDWIDTH; F = HIGHEST BASEBAND FREQUENCY;
C/N = TV TOTAL CNR; KP = A NOISE WEIGHTING FACTOR

AUDIO UP-LINK (2.5 GHZ)

OUTPUT POWER PER CHANNEL AT SLAVE STA. PWR. AMP.	6.0 DB
SLAVE STATION ANTENNA GAIN	36.6 DB
PATH LOSS	-191.6 DB
SATELLITE ANTENNA GAIN	32.2 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT SAT. RCVR	196.6 DB
NOISE BANDWIDTH (0.100 MHZ)	-50.0 DB
UP-LINK CNR	29.8 DB

BACK-OFF OF SATELLITE TRANSPONDER	10.0 DB
CNR FROM INTERMODULATION IN SATELLITE TWT	16.9 DB

AUDIO DOWN-LINK (2.5 GHZ)

OUTPUT PWR PER CHANNEL AT SAT. TRANSPONDER	-28.6 DB
SATELLITE ANTENNA GAIN	32.2 DB
PATH LOSS	-191.5 DB
MASTER STATION ANTENNA GAIN	43.2 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT MASTER STA.RCVR	210.3 DB
NOISE BANDWIDTH	-50.0 DB
DOWN-LINK CNR	15.4 DB

AUDIO TOTAL CNR	13.0 DB
AUDIO TOTAL SNR (=3*(((B/2F)-1)**2)*(C/N)*(B/F)*(1/KP'))	43.5 DB

WHERE KP' IS THE PEAK-TO-AVERAGE POWER RATIO FOR A
SINGLE VOICE SIGNAL; OTHER PARAMETERS AS ABOVE

*** PERU ***

I. IT PARAMETERS

LAND AREA	115000 SQ MI
LATITUDE OF COUNTRY'S GEOGRAPHICAL CENTER	-9.0 DEG
ASSUMED COST OF SATELLITE POWER ($/WATT-YEAR)	$50000.
DISCOUNT FACTOR	10.0%
NO. OF TV-TRANSMIT/AUDIO-RECEIVE (MASTER) STATIONS	12
NO. OF TV-RECEIVE/AUDIO-TRANSMIT (SLAVE) STATIONS	7950
NO. OF TV CHANNELS PER MASTER STATION	2
NO. OF TV CHANNELS PER SLAVE STATION	12
SIGNAL-TO-NOISE RATIO REQUIRED FOR TV	43 DB
SIGNAL-TO-NOISE RATIO REQUIRED FOR AUDIO	43 DB

OUTPUT PARAMETERS

MASTER STATION

ANTENNA:	DIAMETER	39.8 FT	UNIT COST	$ 145436.
RCVR PRE-AMP:	NOISE TEMP	40. DEG K	UNIT COST	$ 40000
TXMTR PWR AMP:	OUTPUT PWR	30.0 W	UNIT COST	$ 6000
INITIAL CAPITAL COST PER STATION				$ 196140
PRESENT WORTH OF TEN-YEAR ANNUAL COST STREAM				$ 393866

SLAVE STATION

ANTENNA:	DIAMETER	10.8 FT	UNIT COST	$ 1475.
RCVR PRE-AMP:	NOISE TEMP	320. DEG K	UNIT COST	$ 1000
TXMTR PWR AMP	OUTPUT PWR	5.0 W	UNIT COST	$ 2000
INITIAL CAPITAL COST PER STATION				$ 17097
PRESENT WORTH OF TEN-YEAR ANNUAL COST STREAM				$ 19147

SATELLITE

SATELLITE ANTENNA N-S DIAMETER	9.0'	**** FT
SATELLITE ANTENNA E-W DIAMETER	11.5'	-0.0 FT
MAXIMUM SLANT RANGE FOR TRANSMISSION		22532.4 MI
POWER CHARGED PER TV CHANNEL		6.55 W
POWER CHARGED PER AUDIO CHANNEL		0.0055486 W
TOTAL COST PER YEAR OF SATELLITE POWER		$ 4463622
PRESENT WORTH OF TEN-YEAR ANNUAL COST STREAM		$ 27424480

