A COMMUNICATIONS SATELLITE SYSTEM DESIGN WITH EDUCATIONAL TELEVISION FOR THE REPUBLIC OF INDONESIA

Thesis by

Harry Joseph Masoni, Jr.

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ABSTRACT

The purpose of this thesis is to apply a feasible and comprehensive systems approach to the design and analysis of a communications satellite system with educational television for an underdeveloped country. The question of the effectiveness of educational television in concept is treated through revelation of historical evidence and case studies pertaining to existing educational television programs throughout the world. The applicability of blending educational television with a complete satellite communications system is illustrated through the detailed design of a system for the Republic of Indonesia. A system providing educational television, national television, and telephony is proposed and all systems elements and technical analyses are subsequently described. The economic viability of the system is illustrated through a detailed financial analysis with both operating and cash flow results. Comparison of the proposed satellite system with an equivalent terrestrial system is briefly made in Appendix C, to demonstrate the cost-effectiveness of the satellite approach.

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Preface

Since I am a work-study Aeronautical Engineer Fellow of Hughes Aircraft Company, it was deemed appropriate to relate the work presented herein to that performed at and for the expressed purposes of Hughes Aircraft Company. An ideal work-study program should be one that pursues a path of academic study consistent with the working interest of the professional engineer, while at the same time, it allows the engineer to apply his professional experience to fulfillment of academic objectives. Such a mutually benefiting blend of academia and industry, I feel, has been achieved in my program.

Indonesia has, over the past few years, expressed an interest in satellite telecommunications. My initial work at Hughes was to conduct, from a very cursory investment standpoint, the economic feasibility of a satellite system as opposed to a terrestrial system. This thesis thus evolved from a personal interest in defining and analyzing, in detail, a satellite communications system providing telephony, national television, and educational television distribution. Current work at Hughes, in which I am heavily involved, is confined to an economic/technical study of a demand assignment telephony-only system with industrial circuit usage. The study represents, in fact, a microscopic look at one element of the broader, more general study represented by this thesis.

1.0 INTRODUCTION

The motives which have prompted the development of telecommunications generally have little to do with specific educational purposes. The fruit of applied science, telecommunications have grown at rapid speed largely in response to economic motives; they are a characteristic feature of contemporary society yet rarely of education. Radio and television cover developing nations with crying needs for education, for information useful to social and economic development, for cultural expression which reflects the genius and aspirations of the people. But, in many countries, broadcasting renders little public service and programs are imported or patterned in style and content after foreign examples. Ground relays and transmissions from satellites span continents and the world, but rarely do they contribute to systematic education or to the promotion of international dialogue and understanding.

The breakthrough in telecommunications comes at a time when education is in a profound crisis and requires new resources to:

- expand in quantity, across countries into rural areas, and downward on the social scale so education may benefit the poor and the illiterate;
- improve the quality of education, remedy the shortage of teachers, introduce new subject matters into the curriculum and bring up to date the knowledge which is taught;
- assure the continuity of education as a permanent, life-long process with opportunities for learning from pre-school

years to old age, and for "going back to school" at any moment and at any place of work or residence;

- bring education into step with the needs of society, the aspirations of youth, the demands of social and economic development, within the context of national independence and worldwide inter-dependence;
- place education, in its instructional sense, into the broader context of cultural expression and a flow of information.

The potential power of telecommunications for education is such that in the future, they will do more than merely assist and support traditional forms of formal education. Entire educational systems will be built around the media of telecommunications, which are aided in turn by teachers who personalize education at the receiving end by teaching materials which accompany media output, by schools and community centers built around the television receivers.

The tasks are so important, the needs so urgent, that the educational use of telecommunications can no longer remain a mere by-product to their employment for commercial and political purposes. A new approach is called for in which telecommunication networks are set up for the primary task of education at the local, national and international levels. This demands new technology, new ways of financing, new legal structures and new controls, not only of telecommunications themselves, but of the entire educational system, from primary education to the universities and from service to the preschool child to the working adult.

The challenge is how telecommunications may:

1) create a technology specifically adapted to widespread use for the development of human resources, as well as for the design and construction of low-cost radio, television and computer equipment, of satellites with adequate capacity for educational transmissions and of receivers for non-electrified areas;
2) allocate adequate resources and frequencies for educational and cultural use;
3) blend the efforts of telecommunications engineers and management with those in charge of planning and operating educational systems.

Such blending is essential since traditional specializations cannot cope with the integration of telecommunications into the educational process. A systems approach is required which encompasses all modern resources of education, including telecommunications, and combines them in such a manner as to draw the maximum benefit from each component, benefits not only of an economic but equally of an educational and psycho-sociological nature.

It is this challenge and the expressed concern of a developing nation, the Republic of Indonesia, for a system of national communications and educational television that provides the impetus for the study presented herein. The questions of the effectiveness of educational television in general and as applicable to developing countries is treated briefly in Section 2.0.

This thesis is concerned primarily with the cost-effective design and analysis of a national satellite system for the Republic of Indonesia. Telecommunications services provided include national television, educational television, and telephony. For purposes of economic analysis, the system is designed to be hypothetically operational by 1976.

2.0 EDUCATIONAL TELEVISION

2.1 Efficacy of Television as an Instructional Tool

Some very broad conclusions about the use of instructional television has emerged from the evidence derived most often from case studies and experience reports. It is the purpose of this section to reveal these conclusions, which may be of great practical import for users, and relate them to existing instructional television systems throughout the world.

Conclusion 1. Television is most effective as a tool for learning when used in a suitable context of learning activities at the receiving end.

Hardly anywhere in the world is television being used to carry the whole weight of instruction. Almost invariably, where it is being used effectively, it is built into a teaching-learning system. The teaching that can be done best by television is provided that way; what can be done better by face-to-face teaching or group supervision is provided in just such a manner.

Thus, in American Samoa and Hagerstown, where television provides the core of the entire curriculum, television itself fills only ten to thirty minutes of the class period (less in the early grades, more in the higher ones). The rest of the time belongs to the classroom teacher, and great efforts are made to coordinate the work of the studio teacher and the classroom teacher. In Chicago, where television comes probably as close to carrying the entire weight of teaching as it does everywhere, the

Chicago Junior College found it necessary to set hours during which television students could consult instructors by telephone, to arrange for lost classes, a few meetings on campus during the term, and to arrange to have papers written and corrected as in campus teaching.[1]

In Italy, where Telescuola taught secondary education to pupils who were out of the reach of secondary schools, and literacy to adults, learning groups were organized in both cases; the quality of group supervisors was gradually upgraded from monitors to certificated teachers.[2] In Peru, where school dropouts and children unable to obtain places in school were taught by television, it was found that the effectiveness of these classes was greatly increased when children could come to a two-hour class on Saturday mornings, at which time, they were given face-to-face teaching.[3] In Japan, where an entire secondary school curriculum is offered by television and correspondence study, the greater weight is carried by correspondence and the television serves to supplement, explain, and motivate the students, and to maintain schedules.[4]

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[1] Schramm, W., et al., "Educational Television in American Samoa," New Educational Media in Action: Case Studies for Planners, Paris: UNESCO and International Institute for Educational Planning, Vol. I, 1967, pp 11-57.

[2] Lyle, J., et al., "The Centra di Telescuola of Italy," New Educational Media in Action: Case Studies for Planners. Paris: UNESCO and International Institute for Educational Planning, Vol. III, 1967, pp 11-39.

[3] Lyle, J., et al., "La Telescuola Papular Americana of Arequipa, Peru," New Educational Media in Action: Case Studies for Planners, Paris: UNESCO and International Institute for Educational Planning, Vol. II, 1967, pp 77-98.

[4] Schramm, W., et al., "Japan's Broadcast-Correspondence High School," New Educational Media in Action: Case Studies for Planners, Paris: UNESCO and International Institute for Educational Planning, Vol. I, 1967, pp 135-167.

Obviously, then, one of the keys to efficient use of instructional television would appear to be the coordination of studio and classroom, and the joint planning and continuing communication between studio and classroom teachers (feedback). In fact, after completing 23 intensive case studies in 18 countries, a group of authors representing the International Institute for Educational Planning stated this conclusion:

> "In effect, then, by their very nature the new educational media enter into a kind of team teaching. It is not precisely the kind of teaching usually called 'team teaching' in modern schools, where the term usually refers to the division of specialized responsibilities for a large group of pupils among a group of teachers and assistants. But the principle is the same. Each teacher has a special task which, supposedly, he can do best. In the case of the media, a teacher at the point of input, a teacher at the point of reception, perhaps another teacher speaking through textual or exercise materials, combine their efforts, each doing his own part of the task of stimulating students' learning activity. When the media are used for adult education (let us take agriculture as a possible subject area) the teacher at the transmitting end may be an extension specialist, the supervisor at the receiving end may be a forum chairman or village-level worker, and the materials may be prepared by a group at the agriculture research station. But the division of responsibilities is the same. Obviously, such a division and combination of responsibility requires a clear and common set of learning objectives, the will to work together, careful planning, and adequate training in the special skills required."[5]

This approach represents something of a shift in emphasis in the study of instructional television. Most of the experiments in the field, following along the line of instructional film experiments, have been concerned with program content - what goes into television at the transmitting end? What derives from such cases and experiences as have been

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[5]W. Schramm, et al., "The New Media: Memo to Educational Planners," Paris, UNESCO, International Institute for Educational Planning, 1967, p 97.

mentioned, however, is that the amount of learning from television depends at least as much on what happens at the receiving end. Of course, attaining learning results from television is not as simple as injecting facts and concepts into a passive pupil. Learning is an active thing. Learners come to television with different goals and different motivations, and both the broadcast and the classroom content must try to stimulate and direct the learner's own activity.

It is only common sense to conclude that if part of the teaching is to be done in the classroom, then the kind of teaching that goes on in the classroom will have something to do with the total amount of learning. But there has been less research than one might expect on the interface of television with classroom activities: What are the most effective ways of combining these two elements of a course?

Most of the research on this topic has dealt with film, but there is little doubt that most of the conclusions can be transferred to television. In the case of television itself, there are experiments to indicate that learning can be increased by building the opportunity for active responses into the televised program itself.[6] The Hagerstown experience has shown that when the televised teaching was so designed that pupils would respond to the studio teacher, then this discussion would, after the television part of the class, be projected or transformed to discussion with the classroom

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[6] Grapper, G. L., and Jumsdaine, A. A., "An Experimental Evaluation of the Contribution of Sequencing, Pretesting, and Active Student Response to the Effectiveness of 'Programmed TV Instruction'," Studies in Televised Instruction, Report No. 3, Pittsburgh: Metropolitan Pittsburgh Educational Television Stations WQED-WQEX, and American Institute for Research, 1961.

teacher and the other pupils. From numerous case studies[7] and experience reports has come evidence that the attitude of the classroom teacher toward the televised part of the class has been transferred to the pupils and been reflected in the effectiveness of the use made of the television. And finally, one of the more elaborate studies of context of instructional television, Denver's experiment with foreign language teaching in the elementary schools, found that different "packages" of classroom activities built around the television made significant differences in the total amount of learning. Thus, in the first year of language study, teacher-directed classroom practice plus electronic aids were highly effective. In the second year, programmed instruction plus teacher-directed practice plus some other activity to provide variety were a highly effective combination. But the general conclusion of the experimenters was that "a well-trained and motivated classroom teacher is the most effective single learning aid." When the television part of the course was held constant, "both the interest and the experience of the classroom teacher influenced learning."[8]

Conclusion 2. Television is more likely to be an efficient part of an educational system when it is applied to an educational problem of sufficient magnitude to call forth broad support.

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[7] Schramm, W., et al., "The New Media: Memo to Educational Planners," Paris: UNESCO, International Institute for Educational Planning, 1967.

[8] Hayman, J. L., Jr., and Johnson, J. T., Jr., "Exact vs. Varied Repetition in Educational Television," Audio-Visual Communication Review 1963a, Vol. II, pp 96-103.

It may well be the size, rather than the nature, of the educational problem that television is used to solve, which relates most closely to its efficiency. It is clear that television can be used to help with a great variety of the problems that educational systems and educational ministries have. For example, the series of case studies which have been referred to previously and which will provide much of the evidence supporting further conclusions in this chapter found instructional television being used in the following areas:

Upgrading Instruction	Teaching Teachers	Extending The School	Literacy of Fundamental Education	Adult Education & Community Development
Colombia	Algeria	Chicago	Italy	Colombia
Hagerstown	Colombia	Italy	Ivory Coast	Italy
Niger	Hagerstown	Japan	Peru	Peru
Nigeria	Italy	Peru		Samoa
Samoa	Nigeria			
	Samoa			

In each of these groups, there was sufficient evidence of success to indicate that television, if used well, can effectively contribute to any of them.[9]

What is television contributing to the solution of these problems? Essentially, it is sharing and distributing teaching. It is serving as a pipe through which superior teaching, elaborate demonstrations, and otherwise scarce subject matter can be distributed more widely than

[9] Schramm, W., et al.,"The New Media: Memo to Educational Planners," Paris, UNESCO, International Institute for Educational Planning, 1967, pp 17-92.

would otherwise be possible. There is no magic about it, except the relative efficiency with which it can deliver teaching learning experiences over wide areas; this distributive efficiency is one of the qualities that distinguishes instructional television from instructional films.

Consider the following examples:

Niger has only about ten percent of its children of school age in classes. It is anxious to bring as many as 300,000 additional children into school, and to build up its secondary education. But in the entire country, there are only 66 teachers who have themselves had secondary education and little chance of getting any more in the next decade or so, because the other needs of a new country for the few secondary school graduates have higher priority than the schools. In this situation, there is every reason to think of sharing the best teachers as widely as possible. And this is what Niger has set out to do: Using some of its best teachers to give the core of instruction on television, using less well-trained ones to supervise the classroom learning activities built around the television, and to extend the televised teaching one grade per year.