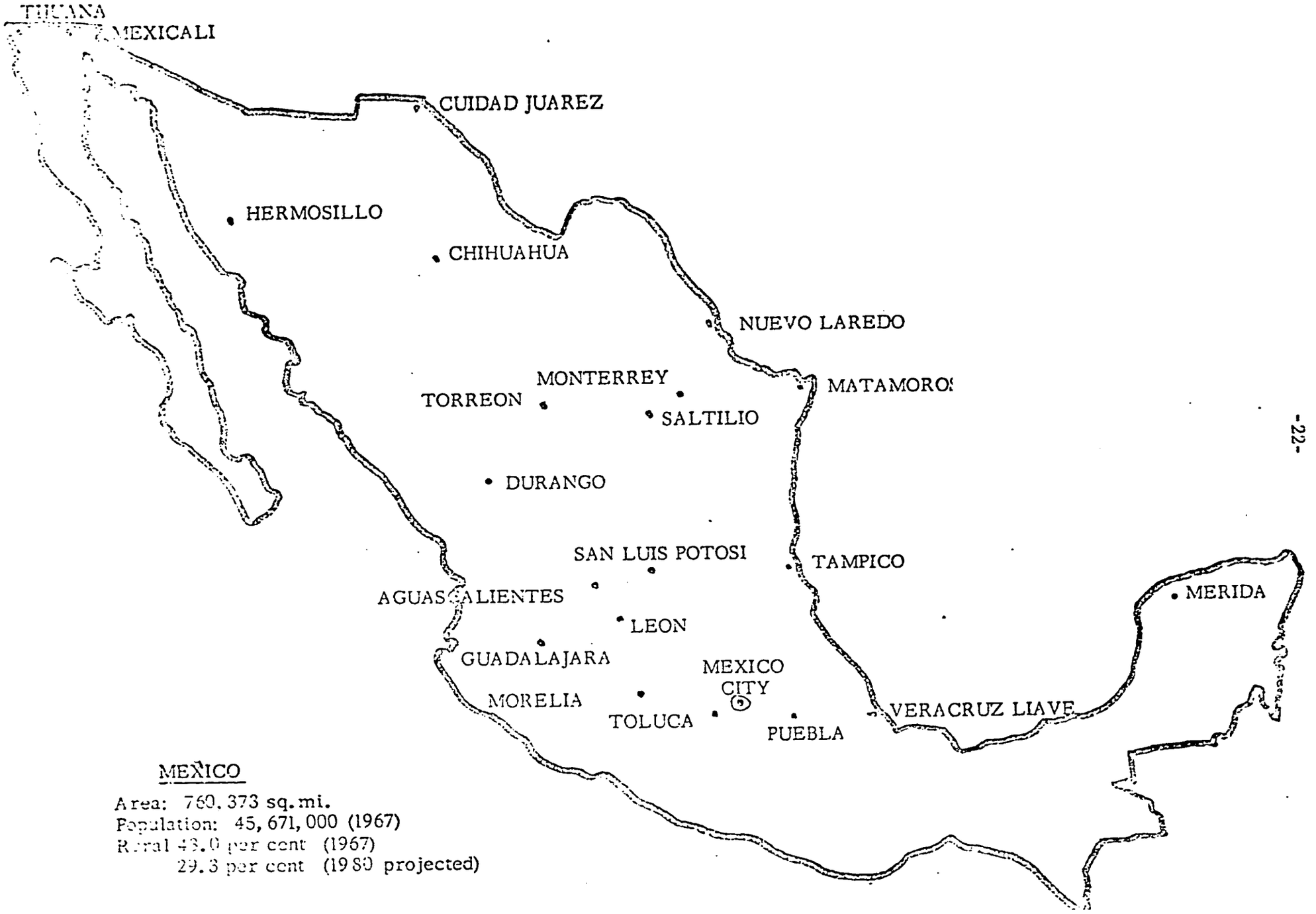
TOTAL INITIAL CAPITAL COST $ 23795872.
(NOT INCLUDING SATELLITE COSTS)

PRESENT WORTH OF TOTAL-SYSTEM TEN-YEAR COST	$ 184375936.
ANNUAL COST OF TOTAL SYSTEM PER SLAVE STATION	$ 3757.
ANNUAL COST OF TOTAL SYSTEM PER SLAVE STATION PER TV CHANNEL	$ 313.

PERU (CON'T)

LINK CALCULATIONS

TV UP-LINK (2.5 GHZ)	
OUTPUT PWR PER CHANNEL OF MASTER STATION PWR AMP	13.5 DB
MASTER STATION ANTENNA GAIN	47.5 DB
PATH LOSS	-191.5 DB
SATELLITE ANTENNA GAIN	35.2 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT SAT. RCVR	196.6 DB
NOISE BANDWIDTH (25.1 MHZ)	-74.0 DB
UP-LINK CNR	27.2 DB
TV DOWN-LINK (2.5 GHZ)	
OUTPUT POWER OF SATELLITE TRANSPONDER	8.2 DB
SATELLITE ANTENNA GAIN	32.2 DB
PATH LOSS	-191.6 DB
SLAVE STATION ANTENNA GAIN	35.7 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT SLAVE STATION RCVR	202.7 DB
NOISE BANDWIDTH	-74.0 DB
DOWN-LINK CNR	13.2 DB
TV TOTAL CNR	13.0 DB
TV TOTAL SNR (=6*(((B/2F)-1)**2)*(C/N)*(B/F)*KP)	42.9 DB
WHERE B = RF BANDWIDTH; F = HIGHEST BASEBAND FREQUENCY; C/N = TV TOTAL CNR; KP = A NOISE WEIGHTING FACTOR	
AUDIO UP-LINK (2.5 GHZ)	
OUTPUT POWER PER CHANNEL AT SLAVE STA. PWR. AMP.	6.0 DB
SLAVE STATION ANTENNA GAIN	35.7 DB
PATH LOSS	-191.6 DB
SATELLITE ANTENNA GAIN	32.2 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT SAT. RCVR	196.6 DB
NOISE BANDWIDTH (0.100 MHZ)	-50.0 DB
UP-LINK CNR	28.9 DB
BACK-OFF OF SATELLITE TRANSPONDER	11.0 DB
CNR FROM INTERMODULATION IN SATELLITE TWT	18.0 DB
AUDIO DOWN-LINK (2.5 GHZ)	
OUTPUT PWR PER CHANNEL AT SAT. TRANSPONDER	-33.6 DB
SATELLITE ANTENNA GAIN	32.2 DB
PATH LOSS	-191.5 DB
MASTER STATION ANTENNA GAIN	47.5 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT MASTER STA.RCVR	210.3 DB
NOISE BANDWIDTH	-50.0 DB
DOWN-LINK CNR	14.8 DB
AUDIO TOTAL CNR	13.0 DB
AUDIO TOTAL SNR (=3*(((B/2F)-1)**2)*(C/N)*(B/F)*(1/KP'))	43.5 DB
WHERE KP' IS THE PEAK-TO-AVERAGE POWER RATIO FOR A SINGLE VOICE SIGNAL; OTHER PARAMETERS AS ABOVE	



MEXICO

Area: 760,373 sq.mi.
Population: 45,671,000 (1967)
Rural 43.0 per cent (1967)
29.3 per cent (1980 projected)

*** MEXICO ***

INPUT PARAMETERS

LAND AREA	760373 SQ MI
LATITUDE OF COUNTRY'S GEOGRAPHICAL CENTER	24.0 DEG
ASSUMED COST OF SATELLITE POWER ($/WATT-YEAR)	$50000.
DISCOUNT FACTOR	10.0%
NO. OF TV-TRANSMIT/AUDIO-RECEIVE (MASTER) STATIONS	1
NO. OF TV-RECEIVE/AUDIO-TRANSMIT (SLAVE) STATIONS	6050
NO. OF TV CHANNELS PER MASTER STATION	4
NO. OF TV CHANNELS PER SLAVE STATION	4
SIGNAL-TO-NOISE RATIO REQUIRED FOR TV	43 DB
SIGNAL-TO-NOISE RATIO REQUIRED FOR AUDIO	43 DB

OUTPUT PARAMETERS

MASTER STATION

ANTENNA:	DIAMETER	51.1 FT	UNIT COST	$ 566922.
RCVR PRE-AMP:	NOISE TEMP	20. DEG K	UNIT COST	$ 80000
TXMTR PWR AMP:	OUTPUT PWR	100.0 W	UNIT COST	$ 10000
INITIAL CAPITAL COST PER STATION				$ 965415
PRESENT WORTH OF TEN-YEAR ANNUAL COST STREAM				$ 2071519

SLAVE STATION

ANTENNA:	DIAMETER	10.8 FT	UNIT COST	$ 1472.
RCVR PRE-AMP:	NOISE TEMP	320. DEG K	UNIT COST	$ 1000
TXMTR PWR AMP	OUTPUT PWR	10.0 W	UNIT COST	$ 3500
INITIAL CAPITAL COST PER STATION				$ 7286
PRESENT WORTH OF TEN-YEAR ANNUAL COST STREAM				$ 9217