American Samoa is trying to jump from a traditional rote-learning type of educational system into modern education, not in the hundred years or more it would ordinarily take, but in a decade or two. Almost its entire native teacher corps has come up through the traditional system and could not itself make such a dramatic change. Therefore, Samoa has consolidated its one-room schools, installed a six-channel television system, and brought in expert studio teachers to give the core of the curriculum.

At the same time, it is helping the Samoan teachers with in-service training and teaching materials to provide an adequate classroom context for the television and to improve upon their own preparation until they can handle a different level of teaching.

Colombia is trying to do much the same task, although limited to a few key courses, and using native teachers, both for studio and classroom. Approximately 400,000 Colombian students are now being taught in part by television.

The Ivory Coast, which was building new industry, needed 700 new supervisors in a hurry. These men had to be able to read and write, and do simple arithmetic. The industries provided television receivers and rooms where the prospective supervisors could take fundamental education courses. The best of the country's few fundamental education teachers were put on television. The courses moved forward urgently, and now the last of the new crop of supervisors have entered upon their responsibilities.

About half of Italy's 8,000 communes have no secondary schools. This is especially serious in remote areas which are too isolated to permit children to attend schools in neighboring communes. To serve such areas, the Centro di Telescuola began in 1958 to broadcast a full curriculum, for the first three years of secondary school, to learning groups organized in these remote areas and presided over by monitors or teachers who share the responsibility with the teachers in the studio.

Hagerstown was neither the best nor the worst among United States school systems when it went into television in 1956. It wanted to be able to offer science throughout elementary as well as secondary schools, foreign language beginning early in the elementary grades, art and music expertly taught in all schools, and some advanced work in mathematics and science in high school. Many of its elementary teachers were not prepared to offer up-to-date courses in science or to teach foreign languages, and it was very short of well-qualified art and music teachers, as well as others. To hire teachers for these places would have been a very large addition to the budget, even if they could have been hired. Furthermore, it was necessary to build new schools, and the question arose whether some space and money could be saved by designing the buildings around large areas for television viewing, plus small rooms for group teaching and discussion. When the opportunity came to go into television, and share its best teaching more widely, Hagerstown jumped, and has since been amply satisfied with the results.

Algeria lost 80 percent of the foreign teachers who had predominated in its teacher corps when it became an independent nation. Nevertheless, it went ahead with a plan for universal education. It recruited 10,000 native monitors, and then seized upon every way it could find to provide in-service training for them. Among other things, it used television where it could, in combination with programmed instruction, correspondence study, and study groups.

It is in cases like these, all-out attacks on large and challenging educational problems, that television seems to be making its greatest impact on education, and most observers would say, having its greatest success. By contrast, it is much harder to find evidence of impact and success where television is being used in a small way, tentatively, and for supplement rather than direct teaching. This is not to say that television cannot be used effectively for curricular supplement, only that it is harder to find satisfying evidence of impact when it is so used.

Admittedly, these conclusions are not based upon a great deal of experimental research evidence; rather, they derive from case studies and comparative observations, buttressed by such hard research as can be found. But assuming that they represent acceptable propositions within the present state of evidence, what is their significance?

For one thing, it has become clear that effective use of instructional television in a school system requires broad support - administrative, financial, and teacher. It is much easier to get the needed support if the objective is demanding and urgent.

This is nowhere more obvious than in the case of administrative support. If instructional television is to play any large part in a school system, it needs strong support from the top. When representatives of Niger and American Samoa were comparing their experiences at the Paris conference on television, in March of 1967, it became apparent to both of them that the principal reason that Samoa had gone ahead faster was the firm support of Governor H. Rex Lee for the project. In contrast, Colombia's first trial at instructional television failed when the only high-ranking government supporter of the project went out of office in a change of government. The countries where instructional television is having its hardest times are, for the most part, those in which the government has lost its interest in the educational side of television, or where responsibility for it is divided among ministries and none of them feels obligated to defend and advance it. On the other hand, where television is being used for a generally recognized need, as in most examples just given, top administration has no difficulty supporting it and calling for national or system-wide support for it just as one might call for support in time of war. In Samoa, Niger, Algeria and others named, television is at war against educational needs of great magnitude and importance.

Major needs and major campaigns, strangely enough, make it easier to get teacher support also. Instructional television has seldom, if ever, come into use without some resistance from teachers. This is because it is basically threatening. Supplementary use of television at the volition of the classroom teacher is less threatening than direct teaching by television. It has behind it the precedent of the use of films, which can be brought into the classroom, if available, when the teacher wishes, and used or not according to preference. But direct teaching by television requires a teacher to share his classroom with a new teacher on the picture tube. It requires him to make his schedule and pace conform to that decided upon for the entire system. It requires him to learn a new role, to give up some of the "telling" and spend more time on the discussion, practice, and guidance that must necessarily take place in the classroom, rather than on the television channel. Some teachers feel that this is a degrading role; particularly in upper secondary and higher education, where teachers are proud of their subject-matter expertise, it is likely to be thought degrading. If the objective is obviously important, if the use of television is large enough that anyone can see it is being taken seriously, then it is easier for a classroom teacher to put aside his objections, make his schedule fit, learn the new role; in effect, he is enlisting in the war against an educational enemy that must be defeated. If the objective is not urgent, if the medium is being used tentatively, then it is much easier for a classroom teacher to drag heels or decline to cooperate.

Finally, a worthy target and a large program make it easier to justify the financial backing that television needs. A small program is likely to show high unit costs, and if it also shows few results, then there is very little reason to keep on voting the budget. Television is a mass medium, to be cut beyond a certain minimum. Quality cannot be achieved without a certain minimum investment. Therefore, the strategy of efficient television use is to direct the tool toward large goals and many users, and thus, justify both costs per user and total costs against the objective.

In other words, there is a certain size below which instructional television is hardly feasible, and a certain critical mass which it must reach before one can expect it to be truly effective. This may help to explain why many of the most exciting uses of the medium are likely to be seen in developing countries, rather than countries like our own, where the most probable users are the school systems that least need instructional television, the wealthy suburban districts, and where the pattern of use is most likely to be either tentative and suspiciously received direct teaching by television, or supplementary use in the pattern borrowed from films.

"Under any careful scrutiny," says the IIEP Volume previously quoted,

> "the new educational media are most likely to commend themselves for use in a context of change. They are not likely to save money or have a great deal of impact if they are merely added on to do a little better what is already being done. Not that enrichment and supplementary uses are not justifiable; films and television, for example, have often proved useful in supplementing and deepening direct teaching, as on a lower level of cost and complexity the use of cut-out pictures and home-made learning aids has often made exciting differences in classrooms that have not been accustomed to any teaching aids (the UNRWA schools are examples). But the broadcast media, especially, are most likely to be used at their full power and efficiency when a system is trying to solve stubborn, basic problems or to bring about some fundamental change. That is to say, they are likely to be most attractive economically, and most useful educationally, when they are employed, for example, to help extend educational opportunities to those who lack them, to upgrade the level of instruction significantly, to improve and update large numbers of teachers, to introduce new subjects or a new curriculum - in other words, to do something distinctly and significantly new. This is why the new media are especially attractive to developing countries, even though the scarcity of economic and technological resources and of trained persons make it more difficult to introduce them there. But even a more developed school system will do well to follow the strategy of concentrating the potential of its new media on the most urgent 'change point'

in the system - that is, the places where educators agree that change and improvement are strongly needed but most difficult to achieve by ordinary means. Herein lies the basic differences between an 'enrichment' approach and more strategic and advantageous uses of the new educational media."[10]

Conclusion 3. Television is more likely to be an efficient tool of learning if it is planned and organized efficiently.

This seems obvious, and yet it sums up a high proportion of the conclusions from the case studies and observer reports. It should be explained that there are in the literature two general kinds of observer reports, as distinguished from controlled experiments and surveys. One of these is project reports. The available literature now contains approximately one-hundred of these, which are prepared by the project staff and are, of course, not critical of what has been done. The other type includes case studies, the majority of which are included in the IIEP volumes, and reports from outside observers, many of whom bring expert knowledge to bear on the project but whose reports are more likely to be in the files of sponsors, foundations, or government agencies than in the literature. These reports have a high incidence of conclusions like the following:

a. School systems typically "muddle into" television without adequate planning. The lead time needed for setting up

[10] Schramm, W., et al., "Japan's Broadcast-Correspondence High School," New Educational Media in Action: Case Studies for Planners, Paris: UNESCO and International Institute for Educational Planning, Vol. I, 1967, p 98.

an instruction television system is almost always underestimated. Typically, the controlling event is getting the hardware financed, delivered, and operating; the software follows along that schedule. Very often the patterns of use are controlled by the available hardware, rather than the reverse.

b. Inadequate attention is given to methods and content of television teaching. Typically, there is not time for a review of curriculum and method when a school is adding to get television into use. But this is an unequalled opportunity to review what is to be taught, against the goals and objectives of the system, and to review and recast the methods of teaching that have grown up over the years. Television will probably provide more time for preparing a course than teachers have ever had before, and to a certain extent, will require new teaching methods. Therefore, it seems like the ideal time to take a fresh look at the teaching.

c. Too little attention is given to mastering the skills of effective teaching by television. A classroom teacher, without previous experience in using television, needs to learn a great deal about the medium, needs to observe himself as a television teacher and to make maximum use of feedback from pupils and other teachers, and to do a great deal of preparation so as to make his broadcast more than a talking face. He needs to gather visuals to arrange demonstrations, interviews, and other variety-producing devices. One of the interesting things done in American Samoa to help teachers learn the skills of television is to record beforehand all programs for broadcast so that a studio teacher can, whenever he wishes, go to a classroom and observe his own performance and the class reaction to it. Most systems arrange for comments to come back from classroom teachers. But the most important time of preparations comes before the class actually goes on the air, and this is what is most often neglected.

d. Too little time and money are allotted to training for the instructional use of television. It has often been noted that the personnel of instructional broadcasting consists largely of educators who do not fully understand television, and broadcasters who do not fully understand education. The product most needed is the combined broadcaster-educator. The studio teachers need to combine these understandings. The officials in charge of administering the policy, deciding the content, organizing the system, need to combine them. Yet these combinations are in short supply, and school systems seldom are able to take the time, before television, to give any of their key personnel an opportunity to master them.

Perhaps the greatest lack is training for the classroom teacher in the new role he must assume with the coming of television. In some developing countries, as the cases have shown, this is a very difficult problem, because many classroom teachers must learn to do a kind of teaching they have never done before. In economically advanced countries, the teachers already have the skills, but must learn, and accept, a new approach. In any case, the efficient preparation of classroom teachers for the of television usually includes some workshop training beforehand, a flow of materials to guide classroom practice related to the television, and continuing contact with the central curriculum office and in-service help and advice throughout at least the first years of the television experience. The more successful projects seem to budget a healthy amount for continuing two-way contact between the classroom teacher and the studio center.

e. In many systems there is too little attention to technical adequacy, especially to set maintenance. This is less often true in industrially developed countries than elsewhere, although even in some of the most advanced countries, school systems have tried to get along without adequate technical help or supplies. In developing regions, however, the lack of technical preparation is often a fatal flaw. Television in such regions varies all the way from American Samoa, which has one of the finest television installations in the world, to a country where neither the studio nor the school can tell from one hour to the next whether the power will be on in any given area, and where there has been so little attention to repairs and maintenance that at any given time as many as two-thirds of the receiving sets may be inoperative. Maintenance of receivers is a serious problem in almost every developing area.

f. Systems are typically under-used. Various studies conclude that most systems have unused technical capacity, and that both users and programs could be added at very low unit costs. This is, of course, a function of planning. The principal needs to be born in mind, however, are that whereas it is all right to start with a pilot project, still television is economically more efficient when used as a mass medium.

These, as has been mentioned, are conclusions of the analytical studies and the expert observers. They are not so easy to support as are many of the conclusions of more quantitative research.

2.2 Educational Television in Developing Countries

Television is being used to contribute to education in more than fifty countries of the world. Many of these are in the stage of "developing." There is no evidence to lead one to believe that children learn any less efficiently from television in developing countries than elsewhere. Less research has been conducted on learning from instructional television in developing countries than in the industrialized countries of Europe and North America, but what has been done is in no respect less favorable or encouraging than the research in the developed regions.

For example, in Niger, where some first-grade classes were taught by television and classroom monitors, the children were carefully tested at the end of the year in the four subjects they had studied - spoken-French, reading, writing and arithmetic. When their performance was compared with the standard average for the grade in Niger, these were the results.

- 79 percent scored better than the standard average in spoken-French.
- 88 percent scored better than the standard average in reading.
- 56 percent scored better than the standard average in writing

- more than half scored better than the overall average for arithmetic, but their performance varied with the level of abstraction - in concrete problems, 89 percent; semi-concrete, 87 percent; mental problems, 75 percent; oral, 70 percent; applied, written, 50 percent; abstract, written, 33 percent.

The Niger examiners concluded that television in the classroom would not only produce satisfactory learning, but would also improve the average of class performance over what it had been.[11,12]

In Samoa, the high school entrance examinations at the end of the first two years of the television experiment made it possible to compare public school children who had been taught by television for two years, for one year and not at all, and children who had been taught throughout the eight grades by American teachers in mission schools. This first set of tests - necessarily tentative until confirmed by later results - indicates that children who have television for even one year do considerably better in the entrance examinations than those who have not had it, and those who have been exposed to television teaching for two years do about as well as the mission school graduates taught by foreign teachers.

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[11] Schramm, W., et al., "The New Media: Memo to Educational Planners," Paris, UNESCO, International Institute for Educational Planning, 1967, p 76.

[12] UNESCO, New Educational Media in Action: Case Studies for Planners, International Institute for Educational Planning, Paris., Vol. 1, 1967.

In Colombia, some thousands of pupils taught in part by television were tested against a comparable group taught from the same syllabus, but without the aid of television. Eight meaningful comparisons were possible; in three of them, the television students did significantly better; in the other five, there were no significant differences. The three comparisons that favored television were Grade 2 language, Grade 5 mathematics, and Grade 4 natural science. The ones in which the differences were not significant were two science and three social studies classes.[13]

In several countries, television has been used as a main source of literacy instruction. Very few quantitative results are available on these cases, but literate graduates stand as evidence of success. For example, in the Ivory Coast, television has been used in connection with monitored groups to teach 800 men to read, write, and do simple arithmetic, so that they could assume positions as middle-level supervisors in industry.[14]

Under suitable conditions, television has been shown to be capable of highly motivating learning in developing regions. Two examples from Africa will illustrate the nature of many reports from developing countries. From Niger, this report was made at the second year of the television experiment with first grade pupils:

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[13] Comstock, G., and N. Maccoby, The Peace Corps Educational Television (ETV) Project in Colombia - Two Years of Research, Introduction Reports 1-10, Stanford: Institute for Communication Research, Stanford University, 1966-1967.

[14] Kahnert, F., et al., "Teaching Literacy by Television in the Ivory Coast," New Educational Media in Action: Case Studies for Planners, Paris: UNESCO and International Institute for Educational Planning, Vol. II, 1967, pp 129-155.

> "The attitude of the pupils can best be described by comparison with pupils receiving the traditional schooling in schools nearby. From our own observation and that of the teachers connected with the stations, the pupils receiving the television instruction have much happier faces, are more spontaneous, and seem far more interested in attending school. In the classroom, they are free and joyous, and sometimes seem to be absolutely enchanted. Two points can be mentioned which will show the interest of the pupils in this method of instruction; unlike the other schools, there is no absence on the part of the pupils - there was none even during a recent epidemic. They not only come to school, but they come early in order not to miss the first television transmission."[15]

From Zambia, this report was made at the end of an experiment in teaching literacy and fundamental education to adults by closed-circuit television:

> "When television is used, the effect of the classroom teacher on student attainment is relatively slight. However, not only the statistical results must be considered. When there was a classroom teacher, there was better classroom organization than when there was no teacher. But even without the classroom teacher, television teaching appeared to have the power to hold a class. The television classes had a far more satisfactory attendance record then the classes at the Adult Education Centers at Tho Kana . . . The holding power of television teaching is a most important advantage, as one of the failures in many courses for adults such as are run by copper mines is that the normal drop-out makes it almost impossible to run the courses efficiently."[16]

The effect need not necessarily be positive. For example, in Samoa, where the general effect in the primary school was to heighten interest and motivation, frequent objections were made by high school

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[15] Lefrank, R., "Radiovision as an Aid to Literacy in Niger," New Educational Media in Action: Case Studies for Planners, Paris: UNESCO and International Institute for Educational Planning, Vol. III, p 33.

[16] Cripwell, K. K. R., Teaching Adults by Television, Salisbury: University College of Rhodesia, Faculty of Education, Occasional Paper No. 6, 1966, p 84.

students that the television lectures were boring, largely because there was unsatisfactory discussion and interchange in the very large classes after the television. Therefore, the way these media are used, as well as the media themselves, determine class reaction.

When media are introduced for upgrading the level of instruction, then it has proved very important to train teachers in their proper use and to keep in close touch with them. The importance of adequately training the teachers in the use of educational television can be hardly overemphasized. The training involves two aspects: Operation and maintenance of the equipment, and playing a proper role in the instructional environment.

For teachers in well-developed countries, the operations and maintenance of television sets may seem trivial. Yet failure to pay attention to such simple things has led to serious problems in developing countries. For instance, in one case, [17] several hundred television sets were issued to schools but after a short time, most of them were found to be defective. In some cases, the sets had even been removed from the schools.

Experience in some of the developing countries has shown that merely training the teachers is not enough to ensure successful use of the media. There must also be follow-up work to make sure that the teachers are doing what they are supposed to do, to find out what their problems are, and to help them solve these problems. This was essentially the

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[17] Beardsworth, T., The Use of New Educational Techniques in the Developing Countries, Ditchley Park, Enstone, Oxfordshire, England: The Ditchley Foundation, 1966.

conclusion of a group of educators who met in 1966 to discuss the use of educational media in several developing countries, including India, Nigeria, Uganda, and West Indies.[18] They found that in many cases, the programs seemed to be of a good quality and suitable for the local audience. But the system often broke down through insufficient briefing of the teachers and lack of follow-up. These educators found it without question essential that some liaison officers should be appointed to visit schools regularly.

In the educational television project in Nigeria, such a liaison system was put into practice. With the assistance of two U. S. AID specialists, the liaison section prepared and distributed visual aids, issued timetables, and distributed detailed notes for each television lesson as well as other materials for use in the classroom. Besides, the liaison section visited the schools and assisted the teachers with any problems that arose at the end of a session.

It is only through such close follow-up that actual problems can be discovered and solved. The magnitude and variety of problems can be illustrated by the experience in Colombia, perhaps one of the best documented studies of instructional television in developing countries. Here are some of the reports by Peace Corps volunteers whose job it was to make sure that the classroom teachers were doing the right things.[19]

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[18] Beardsworth, T., The Use of New Educational Techniques in the Developing Countries, Ditchley Park, Enstone, Oxfordshire England: The Ditchley Foundation, 1966.

[19] Comstock, G., and N. Maccoby, The Peace Corps Educational Television (ETV) Project in Colombia - Two Years of Research, Introduction Reports 1-10, Stanford: Institute for Communication Research, Stanford University, 1966-1967.

Volunteer 1: (March 2, 1965, Medellin) ". . . the director had not changed the recess schedule - and thus, during a TV lesson, everybody but the one class was in recess, and the noise was very distracting . . . He said it would be impossible to change the schedule, but that he would try to keep the noise down to a minimum. . ."

Volunteer 3: (March 9, 1965, Honda, Tolima) "Awful, awful, utilization in this school which hasn't been able to use TV because of all the technical problems. There's lack of order and discipline, with one exception, the teachers are very poor, and it's one chaotic mess. . ."

Volunteer 6: (February 24, 1965, Medellin) "Went to another small town, Copacabana, to see if their Phillips set had been installed. The TV was in the house of one of the parents who was safeguarding it. The director didn't want it nor the problem of having one teacher having to move it all the time, nor the problem of security. . . "

Volunteer 8: (March 4, 1965, Medellin) ". . . During the TV class, the children were restless and did not answer questions put to them by the TV teacher. I asked the teacher why the children didn't answer and she said that she didn't think they were supposed to. . ."

Many more incidents like these can be cited, but the above are enough to indicate that after a lesson has been put on the air, the problem has just begun, not ended. Similar problems have most probably happened in other developing countries which have adopted instructional television. One doesn't hear about them because they have not been as carefully recorded as in Colombia. The point is: There must be close follow-up work to make sure that the classroom teacher is playing his role properly.

Resistance to television and other media is likely to be no less in developing countries, but the size and urgency of the problems are likely to provide greater incentive for overcoming it. Instructional media, being innovative, often run into resistance when first introduced, particularly in developing countries where the value systems do not encourage innovation. The resistance comes at times from school administrators, but more typically from the classroom teachers who feel their status and security are being threatened by the intrusion of the media.

The complexity of resistance by teachers is indicated by the Colombia experience. When the television project was introduced, it actually aroused great enthusiasm among Colombian teachers. Yet the teachers were not always ready to change their ways to make what is suggested to be better use of television. "When teachers are asked to adopt what is described as a markedly new way of teaching, they defensively dismiss the new way as already in use. Having done so, they give it ready and eager lip service, because they have seized on the idea that it is what they are already doing. The sum is a very strange, although not inexplicable, brotherhood of enthusiasm and apathy whose father is fear - fear of change, and what it implies about the value of their way of doing things."[20]

Although teachers tend to resist the use of instructional media, some evidence suggests that such resistance is not insurmountable, if given time. Take India as an example. When television was first introduced to the schools, there was resistance by teachers, but this resistance gradually broke down until most teachers came to accept television as they did any other classroom aid. It was also found, rather interestingly, that resistance came not so much from the good teacher, who accepted it quickly, nor from the poor teacher, who accepted it without admitting the welcomed help. The resistance came mostly from the moderately good teacher who never wanted to admit that anyone could do better than he. By and large, the Indian experience would seem to indicate that the size and urgency of the problems facing educators in developing countries are likely to provide additional incentives for overcoming teachers' resistance.

Just as it is important to train the classroom teacher and make sure that he is playing his role properly, it is also important for the studio teacher to know that the lessons presented on television are appropriate for the pupils. Thus, a successful instructional television depends to a great extent on the continuous feed-back from the classroom teacher

[20] Comstock, G., and N. Maccoby, The Peace Corps Educational Television (ETV) Project in Colombia - Two Years of Research, Introduction Reports 1-10, Stanford: Institute for Communication Research, Stanford University, 1966-1967.

to the studio teacher. In a developing country where the use of instructional media is often initiated from outside the native culture, this kind of feed-back would assume even greater importance.

There is ample evidence that the new media, particularly television, are effective for in-service training of teachers for developing regions. In developing countries where qualified teachers are in short supply, instructional television has much to contribute toward upgrading the performance of teachers. One might expect that the telecast instruction to the pupils would give the classroom teacher an example of how to conduct a lesson more effectively. But a more direct way of improving teaching is through in-service training of teachers. Because of its relatively easy deliverability, television can bring new knowledge and new teaching techniques to a large number of teachers. This type of use of new media has been tried with a considerable amount of success in developing countries.

An example of successful use of the media for in-service training is provided by Algeria.[21] When Algeria obtained independence in 1962, it lost 80 percent of its qualified teachers. But within three years, enrollment in schools nearly doubled. This serious problem was solved in part by the use of a large number of substitute teachers who received in-service training through films, programmed instruction and instructional television.

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[21] Lyle, J., et al., "Two Uses of Mass Media for In-Service Teacher Training in Algeria," New Educational Media in Action: Case Studies for Planners, Paris: UNESCO and International Institute for Educational Planning, Vol. II, pp 157-177.

Certain problems arising from the use of instructional television for in-service training were systematically observed in Colombia. When instructional television was introduced, an in-service training program on the "new math" was offered to the teachers. The program consisted of lectures on set theory, number system, laws of basic operations, etc. The programs were televised at the rate of two a week, each lasting 30 minutes. The new math was chosen because the teachers had voiced considerable anxiety about their ability to understand it. It seemed to be a subject about which they really wanted to know more. Viewing was optional for teachers in three districts. Comparison of test results showed that those teachers who viewed the entire series scored twice as high as those teachers who did not view the series at all. Even though the teachers were not randomly assigned, the authors felt the significant difference in test scores between the viewers and non-viewers was unlikely to be the result of self-selection, because no differences were found between the two groups in such matters as sex, age, education, or teaching experience.[22] Thus, the findings provide further evidence that television could be effectively used for in-service training in a developing country. There will be certain barriers, but these barriers can largely be overcome when the teachers begin to participate in the training programs.

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[22] Comstock, G., and N. Maccoby, The Peace Corps Educational Television (ETV) Project in Colombia - Two Years of Research, Introduction Reports 1-10, Stanford: Institute for Communication Research, Stanford University, 1966-1967.

Thus, the outlook for television in the developing regions is very promising. The serious question is not whether pupils in developing countries can learn from it. Rather, the questions are whether it is the right medium for the situation, whether the country can afford it, whether the necessary technological base and the necessary engineers and technicians are available to support, and whether the logistics and the in-service training can be provided to make it work in the classroom. If these questions can be answered affirmatively, then a number of characteristics of instructional television recommend it to the attention of the developing countries.

3.0 COMMUNICATIONS SATELLITE SYSTEM DESIGN FOR A DEVELOPING COUNTRY - INDONESIA

Indonesia, situated between the Pacific and Indian Oceans, is an archipelago nation of more than 6,000 named islands, 960 of which are inhabited, extending for some 4,800 kilometers from the northern tip of Sumatra to West Irian. The total area of the country is 1,900,000 km^2. Its population totals some 115 million, with 85 percent of the people concentrated on Sumatra and Java. Java, with 76 million people, is one of the most densely populated areas in the world. Sumatra has 19 million people. The remaining inhabited islands are sparsely populated. A map of the country indicating the provincial capitals is shown on Figure 1.

Development of surface transportation in Indonesia's long chain of islands has been difficult and costly, due to the many sea crossings and the mountainous, sometimes swampy terrain. Many parts of the country are inaccessible even by air. Transportation of goods and people is difficult, and therefore, telecommunications become particularly valuable in maintaining coordination between business centers and markets.