SATELLITE

SATELLITE ANTENNA N-S DIAMETER	**** FT
SATELLITE ANTENNA E-W DIAMETER	-0.0 FT
MAXIMUM SLANT RANGE FOR TRANSMISSION	23166.1 MI
POWER CHARGED PER TV CHANNEL	12.81 W
POWER CHARGED PER AUDIO CHANNEL	0.0043461 W
TOTAL COST PER YEAR OF SATELLITE POWER	$ 2667778
PRESENT WORTH OF TEN-YEAR ANNUAL COST STREAM	$ 16390825

TOTAL INITIAL CAPITAL COST $ 16010013.
(NOT INCLUDING SATELLITE COSTS)

PRESENT WORTH OF TOTAL-SYSTEM TEN-YEAR COST	$ 74227984.
ANNUAL COST OF TOTAL SYSTEM PER SLAVE STATION	$ 1988.
ANNUAL COST OF TOTAL SYSTEM PER SLAVE STATION PER TV CHANNEL	$ 497.

MEXICO (CON'T)

LINK CALCULATIONS

TV UP-LINK (2.5 GHZ)	
OUTPUT PWR PER CHANNEL OF MASTER STATION PWR AMP	18.0 DB
MASTER STATION ANTENNA GAIN	49.6 DB
PATH LOSS	-191.7 DB
SATELLITE ANTENNA GAIN	32.4 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT SAT. RCVR	196.6 DB
NOISE BANDWIDTH (25.1 MHZ)	-74.0 DB
UP-LINK CNR	31.0 DB
TV DOWN-LINK (2.5 GHZ)	
OUTPUT POWER OF SATELLITE TRANSPONDER	11.1 DB
SATELLITE ANTENNA GAIN	29.4 DB
PATH LOSS	-191.8 DB
SLAVE STATION ANTENNA GAIN	35.7 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT SLAVE STATION RCVR	202.7 DB
NOISE BANDWIDTH	-74.0 DB
DOWN-LINK CNR	13.1 DB
TV TOTAL CNR	13.0 DB
TV TOTAL SNR (=6*(((B/2F)-1)**2)*(C/N)*(B/F)*KP)	42.9 DB

WHERE B = RF BANDWIDTH; F = HIGHEST BASEBAND FREQUENCY;
C/N = TV TOTAL CNR; KP = A NOISE WEIGHTING FACTOR

AUDIO UP-LINK (2.5 GHZ)	
OUTPUT POWER PER CHANNEL AT SLAVE STA. PWR. AMP.	9.0 DB
SLAVE STATION ANTENNA GAIN	35.7 DB
PATH LOSS	-191.8 DB
SATELLITE ANTENNA GAIN	29.4 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT SAT. RCVR	196.6 DB
NOISE BANDWIDTH (0.100 MHZ)	-50.0 DB
UP-LINK CNR	28.9 DB
BACK-OFF OF SATELLITE TRANSPONDER	11.0 DB
CNR FROM INTERMODULATION IN SATELLITE TWT	18.0 DB
AUDIO DOWN-LINK (2.5 GHZ)	
OUTPUT PWR PER CHANNEL AT SAT. TRANSPONDER	-34.6 DB
SATELLITE ANTENNA GAIN	29.4 DB
PATH LOSS	-191.7 DB
MASTER STATION ANTENNA GAIN	49.6 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT MASTER STA.RCVR	212.1 DB
NOISE BANDWIDTH	-50.0 DB
DOWN-LINK CNR	14.8 DB
AUDIO TOTAL CNR	13.0 DB
AUDIO TOTAL SNR (=3*(((B/2F)-1)**2)*(C/N)*(B/F)*(1/KP'))	43.5 DB

WHERE KP' IS THE PEAK-TO-AVERAGE POWER RATIO FOR A
SINGLE VOICE SIGNAL; OTHER PARAMETERS AS ABOVE

*** MEXICO ***

INPUT PARAMETERS

LAND AREA	760373 SQ MI
LATITUDE OF COUNTRY'S GEOGRAPHICAL CENTER	24.0 DEG
ASSUMED COST OF SATELLITE POWER ($/WATT-YEAR)	$50000.
DISCOUNT FACTOR	10.0%
NO. OF TV-TRANSMIT/AUDIO-RECEIVE (MASTER) STATIONS	22
NO. OF TV-RECEIVE/AUDIO-TRANSMIT (SLAVE) STATIONS	11000
NO. OF TV CHANNELS PER MASTER STATION	2
NO. OF TV CHANNELS PER SLAVE STATION	12
SIGNAL-TO-NOISE RATIO REQUIRED FOR TV	43 DB
SIGNAL-TO-NOISE RATIO REQUIRED FOR AUDIO	43 DB