Indonesia's gross domestic product is estimated to be U. S. $9.2 billion, with a per capita income of U. S. $80. The economy of the country is largely based on agriculture, oil production, rubber and mining. The major export items are petroleum and its by-products (U. S. $272 million), rubber (U. S. $221 million), agricultural products (U. S. $150 million), minerals (U. S. $42 million), and forest produce and lumber

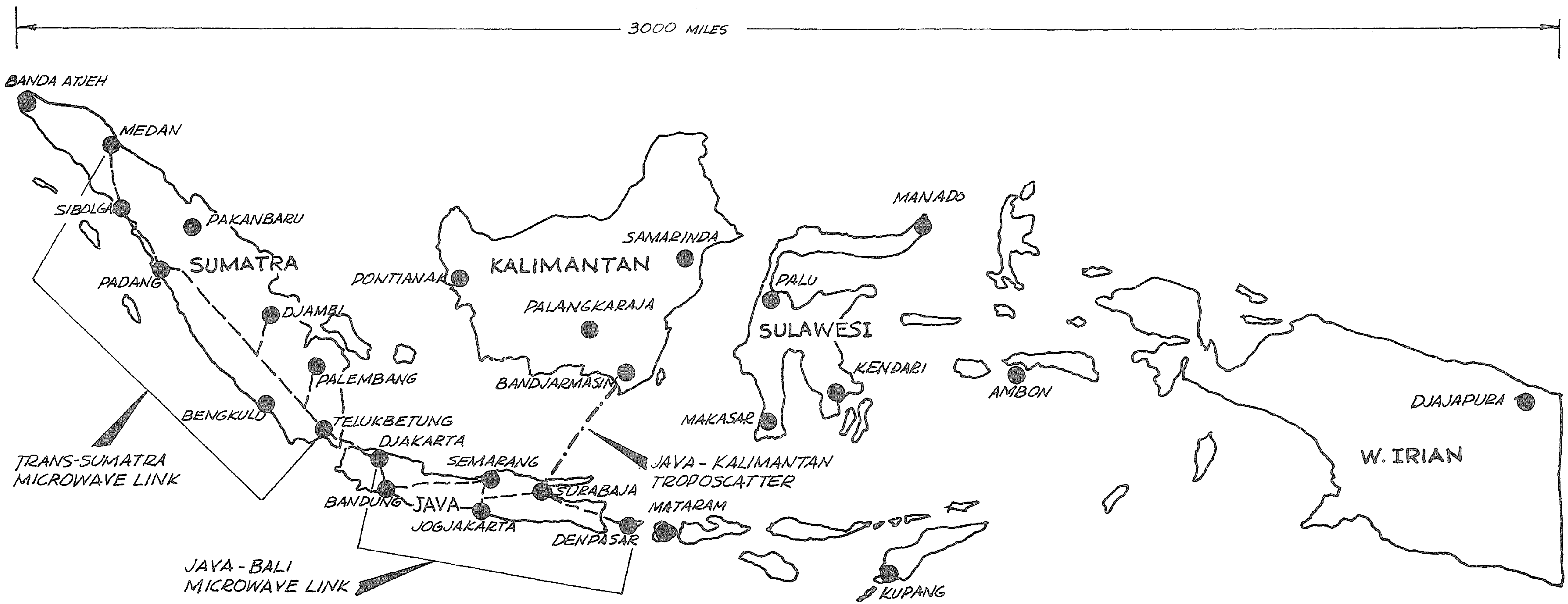


FIGURE 1. INDONESIA

(U. S. $6 million). The island of Sumatra is rich in forest produce, rubber, petroleum and minerals, and contributes 60 percent of Indonesia's total exports. Kalimantan exports oil, mineral and forest produce and has a vast potential for development. Djakarta in Java is the administrative and business center of Indonesia. The development of long distance communications within Sumatra, from Sumatra to Java, and from Kalimantan to Java, is of great importance to the economy of the country and is of high priority.

Indonesia has faced many problems in attempting to provide adequate telecommunications service. Telecommunications development came to a stand-still during World War II. Further setbacks were experienced during the independence movement and subsequent political changes, resulting in an obsolete and ill-maintained network and a disorganized staff. Except for a small amount of development between 1961 and 1965, very little expansion and rehabilitation has taken place.

A satellite transmission system offers many of the features which are difficult to obtain by terrestrial methods. Complete coverage of Indonesia is provided. The satellite communications system provides high grade telephony voice circuits with sufficient capacity to meet telephony growth projections for the country through the 1980's. Furthermore, a national television system can easily be implemented since the satellite is in view of every population center in Indonesia. Finally, educational television can be introduced on a national level; villages located in the most remote areas, as well as the more populous regions of Indonesia, can receive the benefits of educational television (ETV) via many small low cost ETV terminals requiring high power satellite channels for transmission.

Telecommunication services in Indonesia currently provided by the terrestrial system include telephony, teletype (telex), and television. The telephony and telex transmission facilities include open wire, VHF, HF, troposcatter, and microwave; many of these existing facilities are, however, of low quality and capacity and are expensive to operate. While the development of television broadcasting is expanding, provision for a national system is technically difficult and expensive because of the many islands that must be interconnected by submarine cable.

The Indonesian educational system has undergone phenomenal growth since 1945. This growth, however, does not imply a satisfactory condition. For example, consider the growth in primary schools. Despite the fact that the Indonesian Government has built about 500 new schools per year, it is not able to provide sufficiently well trained teachers. A similar situation is found in higher education, where teachers in scientific and technical areas are scarce, and the college graduate in humanities and social sciences are often without jobs after graduation.

The Indonesian Government has recognized a dire need for telecommunications expansion to satisfy the socioeconomic and political needs and desires of the country. This section presents a complete telecommunications satellite system designed to meet the aforementioned needs. The system is described in Section 3.1. The systems elements and associated analyses to support the design are presented in the ensuing two sections. A detailed financial analysis is presented in Section 3.4. Supporting analyses to the basic system analysis are set forth in the appendices.

3.1 System Requirements and Definition

3.1.1 General

A National Communications Satellite System design for the Republic of Indonesia is based upon preliminary requirements suggested by the Directorate General for Post and Telecommunications (PTT). A total telecommunications system concept is envisaged to provide:

1) Growth capacity for telephony throughout the country, particularly in the outer islands and as a backup to the terrestrial microwave net in Java and Sumatra.
2) Extension of television service into each province.
3) Introduction of educational television on a national basis.

The system elements of the program are determined from the services provided by the communication satellite system and the transmission facilities necessary to meet the service needs. Table 1 summarizes the system characteristics.

The satellite communication repeater operates in the 6 GHz band on the uplink and 4 GHz band on the downlink. Eight satellite channels have been designed specifically to support the Indonesian telecommunications requirements. The baseline design provides five channels for telephony services. Four of these channels are used for trunk route service

TABLE 1.

SYSTEM CHARACTERISTICS

		Service
Telephony	o	1,196 Full period voice circuits (point-to-point) on 15 trunk routes.
	o	75 Voice circuits of demand assigned telephony interconnecting 22 cities.
Television	o	One channel color national TV at 26 cities with VHF broadcast.
	o	Two channel, black and white educational TV at 26 cities and at 2,142 schools and universities.
		Space Segment
Two Satellites	o	Hughes Satellite (HS 347), 8 channels
Two Boosters	o	Thor Delta 2914
		Ground Segment
Master Control Station	o	Single station at Djakarta
Multiservice Station	o	25 Provincial capitals
ETV Terminals	o	148 Schools receive ETV via VHF rebroadcast at 26 major cities.
	o	1,994 ETV terminals with four video monitors at urban and rural schoolhouses.

and a fifth is proposed to operate in a demand assignment mode. Voice channel allocations have been designed so that future telephony growth can also be accommodated. The remaining channels have been assigned to television service. Two high-power educational television channels and a single national television channel are proposed to support the service requirements. The increased power provided by the satellite for the educational television service allows for the use of small, low-cost ETV terminals designed for unattended operation.

A comprehensive and complete telecommunication system is designed. Analysis of each service and the interrelationships between services in the satellite and ground segment leads to a cost-effective system design. The number of voice circuits proposed is based upon circuit projections derived from the World Bank Report, "Appraisal of the Telecommunications Expansion Program of PERUMTEL Indonesia," dated 1 June 1970. The projections are developed in Section 3.4.7.

A great deal of flexibility is introduced by use of specialized circuits which can connect any pair of cities in the system on demand. 1,196 voice circuits provide telephony service between major city centers on a preassigned basis. The frequency division multiplex/frequency modulation (FDM/FM) format is used.

Fifteen trunk routes were selected based on the PTT traffic requirements for that number of cities. In addition, these fifteen cities and seven others are equipped to provide low density service between one another by demand assignment of circuits. An approach has been selected whereby any of these cities may be interconnected by an operator at the specific ground station. The necessary ground equipment is provided at these 22 cities to support 75 demand assigned voice circuits. The actual circuit value of the demand assigned service is greater than its preassigned counterpart, because of the large number of possible connections. The advantage of a single demand circuit over the preassigned circuit would be as much as a factor of three. Therefore, the equivalent number of total circuits provided is 1,196 + 3 (75) = 1,421. Growth is provided for 225 to 975 additional circuits. The actual number depends on the modulation format used for the demand assignment approach.

Table 2 identifies by an asterisk the cities interconnected by the existing terrestrial system and those proposed for the service by the satellite system. The telephony and television services proposed at each of these cities were established both to complement the existing terrestrial system and to meet growth objectives. Direct telephony service via satellite is provided at only the identified cities in order to minimize the ground segment investment. Cities such as Medan are interconnected by the existing terrestrial facilities and therefore have an indirect access to the satellite. Particular emphasis is placed on supplying telephone service to cities in the outer islands or to those inner-island cities that are not interconnected to the microwave system.

Figure 2 illustrates the proposed telephony interconnections as well as the currently existing and planned microwave-troposcatter links on Sumatra, Java, and Kalimantan. The lines between cities represent the preassigned or dedicated circuits. The capacity of the voice channel at each city is identified in Table 3. A more detailed description of the telephone plan is presented in Section 3.3.2.

TABLE 2.

CITIES INTERCONNECTED BY EXISTING OR PROPOSED TELECOMMUNICATIONS SYSTEM

City	Serviced By		Satellite Services Provided	
	Terrestrial System	Satellite System	Telephony	Television
Banda Atjeh		X	X	X
Medan	X			
Sibolga	X	X		X
Pakanbaru		X	X	X
Bukittinggi	X			
Padang	X	X	X	X
Djambi	X	X		X
Palembang	X	X	X	X
Bengkulu		X	X	X
Telukbetung	X	X		X
Djakarta	X	X	X	X
Bandung	X			X
Tegal	X			
Salatiga	X			
Semarang	X	X	X	X
Pekalongan	X			
Jogjakarta	X	X	X	X
Madiun	X			
Surabaja	X	X	X	X
Malang	X			
Djember	X			
Denpasar	X	X	X	X
Mataram		X	X	X
Kupang		X	X	X
Pontianak		X	X	X
Bandjarmasin	X	X	X	X
Samarinda		X	X	X
Palangkaraja		X	X	X
Makasar		X	X	X
Palu		X	X	X
Kendari		X	X	X
Manado		X	X	X
Ambon		X	X	X
Djajapura		X	X	X

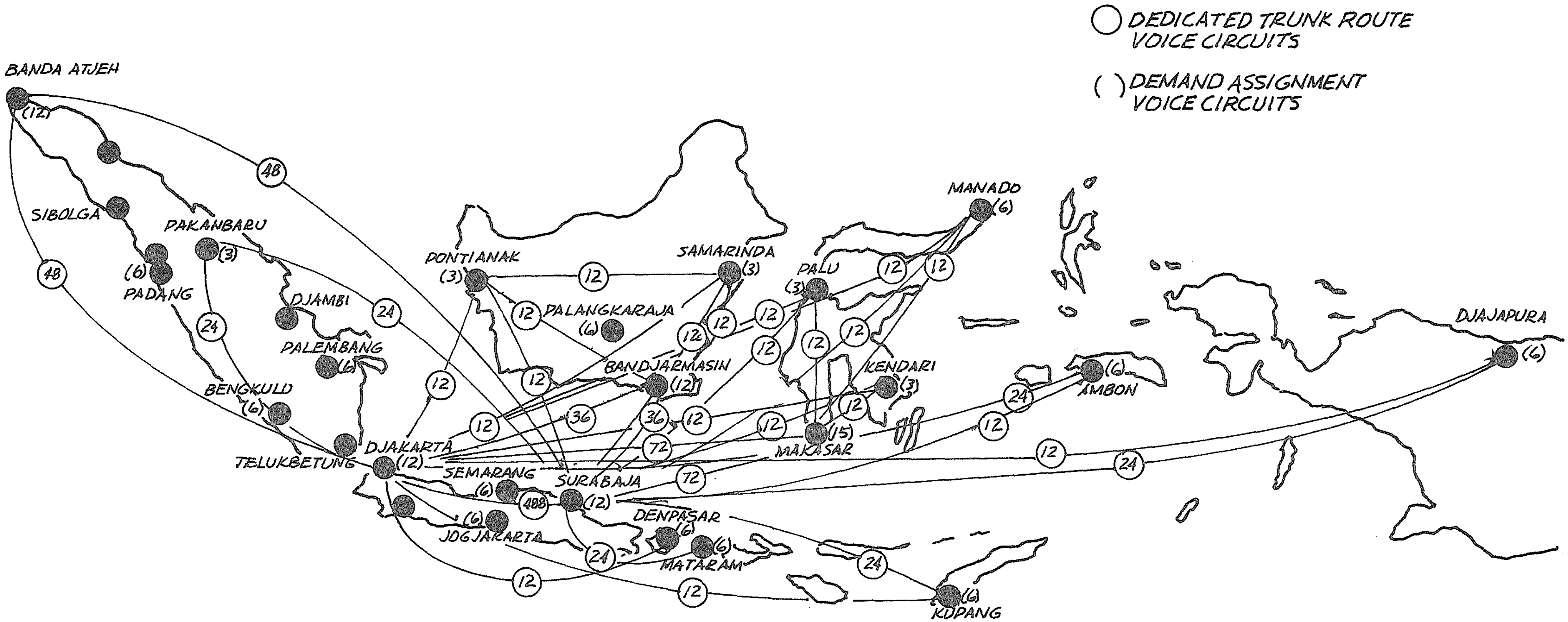


FIGURE 2. SATELLITE TELEPHONY TRUNKING MODEL.

TABLE 3.
TELEPHONY CHANNEL DISTRIBUTION

City	Dedicated Channels	Demand Assigned Channels
Djakarta	800	12
Surabaja	800	12
Banda Atjeh	96	12
Pakanbaru	48	3
Bandjarmasin	96	12
Pontianak	48	3
Samarinda	48	3
Makasar	180	15
Palu	48	3
Kendari	48	3
Manado	36	6
Mataram	36	6
Kupang	36	6
Ambon	36	6
Djajapura	36	6
Padang	-	6
Palembang	-	6
Bengkulu	-	6
Semarang	-	6
Jogjakarta	-	6
Denpasar	-	6
Palangkaraja	-	6
Total Channels	2,392	150
Total Circuits	1,196	75

Table 2 also identifies the cities receiving television service. Earth stations located at specific cities identified in Table 2 are designed to receive and then rebroadcast both national and educational television programs at VHF. The actual number of cities chosen for television service is based upon the desire to provide distribution to the 26 provinces. All schools and homes within the VHF transmitter coverage can receive the television programs. Selected schools outside these cities will receive the ETV signals at ground terminals co-located with the school houses.

The educational television approach was established following a lengthy review of the current status and future needs of the educational sector in Indonesia. This review indicated that emphasis on teacher and vocational education could most immediately meet the nation's development requirements and was necessary before broader goals in secondary education could be met. Therefore, it is proposed to locate ETV facilities at all of the 1,472 teacher colleges, universities, and vocational colleges throughout Indonesia. In addition, the satellite ETV signal could be received at the 670 existing technological schools. Thus, a total of 2,142 schools would be receiving the two ETV channels, reaching approximately 600,000 students. It is estimated that 148 of these schools would be in the VHF rebroadcast reception area and that the remaining 1,994 schools would be supplied with ETV receive-only terminals.

3.1.2 Space Segment

The space segment selection is based on program duration, launch risk, and maintenance of inorbit operation continuity.

As indicated earlier, a 7-year program has been postulated. A number of alternative complements of satellites and boosters exist. The system chosen is a fully-redundant space segment configuration with two satellites and two boosters with launch failure insurance premiums.

The spacecraft selected for the Indonesian System, the HS 347, is a slightly modified version of the HS 333 satellite, now being used by Hughes. The reason for applying a currently existing satellite design (except for slight modification to the communications subsystem) to be used for the system is based on the following two points. First, to completely design a communications satellite appropriate for use in the proposed system would require analysis beyond the scope of this study. Furthermore, the current HS 333 basic design is ideally suited for such a domestic satellite system application.

The HS 347 spacecraft weighs approximately 1,200 pounds and is placed into transfer orbit by the Thor Delta 2914 launch vehicle. HS 347 is an active multichannel repeater communication satellite. It operates in a synchronous, circular, equatorial earth orbit to provide single carrier transmission of television signals and/or multiple carrier transmission of voice and digital signals. The satellite also contains an apogee rocket motor to inject it into synchronous orbit. The satellite is stabilized by the spinning of the main body and provides continuous coverage of Indonesia by mechanically despinning the telecommunications antenna. The spacecraft will be located over Indonesia at a longitude of 130°E and is designed to maintain that position for over 7 years. An onboard propulsion system under the control of the master control station located in Indonesia is activated on a scheduled basis to maintain the spacecraft attitude and position.

3.1.3 Ground Segment

The ground stations planned for the Indonesian system are equipped for telephony and television operation. There are three types of station configurations: A master control station, 25 multiservice stations, and 1,994 ETV receive-only terminals.

The proposed location for the master station is in Djakarta. In this way, the technical and managerial interfaces between the PTT, the television broadcast studios, and the existing microwave net can all be met. This station also serves to track the satellite, receive telemetry, and generate and transmit the necessary commands to control the satellite. The station facilities are designed to house all of the transmit and receive telephony equipment, as well as the television transmit and rebroadcast equipment for the three TV channels.

Ground stations are also located in each of the country's provinces and at the cities identified in Table 2. A total of 25 multiservice stations are designed to receive the three television channels. Twenty-two of these stations are also supplied with varying units of telephony equipment to support the dedicated and demand assigned voice channels tabulated in Table 3.

The master control and multiservice stations are designed to utilize a 35-foot antenna. The transmit gain of the 35-foot antenna is 54 dB and the receive gain is 50.2 dB. A G/T* of 27.2 dB^{o}K is achieved with a receiving system noise temperature of 200^{o}K. Separate 1.5 kw transmitters are utilized at the master station for the national and educational television channels. In addition, 800 permanently assigned FDM/FM telephone voice channels are transmitted by a third 1.5 kw transmitter. The baseline design incorporates 12 demand assignment voice channels at the master station. A 1-watt transmitter is required for each of the demand assigned channels. The multiservice stations also utilize 1.5 kw transmitters for FDM/FM telephony and 1-watt transmitters for each demand assigned channel.

The master and multiservice stations are equipped to receive the three television signals and to rebroadcast these signals locally at VHF. The basic rebroadcast equipment including a 200-foot tower antenna and a 1-kw transmitter are co-located at each station. The Effective Isotropic Radiated Power (EIRP) is sufficient to cover a 25-mile radius with good signal quality.

The ETV terminals are located at school facilities throughout Indonesia and are simple receive stations designed for unattended operations. A 13-foot parabolic antenna is selected to receive the satellite signal energy. The signal quality specified for the ETV channels is 43.9 dB. A G/T of 13.9 dB/^{o}K is required to meet this television signal-to-noise ratio.

*G/T is (Receive Gain)/(Receiving System Noise Temperature) and is an accepted figure of merit for ground station characterization.

The ETV RF signal is demodulated and the video signals are extracted and transmitted directly through coaxial cables interconnected to the school where the ETV programs are displayed on four video monitors.

3.1.4 System Implementation

The ground segment will be phased in over the duration of the program. It is proposed that the master control and multiservice stations be activated prior to launch to provide complete telephony and national television service. A total of 888 educational facilities will also become operational at this time. During the first year of operation, an additional 1,254 receive-only terminals will be introduced. For purposes of financial analysis, the hypothetical implementation is based on deployment in 1976.

3.1.5 Financial Highlights

As summarized in Table 4, the total capital investment requirement for the multiservice program is U. S. $77.7 million. Of the amount, U. S. $37.5 million is required for the space segment consisting of two satellites and launch vehicles, plus launch failure insurance. The ground segment of the program includes all facilities necessary to provide the previously described telephony and television services and requires a total capital investment of U. S. $36.6 million.

The full multiservice program would be installed on a time-phased basis with all satellite and some earth station construction beginning two years before service commencement. Such a program would require pre-operational capital expenditures of approximately U. S. $68 million, with the remaining investment scheduled during the first six years of operation.

TABLE 4.

INVESTMENT, U. S. $ MILLIONS

System Elements	Quantity	Total Investment	Service Allocation		
			Tele-phony	NTV	ETV
Space Segment					
Satellite Plus Insurance	2	$ 22.5			
Launch Vehicles	2	15.0			
Total Space		$ 37.5	$23.6	$ 4.5	$ 9.4
System Engineering/ Program Management		2.9	1.7	0.3	0.9
Training		0.7	0.4	0.1	0.2
Ground Segment					
Master Station	1	3.9	3.6	0.1	0.2
Multiservice Stations	25	17.3	15.9	0.5	0.9
VHF Rebroadcast	26	4.6	-	1.6	3.0
ETV Terminals	1,994	6.3	-	-	6.3
TV Monitors/Receivers	8,544	1.5	-	-	1.5
Regional Service Centers	26	3.0	1.7	0.2	1.1
Total Ground		$ 36.6	$21.2	$ 2.4	$13.0
TOTAL SYSTEM		$ 77.7	$46.9	$ 7.3	$23.5

The investment allocation between the three services is based on the number of satellite transponders used and associated ground station equipment required.

The major assumptions included in the 7-year financial analysis were selected to reflect an economically conservative profile and are summarized in Table 5. All capital recovery and debt repayment are calculated on a straight-line basis over periods directly related to the lifetime of the facilities. Operating expenses are increased 3 percent annually to account for inflation. Provision is made for a continuous U. S. $1. 0 million working capital fund and for income taxes at 45 percent of net operating income.

System financing is assumed to be obtained through international developmental institutions. Such financing is anticipated to cover 90 percent of the capital investment requirements, including a 2-year grace period and a 7 percent interest rate. The remaining capital investment will be provided through a combination of internally generated cash and short-term government loans.

For the purpose of establishing rates for each category of service, revenue requirements have been calculated. Table 6 reflects the average annual revenue requirements for each of the initial seven years of operation.

The revenue requirement allocations are based on the amounts of capital investment and operating expenses directly identifiable with each category of service. The results have been totaled and ratios established as a means of distributing common costs to produce a total revenue requirement allocation for each service category.

TABLE 5.

FINANCIAL ASSUMPTIONS

Program Period - 7 Years	Return on Investment o 10% after taxes objective
Depreciation & Amortization (Straight Line) o Space - 7 Years o Ground - 15 Years o Other - 15 Years	Financing Debt - 90% - 70.7 million o Grace period - 2 Years o Repayment period - 7 Years Space 15 Years Ground
Annual Operating Expenses o Total - $2.7 million o 3% Annual Inflation Factor	o Interest Rate - Grace Period - 1/2% Fee Operational Period - 7%
Annual Working Capital o $1 million	
Taxes o 45% of net operating income	Government Loan - $7.9 million o Interest Free o Lump-sum repayment in 5th Year

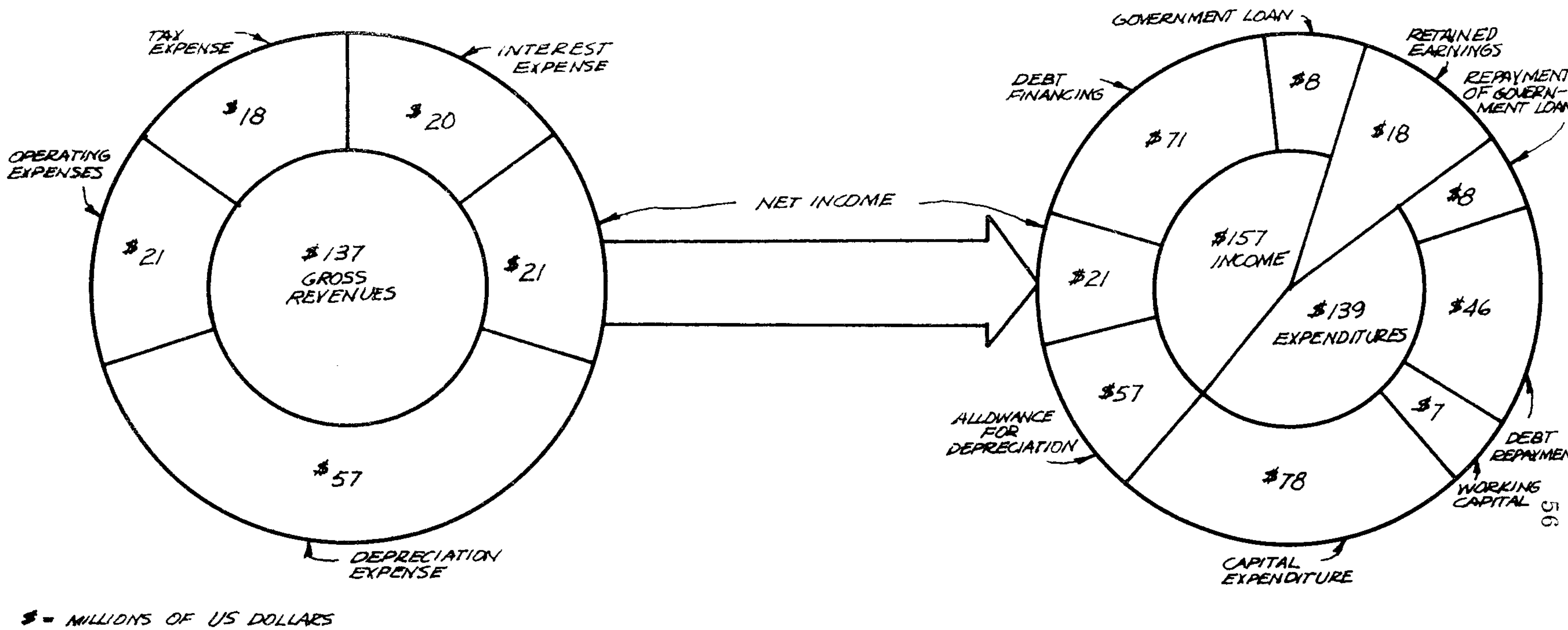
TABLE 6.

AVERAGE ANNUAL REVENUE REQUIREMENTS
U. S. $ MILLIONS

Item	Telephony	NTV	ETV
Depreciation	$ 4.9	$ 0.9	$ 2.4
Operations & Maintenance Expense	1.8	0.1	1.0
Income Taxes (45%)	2.2	0.3	1.2
Return on Investment	2.8	0.4	1.5
	$ 11.7	$ 1.7	$ 6.1

The cumulative 7-year operating results for the satellite system and a source and applications of funds summary are shown in Figure 3. Net operating revenues of U. S. $21 million would be derived after deducting all operating tax and interest expenses and recovering all capital except U. S. $21 million of ground investment. The ground facilities represented by this investment would be available for continued service using follow-on satellite facilities. The cash flow summary indicates that U. S. $18 million of retained earnings could be generated after covering all expenditures including debt repayments maturing during the initial seven years.

Based upon the costs and usage associated with the multiservice system model, some important financial characteristics have been derived First, the average annual telephony revenue requirements and usage estimates amount to U. S. $11.7 million and 49.5 million paid minutes, respectively. Adding U. S. $3.3 million local switching revenue requirements allocation to the U. S. $11.7 million produces the total additional revenue requirement necessary to support the projected telephony requirements. The revenue requirements do not represent just incremental costs but instead are based upon estimates reflecting full cost distribution. Of major significance is the fact that such revenue requirements are directly comparable with the existing rates for similar services. The current charge in Indonesia for urgent rate service (calls over 750 km) is U. S. $1.05; the comparable satellite figure, where the average circuit length is 1,500 km is substantially less: U. S. $0.30.



OPERATING RESULTS

CASH FLOW

FIGURE 3. FINANCIAL PROJECTIONS

Currently, national television is provided to four cities in Indonesia with PERUMTEL deriving approximately U. S. $600,000 annually in television transmission revenues. Under the multiservice system, the equivalent rate would be U. S. $1.7 million for NTV service to 26 cities. The ETV cost picture is equally impressive. It is estimated that approximately 600,000 students per year could take advantage of the ETV services. By excluding the return and tax components from the ETV revenue requirement, the cost per student year would amount to only U. S. $5.60.

3.2 System Elements

The major functional elements of the system are the satellites and the ground stations. These segments are integrated into a single communications system via the system interfaces shown in Figure 4.

3.2.1 Space Segment

A brief general description of the HS 347 Spacecraft was given in Section 3.1.2. The important satellite characteristics are highlighted in Table 7.