OUTPUT PARAMETERS

MASTER STATION

ANTENNA:	DIAMETER	44.7 FT	UNIT COST	$ 523045.
RCVR PRE-AMP:	NOISE TEMP	20. DEG K	UNIT COST	$ 80000
TXMTR PWR AMP:	OUTPUT PWR	10.0 W	UNIT COST	$ 3500
INITIAL CAPITAL COST PER STATION				$ 596386
PRESENT WORTH OF TEN-YEAR ANNUAL COST STREAM				$ 1274759

SLAVE STATION

ANTENNA:	DIAMETER	10.7 FT	UNIT COST	$ 1400.
RCVR PRE-AMP:	NOISE TEMP	320. DEG K	UNIT COST	$ 1000
TXMTR PWR AMP	OUTPUT PWR	5.0 W	UNIT COST	$ 2000
INITIAL CAPITAL COST PER STATION				$ 16935
PRESENT WORTH OF TEN-YEAR ANNUAL COST STREAM				$ 18865

SATELLITE

SATELLITE ANTENNA N-S DIAMETER	9.6 FT
SATELLITE ANTENNA E-W DIAMETER	5.7 FT
MAXIMUM SLANT RANGE FOR TRANSMISSION	23166.1 MI
POWER CHARGED PER TV CHANNEL	13.27 W
POWER CHARGED PER AUDIO CHANNEL	0.0065686 W
TOTAL COST PER YEAR OF SATELLITE POWER	$ 8834034
PRESENT WORTH OF TEN-YEAR ANNUAL COST STREAM	$ 54276288

TOTAL INITIAL CAPITAL COST $ 41007328.
(NOT INCLUDING SATELLITE COSTS)

PRESENT WORTH OF TOTAL-SYSTEM TEN-YEAR COST	$ 289843712.
ANNUAL COST OF TOTAL SYSTEM PER SLAVE STATION	$ 4269.
ANNUAL COST OF TOTAL SYSTEM PER SLAVE STATION PER TV CHANNEL	$ 356.

MEXICO (CON'T)

LINK CALCULATIONS

TV UP-LINK (6.0 GHZ)	
OUTPUT PWR PER CHANNEL OF MASTER STATION PWR AMP	8.7 DB
MASTER STATION ANTENNA GAIN	56.1 DB
PATH LOSS	-199.3 DB
SATELLITE ANTENNA GAIN	40.0 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT SAT. RCVR	196.6 DB
NOISE BANDWIDTH (25.1 MHZ)	-74.0 DB
UP-LINK CNR	28.2 DB
TV DOWN-LINK (2.5 GHZ)	
OUTPUT POWER OF SATELLITE TRANSPONDER	11.2 DB
SATELLITE ANTENNA GAIN	29.4 DB
PATH LOSS	-191.8 DB
SLAVE STATION ANTENNA GAIN	35.6 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT SLAVE STATION RCVR	202.7 DB
NOISE BANDWIDTH	-74.0 DB
DOWN-LINK CNR	13.1 DB
TV TOTAL CNR	13.0 DB
TV TOTAL SNR (=6*(((B/2F)-1)**2)*(C/N)*(B/F)*KP)	42.9 DB

WHERE B = RF BANDWIDTH; F = HIGHEST BASEBAND FREQUENCY;
C/N = TV TOTAL CNR; KP = A NOISE WEIGHTING FACTOR

AUDIO UP-LINK (6.0 GHZ)	
OUTPUT POWER PER CHANNEL AT SLAVE STA. PWR. AMP.	6.0 DB
SLAVE STATION ANTENNA GAIN	43.2 DB
PATH LOSS	-199.5 DB
SATELLITE ANTENNA GAIN	37.0 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT SAT. RCVR	196.6 DB
NOISE BANDWIDTH (0.100 MHZ)	-50.0 DB
UP-LINK CNR	33.4 DB
BACK-OFF OF SATELLITE TRANSPONDER	10.0 DB
CNR FROM INTERMODULATION IN SATELLITE TWT	16.9 DB
AUDIO DOWN-LINK (2.2 GHZ)	
OUTPUT PWR PER CHANNEL AT SAT. TRANSPONDER	-31.8 DB
SATELLITE ANTENNA GAIN	28.3 DB
PATH LOSS	-190.6 DB
MASTER STATION ANTENNA GAIN	47.4 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT MASTER STA.RCVR	212.1 DB
NOISE BANDWIDTH	-50.0 DB
DOWN-LINK CNR	15.3 DB
AUDIO TOTAL CNR	13.0 DB
AUDIO TOTAL SNR (=3*(((B/2F)-1)**2)*(C/N)*(B/F)*(1/KP'))	43.5 DB

WHERE KP' IS THE PEAK-TO-AVERAGE POWER RATIO FOR A
SINGLE VOICE SIGNAL; OTHER PARAMETERS AS ABOVE

COLOMBIA

Area: 439,828 sq. mi.
Population: 18,100,000 (1965)
Rural 53.9 per cent (1960)
37.9 per cent (1980 projected)

*** COLOMBIA ***

INPUT PARAMETERS

LAND AREA	439828 SQ MI
LATITUDE OF COUNTRY'S GEOGRAPHICAL CENTER	5.0 DEG
ASSUMED COST OF SATELLITE POWER ($/WATT-YEAR)	$50000.
DISCOUNT FACTOR	10.0%
NO. OF TV-TRANSMIT/AUDIO-RECEIVE (MASTER) STATIONS	1
NO. OF TV-RECEIVE/AUDIO-TRANSMIT (SLAVE) STATIONS	193
NO. OF TV CHANNELS PER MASTER STATION	4
NO. OF TV CHANNELS PER SLAVE STATION	4
SIGNAL-TO-NOISE RATIO REQUIRED FOR TV	43 DB
SIGNAL-TO-NOISE RATIO REQUIRED FOR AUDIO	43 DB

OUTPUT PARAMETERS

MASTER STATION

ANTENNA:	DIAMETER	28.4 FT	UNIT COST	$ 68476.
RCVR PRE-AMP:	NOISE TEMP	90. DEG K	UNIT COST	$ 17000
TXMTR PWR AMP:	OUTPUT PWR	10.0 W	UNIT COST	$ 3500
INITIAL CAPITAL COST PER STATION				$ 132574
PRESENT WORTH OF TEN-YEAR ANNUAL COST STREAM				$ 245601

SLAVE STATION

ANTENNA:	DIAMETER	12.2 FT	UNIT COST	$ 7276.
RCVR PRE-AMP:	NOISE TEMP	180. DEG K	UNIT COST	$ 7000
TXMTR PWR AMP	OUTPUT PWR	0.5 W	UNIT COST	$ 500
INITIAL CAPITAL COST PER STATION				$ 14595
PRESENT WORTH OF TEN-YEAR ANNUAL COST STREAM				$ 24702

SATELLITE

SATELLITE ANTENNA N-S DIAMETER	9.4 FT
SATELLITE ANTENNA E-W DIAMETER	13.3 FT
MAXIMUM SLANT RANGE FOR TRANSMISSION	22419.5 MI
POWER CHARGED PER TV CHANNEL	2.24 W
POWER CHARGED PER AUDIO CHANNEL	0.0212644 W
TOTAL COST PER YEAR OF SATELLITE POWER	$ 468389
PRESENT WORTH OF TEN-YEAR ANNUAL COST STREAM	$ 2877787

TOTAL INITIAL CAPITAL COST (NOT INCLUDING SATELLITE COSTS)	$ 2023046.
PRESENT WORTH OF TOTAL-SYSTEM TEN-YEAR COST	$ 7891011.
ANNUAL COST OF TOTAL SYSTEM PER SLAVE STATION	$ 6624.
ANNUAL COST OF TOTAL SYSTEM PER SLAVE STATION PER TV CHANNEL	$ 1656.

COLOMBIA(CON'T)