The satellite antenna pattern is designed to provide coverage of the entire Republic of Indonesia as illustrated in Figure 5. The nominal location of the satellite will be directly above the equator at 22,300 statute miles and at a longitude of 130 degrees. The communication repeater operates in the 6 GHz band on the uplink and the 4 GHz band on the downlink. Typically, the 500 MHz is divided into 12 channels, 40 MHz apart with 36 MHz of usable bandwidth. The remaining 20 MHz bandwidth

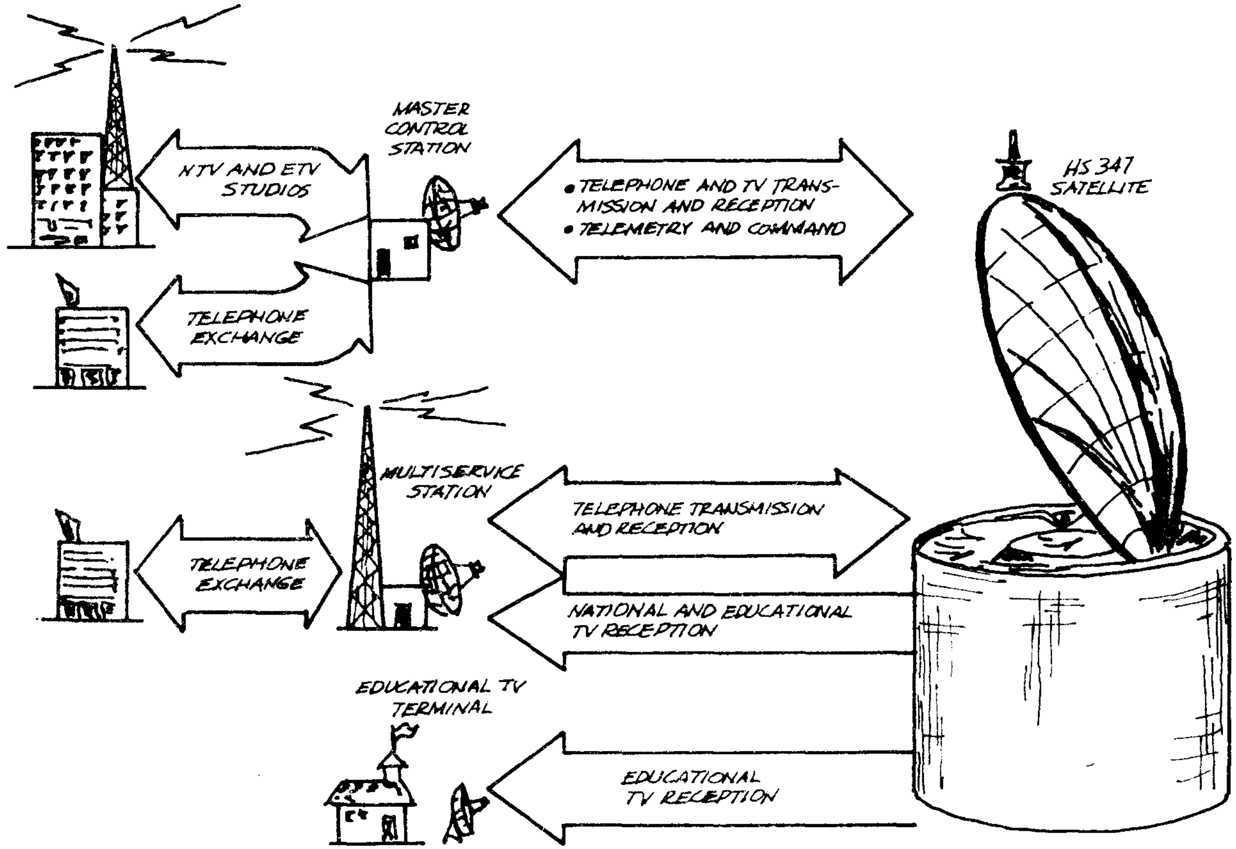


FIGURE 4. SYSTEM INTERFACES

TABLE 7.

SATELLITE CHARACTERISTICS

Spacecraft Weight	1,200 pounds
Number of Communications Channels	8
Receive Frequency	5.9 to 6.4 GHz
Transmit Frequency	3.7 to 4.2 GHz
Maximum RF Power	60 Watts
EIRP/Channel ETV	39.8 dBW
Nominal EIRP/Channel	35 dBW
Receive G/T	-7 dB/^{o}K
Antenna Coverage	All Indonesia
Orbit Inclination Control	$\pm$0.1 Degree
Longitude Drift Control	$\pm$0.1 Degree
Design Life (Stationkeeping)	7 Years

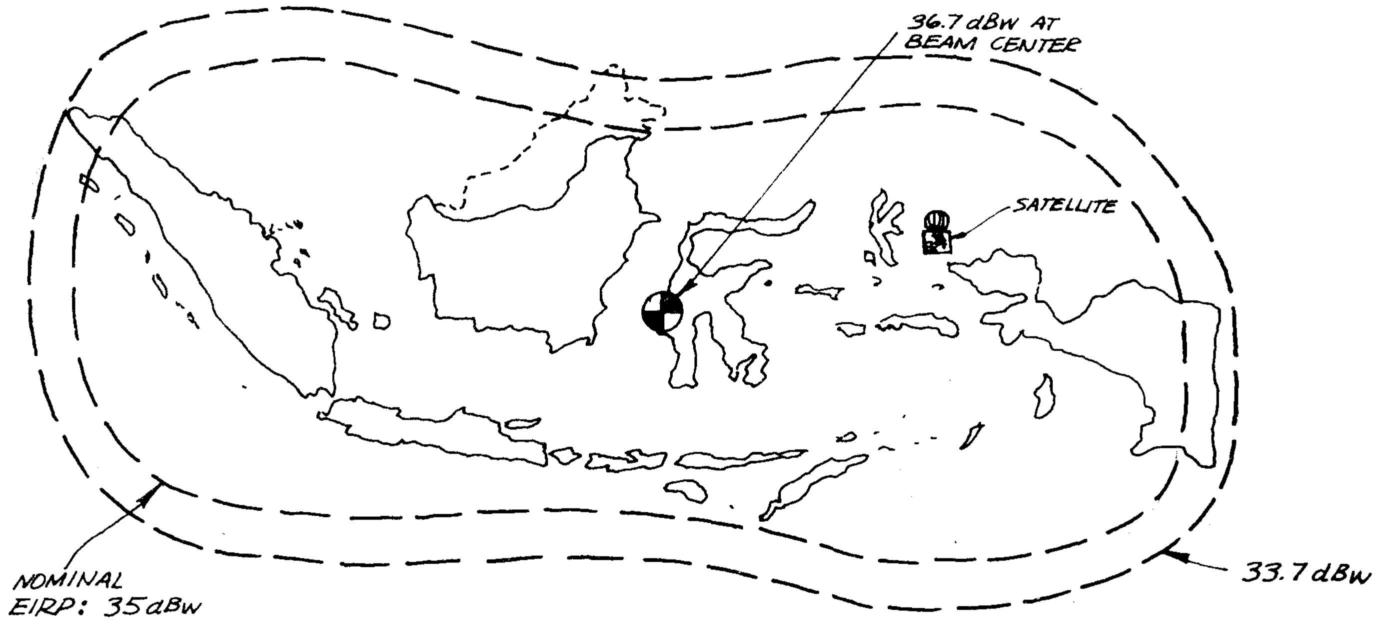


FIGURE 5. SATELLITE ANTENNA COVERAGE

is used to provide command, telemetry, and ranging functions on the satellite. However, in this application of the HS 333, a modification is proposed in the communication repeater to provide high satellite power for educational television service. Hence, eight channels are used: Six channels with an effective radiated power (EIRP) of 35 dBW and two channels with an EIRP of 39.8 dBW. The channels are assigned to the three services. Four channels in the satellite will receive and retransmit multiplexed voice signals with a maximum capacity of 800 one-way voice channels per transponder when used in a single carrier (trunk) mode with an earth station G/T = 27.2 dB. In the multiple access mode, the capacity is a function of the number of voice channels per carrier. A fifth channel is used for demand assigned telephony with a capacity of 300 one-way voice channels. The remaining three satellite channels receive and retransmit television signals, one channel in color and two channels in black and white.

A block diagram of the communications repeater is shown in Figure 6. The repeater is a microwave fixed gain system. A wideband receiver at 6 GHz is used to receive all channels; it establishes the noise figure of the system, converts the signals to the 4 GHz band, and provides amplification prior to channelization. Two multiplexers are then used to separate the signals into the eight RF channels. Each channel is then separately amplified by high efficiency travelling wave tube (TWT) amplifiers which provide a saturated output of 5 watts for six of the RF channels. Two channels have a saturated output of 15 watts. The channels are then combined by means of two low-loss output multiplexers.

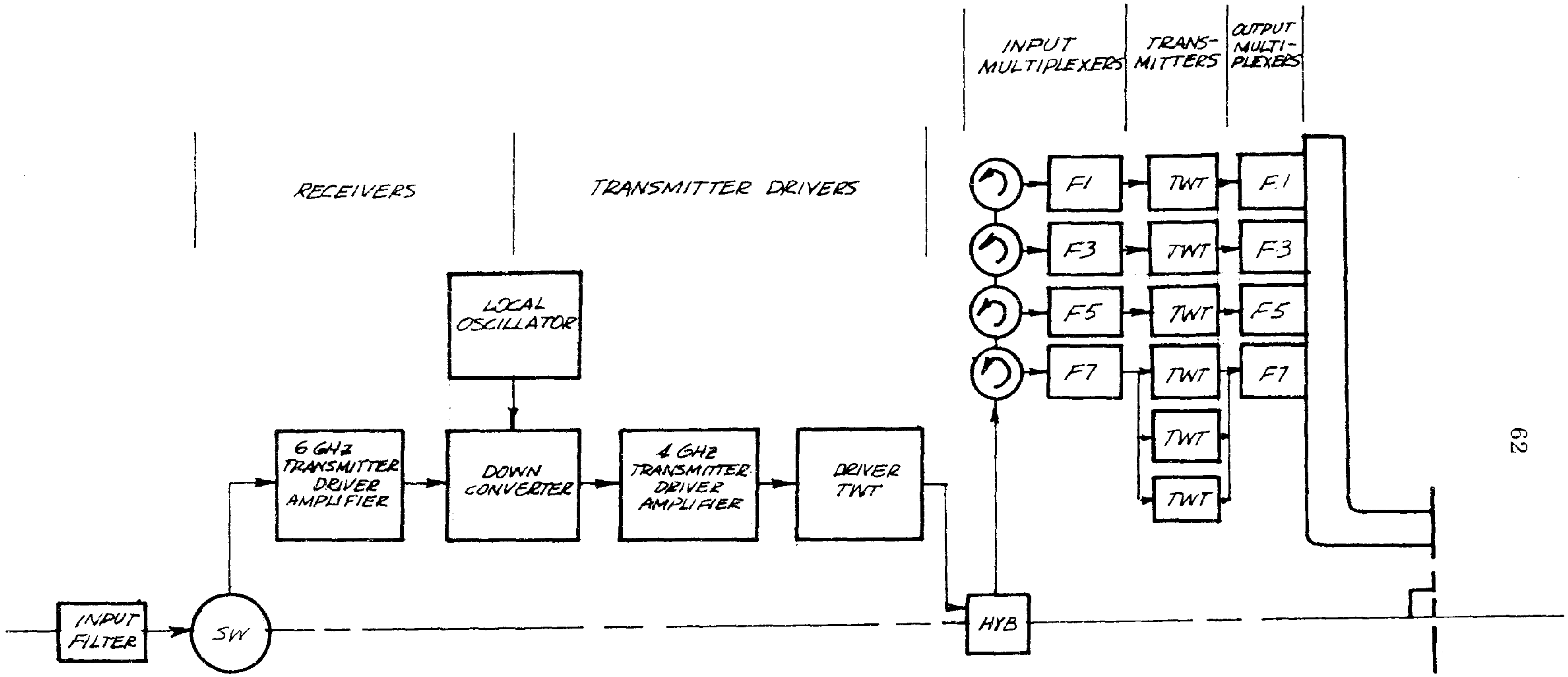


FIGURE 6. COMMUNICATION REPEATER

Redundant receivers are provided, but the output stages are not redundant. The solar array, which generates the prime power for the satellite, is designed to provide seven-channel operation by the conclusion of the seventh year. During solar eclipse, the batteries will provide continuous service. Following the seventh year, the operating channels can be selected based upon the importance of the service provided.

The spacecraft is spin-stabilized with a mechanically despun antenna system. Power is provided by a 74-inch diameter cylindrical solar array, approximately 60 inches long. The spaceframe consists of a 30-inch diameter thin walled cylinder coaxial with the satellite and a 73-inch diameter electronic platform. The cylinder surrounds the apogee motor and supports the electronic platform. The platform supports the cylindrical solar panel at its periphery and the hydrazine fuel system is supported by the inner cylinder.

The despin motor bearing assembly, which supports the antenna, is mounted on the electronic platform. An RF rotating joint conducts the signals from the spinning electronic platform to the despun antenna feed system. The antenna consists of a lightweight 60-inch diameter parabolic reflector and associated feed system. The transmit feed assembly is made up of two feed horns, and the receive feed system is a partially separated three-horn system with a subreflector. An omnidirectional antenna for command and telemetry is mounted on top of the parabolic receiver.

The pointing of the antenna is only controlled in azimuth, the east-west direction. Control is by means of a pilot signal, which is transmitted from the master ground station. A sum and difference signal is derived from the receive feed and is used to control the drive to the despin motor. The hydrazine propulsion system and the associated control system have been designed to maintain the satellite position to better than ± 0.1 degree in longitude and the orbit inclination to better than ± 0.1 degree. The satellite is established and maintained in the desired orbit by computing the orbital parameters which are converted into propulsion system commands and transmitted to the satellite from the master station. The overall system design relies on the maintenance of satellite position to allow use of nontracking ground antennas for the earth stations.

3.2.2 Ground Segment

The major functions of the ground stations are summarized in Table 8. Services provided at each type of station are identified. Both the total number of stations and the portion of that number located in the cities currently tied to the terrestrial microwave are identified.

The locations of the earth stations are shown on the map in Figure 7. A single master station is located in Djakarta. This station serves as the focal point for satellite control and telephony traffic management. A large volume of traffic is handled at both Djakarta and Surabaja. The multiservice station at Surabaja can also access the terrestrial system. These two stations will provide a backup to the backbone microwave system and also serve as the backbone centers for traffic between the outer islands and Java/Sumatra. Television programming is prepared at the studios and

TABLE 8.

GROUND STATION FUNCTIONAL CHARACTERISTICS

Station Type	Service Configuration	Total Number of Stations	Number on Microwave Link
Master Control	o Transmit/receive trunk and demand access telephony. o Transmit national TV o Transmit educational TV o Telemetry, command, and ranging.	1	1
Multiservice	Class 1) o Transmit/receive trunk and demand access telephony. o Receive national and educational TV.	14	2
	Class 2) o Transmit/receive demand access telephony. o Receive national and educational TV.	7	5
	Class 3) o Receive national and educational TV.	4	4
Educational TV	o Receive educational TV	1,994	-

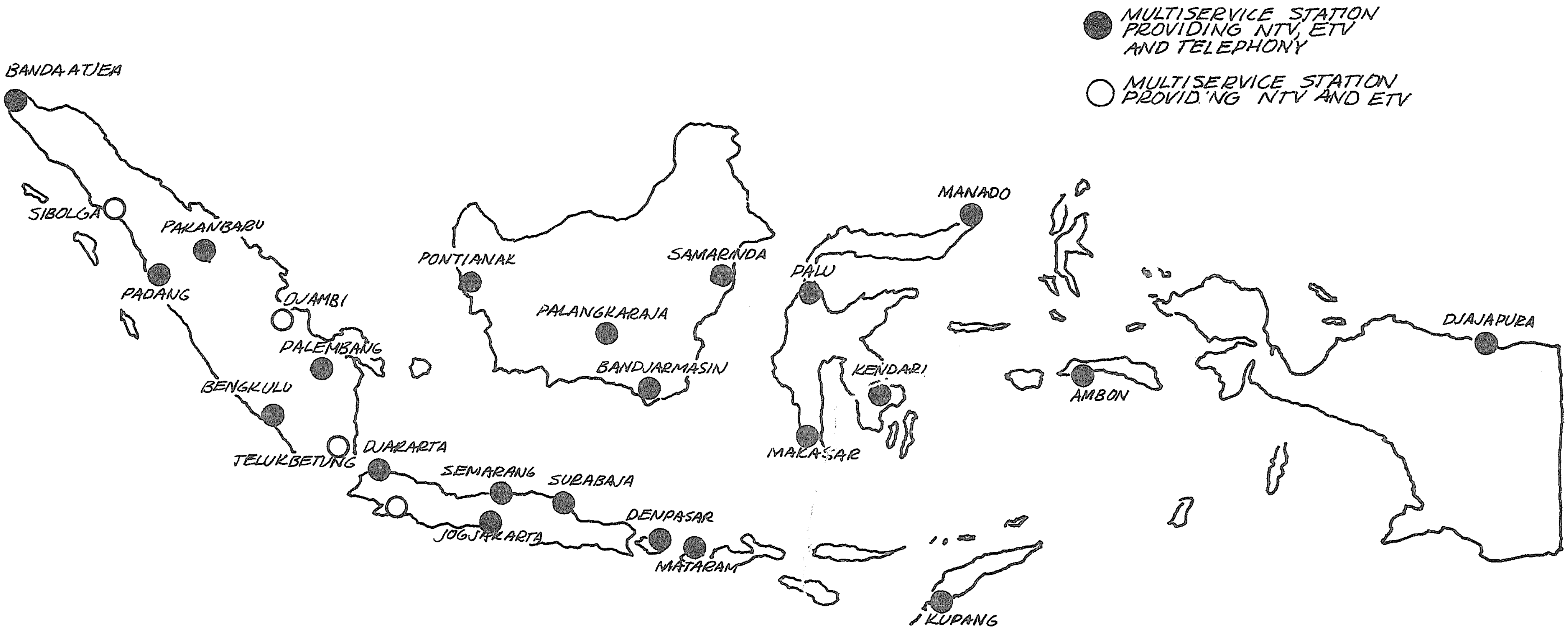


FIGURE 7. GROUND STATION LOCATIONS

then transmitted from the Djakarta station to the satellite. The television signals are retransmitted from the satellite to the entire country. These signals are received at stations located at each of the 26 provincial cities and then rebroadcast via terrestrial means at VHF to individual receivers in the cities. In addition to reception in the major cities, the two channels of ETV are received by 1,994 terminals located at school houses throughout the country in both urban and rural communities. This will allow the islands of Kalimantan and Sulawesi, as well as communities as far as West Irian, to be culturally tied to Java and Sumatra.

The approach to telephone expansion is to establish service in the outer islands as well as augment the existing message service. Major trunks of two-way communications between many of the provincial capitals and either Djakarta or Surabaja are featured in this system. This permits access to all cities currently tied to the microwave system. Ground stations at more than 20 cities are equipped to receive and transmit from 12 to 800 two-way voice channels per trunk for inter- or intra-island service. In addition, these same cities include 3 to 15 two-way demand assigned voice channels. The demand assigned channels provide connections between all cities in the system. Hence, any multiservice station can be interconnected via satellite to any other demand access equipped multiservice station throughout the country, providing instantaneous national communicaticns.

A common design approach has been taken for the ground station located at Djakarta and those at the major cities. Physical differences are minimized. Although a master control station and three different types of multiservice stations have been identified, the basic building blocks for each are similar. All terminals are configured with a fixed 35-foot parabolic antenna. The interface between these stations and the three-channel television rebroadcast transmitter is identical. Equipment at each of the multiservice stations is housed within a building with the capacity to support the telephony and television requirements at Surabaja. The master station is a larger facility because of the requirements imposed by television transmission and satellite telemetry and control.

3.2.2.1 Master Station.

The master station serves as the interface with both the television broadcasting studio and the local telephone exchange. The actual interface depends upon the physical location of the station relative to the distribution centers for the telephony and TV services. It is assumed that all services are co-located; however, consideration has been given to locating the master station outside of the city and including a microwave tail for reception of the TV programs and both transmission and reception of telephony. In the event that the earth station is co-located with the television stations, the interfaces are minimal, as standard 72-ohm coaxial interstudio cable may be used to feed the earth station from one of the distribution line amplifiers, which are commonly part of the TV station equipment. In this event, standard telephone cables would supply the interconnections with the telephone multiplexer equipment and the local telephone exchange.

The master station also includes a TV rebroadcast capability. The three-channel rebroadcast station consists of a 200-foot tower antenna and 1 kw transmitter and meets or exceeds the field strength requirements for nominal operation. A coverage radius of 25 miles is assumed. Television receivers located in homes and schools will be able to receive the video signals.

A major function of the master station is to monitor the status of the satellite and to initiate the necessary commands to maintain the proper location and desired attitude. To accomplish this function, specialized equipment is included for telemetry reception, ranging, and command generation and transmission. The orbital position of the satellite is continuously monitored by use of a computational capability included at this station. A feature of the HS 347 design is the pilot tone tracking. A beacon signal is transmitted from the master station to the satellite. Equipment on the satellite positions the antenna to acquire and track the signal and therefore eliminates the necessity for a tracking capability at any of the ground stations. In this manner, the satellite coverage contour of Indonesia remains fixed.

A summary of the major characteristics of the master station is given in Table 9. The G/T required is 27.2 dB/^{o}K and is achieved with an antenna of 35-foot diameter and a system noise temperature of 200^{o}K. The uplink design utilizes separate 1.5 kw transmitters for the national and educational channels. In addition, 800 permanently assigned FDM/FM telephone voice channels are transmitted by a third 1.5 kw transmitter. Djakarta has been assigned 12 demand access voice channels for which 12 1-watt transmitters are used.

TABLE 9.
MASTER CONTROL STATION
CHARACTERISTICS

Antenna	35-Foot Diameter
Antenna Gain (Transmit)	54.8 dB
Antenna Gain (Receive)	50.2 dB
Transmit Frequencies	5925 to 6425 GHz
Receive Frequencies	3700 to 4200 GHz
Feed Bilinear Polarization (Telemetry polarization is orthogonal to command polarization)	
Receiving System Noise Temperature	$200^{\circ}K$
Transmitters	1.5 kw (3), 1 watt (12)

The demand assigned approach selected for implementation is based upon low cost manual operating techniques. A block diagram of the specialized telephony equipment added to the stations is shown in Figure 8. The design is based upon the following philosophy:

1) A single message per RF carrier
2) Fixed tuned receivers
3) Multiple receivers per city based upon the number of demand assigned voice channels
4) Manually set transmitters with frequency adjustable RF carriers
5) A single manually tuned receiver monitor which is controlled by an operator to determine channel availability at each city.

The block diagram illustrates the arrangement of the equipment. Incoming calls are received on fixed tuned receivers. A variable frequency receiver is operator-controlled to determine the status of the desired voice circuits. The outgoing calls are transmitted by 1 watt TWT's which are summed and transmitted to the satellite.

A typical procedure for placing a call between cities is as follows:

1) The operator reviews the channel frequency range of the desired circuits at the city in question. Synthesizer dial settings are preassigned and tabulated for operator usage. The channels are then sequentially monitored to determine the availability of a receive channel.

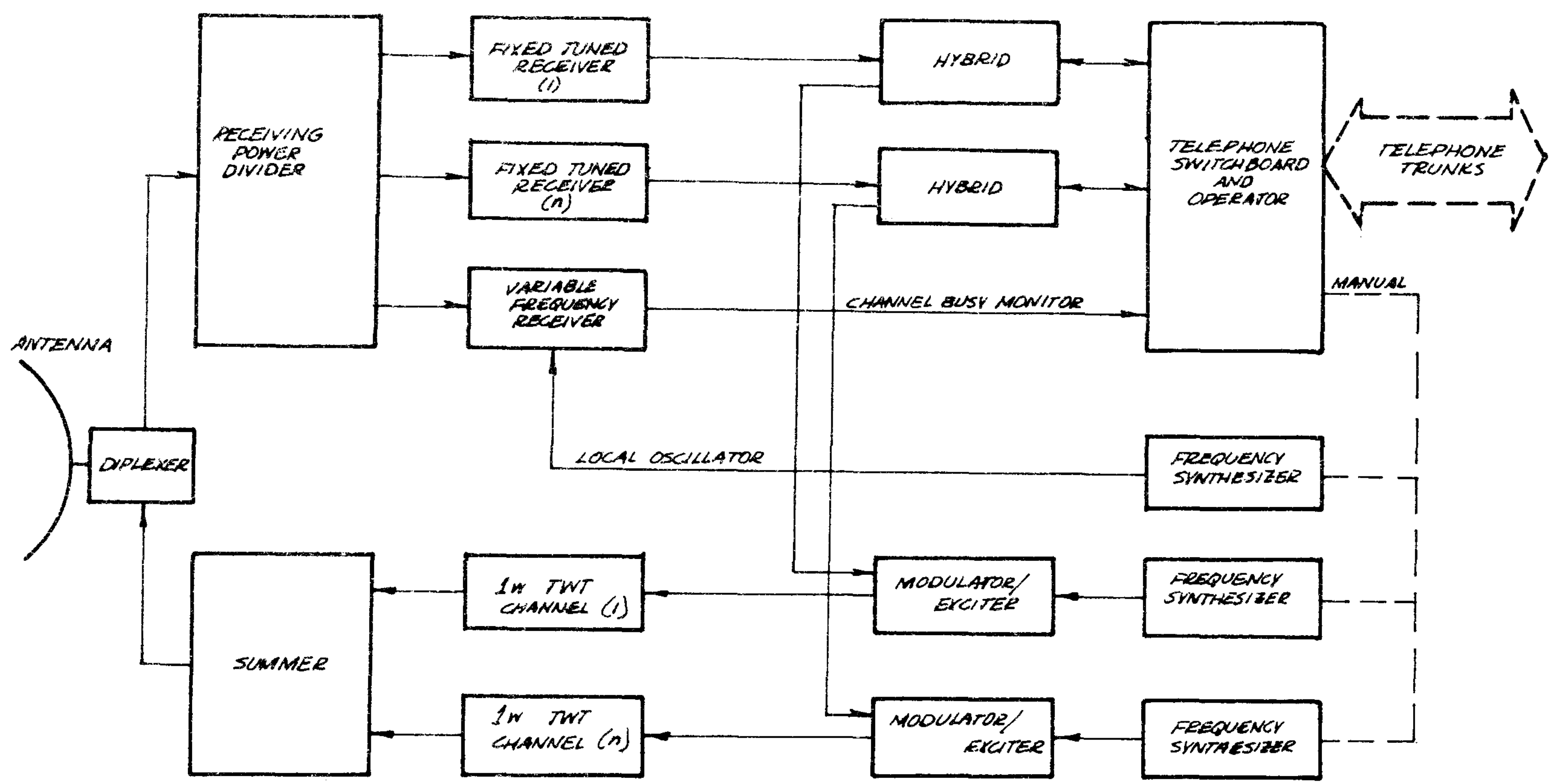


FIGURE 8. MANUAL DEMAND ACCESS

2) A local transmitter synthesizer is then set by the operator at the available receiver frequency.

3) The transmitter is placed in an operating condition and the operator then rings with the standard telephone equipment. A response to this low frequency ring is obtained by the operator being addressed.

4) The ringing station identifies itself by voice and establishes which return frequency should be used.

In this way, a closed circuit is established. At the conclusion of the conversation, the frequency assignment becomes available for usage, and the process described above is repeated.