LINK CALCULATIONS

TV UP-LINK (6.0 GHZ)	
OUTPUT PWR PER CHANNEL OF MASTER STATION PWR AMP	8.0 DB
MASTER STATION ANTENNA GAIN	52.1 DB
PATH LOSS	-199.1 DB
SATELLITE ANTENNA GAIN	43.6 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT SAT. RCVR	196.6 DB
NOISE BANDWIDTH (25.1 MHZ)	-74.0 DB
UP-LINK CNR	27.2 DB
TV DOWN-LINK (2.5 GHZ)	
OUTPUT POWER OF SATELLITE TRANSPONDER	3.5 DB
SATELLITE ANTENNA GAIN	33.0 DB
PATH LOSS	-191.6 DB
SLAVE STATION ANTENNA GAIN	37.2 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT SLAVE STATION RCVR	205.0 DB
NOISE BANDWIDTH	-74.0 DB
DOWN-LINK CNR	13.2 DB
TV TOTAL CNR	13.0 DB
TV TOTAL SNR (=6*(((B/2F)-1)**2)*(C/N)*(B/F)*KP)	42.9 DB
WHERE B = RF BANDWIDTH; F = HIGHEST BASEBAND FREQUENCY; C/N = TV TOTAL CNR; KP = A NOISE WEIGHTING FACTOR	
AUDIO UP-LINK (6.0 GHZ)	
OUTPUT POWER PER CHANNEL AT SLAVE STA. PWR. AMP.	-4.0 DB
SLAVE STATION ANTENNA GAIN	44.8 DB
PATH LOSS	-199.2 DB
SATELLITE ANTENNA GAIN	40.6 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT SAT. RCVR	196.6 DB
NOISE BANDWIDTH (0.100 MHZ)	-50.0 DB
UP-LINK CNR	28.8 DB
BACK-OFF OF SATELLITE TRANSPONDER	11.0 DB
CNR FROM INTERMODULATION IN SATELLITE TWT	18.0 DB
AUDIO DOWN-LINK (2.2 GHZ)	
OUTPUT PWR PER CHANNEL AT SAT. TRANSPONDER	-27.7 DB
SATELLITE ANTENNA GAIN	31.9 DB
PATH LOSS	-190.4 DB
MASTER STATION ANTENNA GAIN	43.4 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT MASTER STA.RCVR	207.6 DB
NOISE BANDWIDTH	-50.0 DB
DOWN-LINK CNR	14.8 DB
AUDIO TOTAL CNR	13.0 DB
AUDIO TOTAL SNR (=3*(((B/2F)-1)**2)*(C/N)*(B/F)*(1/KP'))	43.5 DB
WHERE KP' IS THE PEAK-TO-AVERAGE POWER RATIO FOR A SINGLE VOICE SIGNAL; OTHER PARAMETERS AS ABOVE	

*** COLOMBIA ***

INPUT PARAMETERS

LAND AREA	439828 SQ MI
LATITUDE OF COUNTRY'S GEOGRAPHICAL CENTER	5.0 DEG
ASSUMED COST OF SATELLITE POWER ($/WATT-YEAR	$50000.
DISCOUNT FACTOR	10.0%
NO. OF TV-TRANSMIT/AUDIO-RECEIVE (MASTER) STATIONS	18
NO. OF TV-RECEIVE/AUDIO-TRANSMIT (SLAVE) STATIONS	306
NO. OF TV CHANNELS PER MASTER STATION	2
NO. OF TV CHANNELS PER SLAVE STATION	12
SIGNAL-TO-NOISE RATIO REQUIRED FOR TV	43 DB
SIGNAL-TO-NOISE RATIO REQUIRED FOR AUDIO	43 DB

OUTPUT PARAMETERS

MASTER STATION

ANTENNA:	DIAMETER	19.5 FT	UNIT COST	$ 27903.
RCVR PRE-AMP:	NOISE TEMP	50. DEG K	UNIT COST	$ 17000
TXMTR PWR AMP:	OUTPUT PWR	30.0 W	UNIT COST	$ 6000
INITIAL CAPITAL COST PER STATION				$ 56050
PRESENT WORTH OF TEN-YEAR ANNUAL COST STREAM				$ 112794

SLAVE STATION

ANTENNA:	DIAMETER	12.0 FT	UNIT COST	$ 6771.
RCVR PRE-AMP:	NOISE TEMP	180. DEG K	UNIT COST	$ 7000
TXMTR PWR AMP	OUTPUT PWR	1.0 W	UNIT COST	$ 850
INITIAL CAPITAL COST PER STATION				$ 30779
PRESENT WORTH OF TEN-YEAR ANNUAL COST STREAM				$ 47839

SATELLITE

SATELLITE ANTENNA N-S DIAMETER	9.4 FT
SATELLITE ANTENNA E-W DIAMETER	13.3 FT
MAXIMUM SLANT RANGE FOR TRANSMISSION	22419.5 MI
POWER CHARGED PER TV CHANNEL	2.29 W
POWER CHARGED PER AUDIO CHANNEL	0.0410046 W
TOTAL COST PER YEAR OF SATELLITE POWER	$ 1545591
PRESENT WORTH OF TEN-YEAR ANNUAL COST STREAM	$ 9496109

TOTAL INITIAL CAPITAL COST (NOT INCLUDING SATELLITE COSTS)	$ 6021167.
PRESENT WORTH OF TOTAL-SYSTEM TEN-YEAR COST	$ 26165440.
ANNUAL COST OF TOTAL SYSTEM PER SLAVE STATION	$ 13852.
ANNUAL COST OF TOTAL SYSTEM PER SLAVE STATION PER TV CHANNEL	$ 1154.

COLOMBIA(CON'T)

LINK CALCULATIONS

TV UP-LINK (6.0 GHZ)	
OUTPUT PWR PER CHANNEL OF MASTER STATION PWR AMP	13.5 DB
MASTER STATION ANTENNA GAIN	48.8 DB
PATH LOSS	-199.1 DB
SATELLITE ANTENNA GAIN	43.6 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT SAT. RCVR	196.6 DB
NOISE BANDWIDTH (25.1 MHZ)	-74.0 DB
UP-LINK CNR	29.4 DB
TV DOWN-LINK (2.5 GHZ)	
OUTPUT POWER OF SATELLITE TRANSPONDER	3.6 DB
SATELLITE ANTENNA GAIN	33.0 DB
PATH LOSS	-191.6 DB
SLAVE STATION ANTENNA GAIN	37.0 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT SLAVE STATION RCVR	205.0 DB
NOISE BANDWIDTH	-74.0 DB
DOWN-LINK CNR	13.1 DB
TV TOTAL CNR	13.0 DB
TV TOTAL SNR (=6*(((B/2F)-1)**2)*(C/N)*(B/F)*KP)	42.9 DB
WHERE B = RF BANDWIDTH; F = HIGHEST BASEBAND FREQUENCY; C/N = TV TOTAL CNR; KP = A NOISE WEIGHTING FACTOR	
AUDIO UP-LINK (6.0 GHZ)	
OUTPUT POWER PER CHANNEL AT SLAVE STA. PWR. AMP.	-1.0 DB
SLAVE STATION ANTENNA GAIN	44.6 DB
PATH LOSS	-199.2 DB
SATELLITE ANTENNA GAIN	40.6 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT SAT. RCVR	196.6 DB
NOISE BANDWIDTH (0.100 MHZ)	-50.0 DB
UP-LINK CNR	31.7 DB
BACK-OFF OF SATELLITE TRANSPONDER	10.0 DB
CNR FROM INTERMODULATION IN SATELLITE TWT	16.9 DB
AUDIO DOWN-LINK (2.2 GHZ)	
OUTPUT PWR PER CHANNEL AT SAT. TRANSPONDER	-23.9 DB
SATELLITE ANTENNA GAIN	31.9 DB
PATH LOSS	-190.4 DB
MASTER STATION ANTENNA GAIN	40.1 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT MASTER STA.RCVR	207.6 DB
NOISE BANDWIDTH	-50.0 DB
DOWN-LINK CNR	15.4 DB
AUDIO TOTAL CNR	13.0 DB
AUDIO TOTAL SNR (=3*(((B/2F)-1)**2)*(C/N)*(B/F)*(1/KP'))	43.5 DB
WHERE KP' IS THE PEAK-TO-AVERAGE POWER RATIO FOR A SINGLE VOICE SIGNAL; OTHER PARAMETERS AS ABOVE	

IV. Sketch of Progress

Several parts of the final model are presently being constructed. For the terrestrial systems costs needed for comparison with the satellite system costs I have been working closely with Pacific Telephone and Telegraph Co. of San Jose. Two parts of the overall program of six parts have been written. These parts deal with costs for T Carrier equipment on cable-pairs and N Carrier equipment on cable-pairs. Each is appropriate for a different cross-section and total link length. The other parts to the program will deal with microwave radio, open-wire lines, the determination of the least-cost cable-pair size to serve in a given situation, and the coupler program that will take the output from these separate parts and provide answers in the following matrix format. The length, L, of the telecommunications link under study will be given along the abscissa of the output graph. The increase in channel demand per year that must be satisfied by the link, YID, will be given along the ordinate. The matrix element designated by any pair of values (L, YID) will contain the least-cost type of terrestrial telecommunications facility that will satisfy these requirements and the present worth of the facility for the whole period of study.

In considering the time element in a satellite system it is necessary to know the costs of upgrading earth stations. This cost has been difficult to obtain from industry inasmuch as the type of station with which we are dealing (very low cost) is not in widespread use. Nevertheless, some handle on these costs will be obtained from data gathered for the teleconferencing report. The cost will be taken to be the replacement cost of the component (either antenna, preamplifier, or power amplifier) or components whose upgrading will render the required increase in earth station channel capacity.

A step toward the completion of the integration of educational requirements and telephony requirements into one system has been made with the completion of a version of the original least-cost satellite system program that treats the case where only telephony service is desired. The system is simple in configuration in that each earth station is assumed to have the same G/T and the same power amplifier. Further work will allow perhaps three different sizes of earth station to be determined, according to the demand requirements.