3.2.2.2 Multiservice Station

The multiservice station is common to 25 cities. As previously discussed, the difference is only in the type of services offered. The stations at 14 cities provide both television and telephony service. A varying number of voice channels is provided at these cities. Stations at seven other cities provide ETV and NTV reception/rebroadcast, and also include six demand assigned channels to integrate these cities into the existing microwave net. Finally, there are four stations at cities that are also a part of the terrestrial system. They are provided the capability to receive and rebroadcast both the ETV and NTV signals.

A summary of the number of telephony channels proposed for each city is given in Table 10. A three-phase build-up is proposed and shown in the table. For example, in the first phase, the city of Surabaja will be equipped to transmit 452 channels in the FDM/FM format and six channels

TABLE 10.

TYPICAL PHASING OF TELEPHONY INSTALLATION

City	Preassigned Channels			Demand Assigned Channels		
	Phase			Phase		
	1	2	3	1	2	3
Djakarta	452	572	800	6	9	12
Surabaja	452	572	800	6	9	12
Banda Atjeh	24	48	96	6	9	12
Pakanbaru	24	36	48	3	3	3
Bandjarmasin	24	48	96	6	9	12
Pontianak	24	36	48	3	3	3
Samarinda	24	36	48	3	3	3
Makasar	36	96	180	6	12	15
Palu	24	36	48	3	3	3
Kendari	24	36	48	3	3	3
Manado	12	24	36	6	6	6
Mataram	12	24	36	6	6	6
Kupang	12	24	36	6	6	6
Ambon	12	24	36	6	6	6
Djajapura	12	24	36	6	6	6
Padang	-	-	-	6	6	6
Palembang	-	-	-	6	6	6
Bengkulu	-	-	-	6	6	6
Semarang	-	-	-	6	6	6
Jogjakarta	-	-	-	6	6	6
Denpasar	-	-	-	6	6	6
Palangkaraja	-	-	-	6	6	6
Sibolga	-	-	-	-	-	-
Djambi	-	-	-	-	-	-
Telukbetung	-	-	-	-	-	-
Bandung	-	-	-	-	-	-
TOTAL CHANNELS	1,168	1,636	2,392	117	129	150

of demand access telephony. Both services grow to the final capacity, which is 800 FDM/FM and 12 demand assigned channels.

3.2.2.3 Educational Television Terminals

ETV receive-only terminals are located at schools or community centers in both urban and rural regions of the country. These terminals directly receive the two channels of black and white video and distribute the signals to four monitors located within the educational facility. The stations are simple, inexpensive, and are designed for unattended operation.

The major feature of the terminal is a small 13-foot antenna. To meet the TV performance requirements, the $G/T = 13.9$ dB/^{o}K necessitates a system noise temperature of 600^{o}K. A transistorized low noise amplifier of this type is expected to be available in the near future.

3.2.2.4 Ground Segment Redundancy and Spares

Redundancy exists in all major portions of the ground segment. The spares philosophy followed is selected in the interest of reducing costs and increasing effectiveness. By pooling resources into local centers or depots, a group of maintenance personnel is used to service and repair multiple ground stations and terminals. This approach reduces the number of spares required, the number of personnel needed, and the type of test equipment necessary at the stations and leads to a more cost-effective approach.

3.3 Systems Analysis

3.3.1 General.

The service requirements defined for the Indonesian Communications Satellite System have a direct impact on the allocation of satellite repeater resources. As mentioned earlier, the nominal spacecraft repeater is divided into 12 channels, with the center frequencies of adjacent channels separated by 40 MHz. The guard band between adjacent channels is generally assumed to be 4 MHz, so that the useful channel bandwidth is 36 MHz.

In establishing the bandwidth and power distribution between services, an analysis of both the uplink and downlink was conducted. Each of the service requirements was analyzed to establish the ground station G/T requirements, as well as the satellite EIRP requirements. Based upon this analysis, several basic conclusions were reached.

1) The single channel of national television would be provided by the use of a single 40 MHz transponder operating in a saturated mode.

2) Paralleling three TWT's for each channel of educational television would be necessary. Two ETV channels, each requiring a 22 MHz bandwidth, would use six of the twelve available TWT's.

3) The desired telephony service would be provided by the remaining channels.

A total of seven satellite TWT's are allocated to the two television services. The remaining five channels are available for telephony.

Table 11 summarizes the system design parameters. Sufficient margin is provided in the establishment of both the signal and test-tone-to noise ratios to guarantee satisfactory performance. The resulting S/N = 59.1 dB for the color NTV service, whereas an S/N of 43.9 dB is adequate for the black and white ETV service. A required test-tone-to noise ratio of 51 dB is assumed for the telephony service.

For NTV and ETV transmission, a single carrier accesses each transponder, which is driven to saturation. The NTV links utilize 35-foot antennas on both uplink and downlink, with the result that the system carrier-to-noise and output signal-to-noise ratios are more than adequate, as shown by the link analysis in Tables 12 and 13. For ETV, it is necessary to reduce the RF bandwidth to 22 MHz to produce an adequate carrier-to-noise ratio with the inexpensive receive terminal assumed (13-foot antenna, 600°K noise temperature). Because of the resulting smaller modulation index, the output signal-to-noise ratio is reduced to 43.9 dB.

For telephony, the available transmit terminal EIRP and the receive terminal G/T are identical to those of the NTV terminals. The uplink signal power, when there are four or more carriers, is adusted to produce a transponder output backoff of 4 dB. This reduces the intermodulation products to a tolerable level, while not unduly penalizing the retransmitted EIRP. The indicated carrier-to-intermodulation ratio pertains to the center carrier. The FM improvement factor has been computed using standard formulas for loading and peaking factors. The resulting

TABLE 11.

SYSTEM DESIGN REQUIREMENTS

Service	Power (Watts)	RF Band-width used (MHz)	EIRP (dBW)	Antenna Diameter (Ft.)	System Temp-erature (°K)	G/T (dB/°K)
NTV	5	36	35	35	200	27.2
ETV	15 per channel	22 per channel	39.8	13	600	13.9
Telephony	V a r i a b l e			35	200	27.2

TABLE 12.

TELEVISION LINK ANALYSES

	UPLINK	
	NTV	ETV
Ground Transmit Power, dBW	31.8	31.8
Transmit Losses, dB	-1.0	-1.0
Transmit Antenna Gain, dB	54.8	54.8
Ground EIRP, dB	85.6	85.6
Path Loss, dB	-200.0	-200.0
Miscellaneous Losses, dB	-3.0	-3.0
Receive Antenna Gain, dB	26.8	26.8
Receive Carrier Power, dBW	-92.2	-92.2
Boltzmann's Constant, dBW-°K	-228.6	-228.6
Spacecraft System Noise Temperature, dB-°K	33.7	33.7
Noise Bandwidth, dB-Hz	75.6	73.4
Noise Power, dBW	-119.3	-121.5
Uplink C/N, dB	27.1	29.3
	DOWNLINK	
Spacecraft EIRP, dBW	35.0	39.8
Path Loss, dB	-196.0	-196.0
Miscellaneous Loss, dB	-1.0	-1.0
Receive Antenna Gain, dB	50.2	41.7
Receive Carrier Power, dBW	-111.8	-115.5
Boltzmann's Constant, dBW-°K	-228.6	-228.6
Ground System Noise Temperature, dB-°K	23.0	27.8
Noise Bandwidth, dB-Hz	75.6	73.4
Noise Power, dBW	-130.0	-127.4
Downlink C/N, dB	18.2	11.9
Total C/N, dB	17.7	11.8
FM Improvement, dB	19.1	9.5
Noise Weighting, dB	16.3	16.3
Peak-to-Peak Video/Form Factor, dB	6.0	6.0
Output Signal/Noise, dB	59.1	43.9

TABLE 13.

TYPICAL TELEPHONY TRUNK LINK ANALYSIS

96 VOICE CHANNELS/CARRIER

	Uplink	Downlink
EIRP/Carrier, dBW	70.4	23.1
Path Loss, dB	-200.0	-196.0
Miscellaneous Losses, dB	- 3.0	- 1.0
Receive Antenna Gain, dB	26.8	50.2
Carrier Power, dBW	-105.8	-123.7
Boltzmann's Constant, dBW-°K	-228.6	-228.6
System Noise Temperature, dB-°K	33.8	23.0
Noise Bandwidth/Carrier, dB	68.7	68.7
Noise Power, dBW	-126.1	-136.9
C/N Thermal, dB	20.3	13.2
C/N Required, dB	-	10.0
Threshold Margin, dB	-	3.2
C/N Intermodulation, dB	-	17.7
C/N Total, dB	-	11.3
FM Improvement, dB	-	36.5
Weighting and Pre-emphasis, dB	-	6.5
Output Test-Tone-To-Noise, dB	-	54.3

test-tone-to-noise ratios can be compared, for example, with a value of 51 dB, which corresponds to a noise allocation to the satellite links of 8,000 pWp.

Because each 22 MHz ETV signal is transmitted in a single 40 MHz satellite channel, despite the use of three TWT's, transmission of the two ETV signals results in four satellite channels (144 MHz) remaining unoccupied. It is not necessary that these channels be adjacent to the two channels containing the ETV channels. In fact, if the empty channels are used to separate the telephony channels, any possibility of adjacent channel interference due to multicarriers transponder operation is eliminated. One such communications repeater arrangement is shown in Figure 9. Both the transmit and receive frequency plan is shown as are the channel service allocations.

3.3.2 Telephony Model Description

A preliminary estimate of the Indonesian traffic requirements in terms of the number of voice circuits terminated at various province capitals has been provided by the PTT Directorate as given in Table 14. These channel requirements have been used as gross guidelines in establishing a flexible system for telephony service. To meet the total voice channel requirements in Table 14 would require somewhat more than five satellite channels when operating in the standard FDM/FM format. A more detailed projection of voice circuit requirements is based upon the data from the IDA Report, as described in the financial analysis. In order to provide both a flexible system and one that would complement the existing terrestrial network, it is assumed that only four satellite channels would be used for point-to-point trunk route traffic, while one channel is

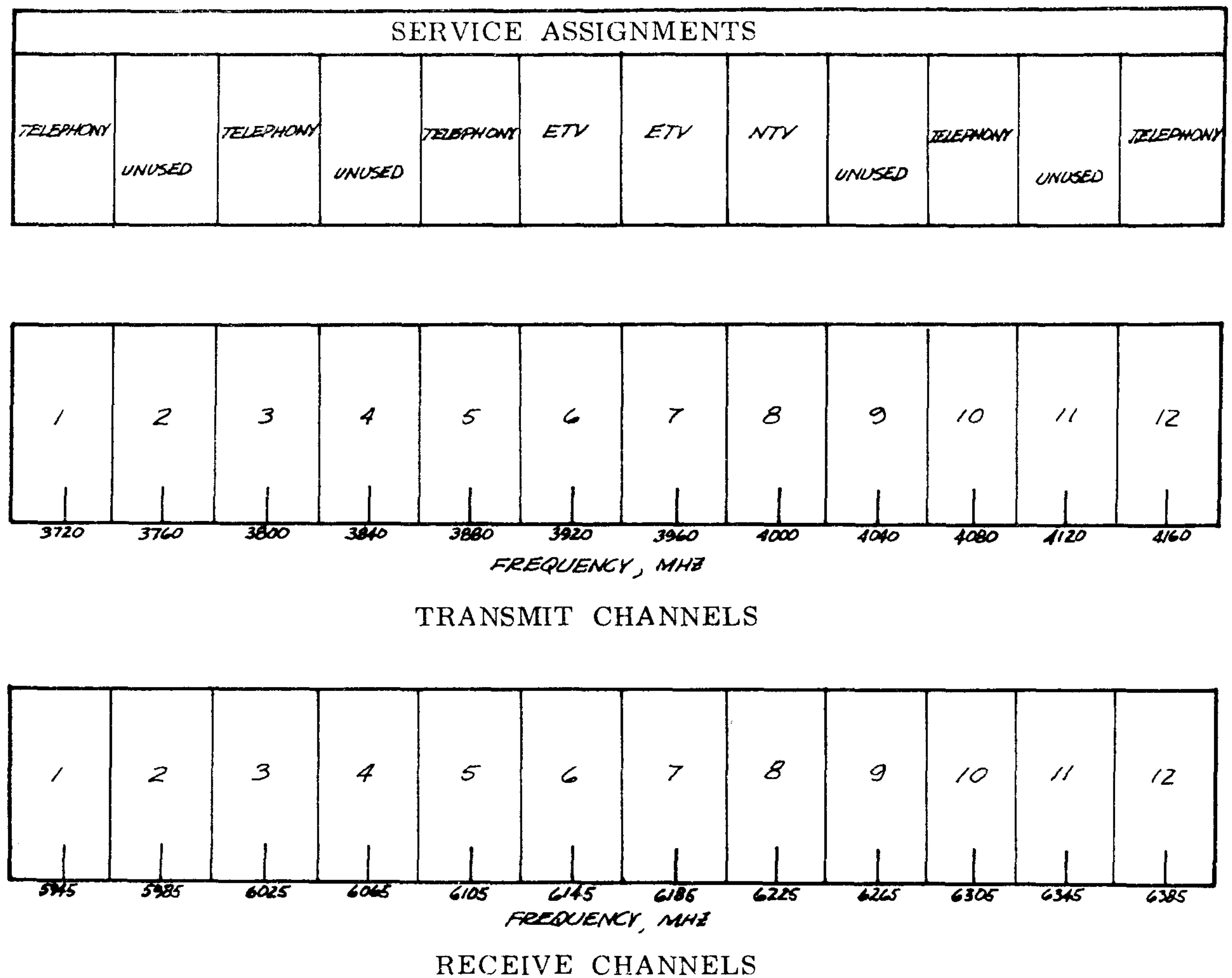


FIGURE 9. FREQUENCY ALLOCATION OF SPACECRAFT CHANNELS

TABLE 14.

PTT PRELIMINARY TELEPHONY TRAFFIC REQUIREMENTS

Cities	Desired Channel Capacity
Djakarta	960
Surabaja	960
Banda Atjeh	120
Sibolga	120
Djambi	120
Denpasar	120
Kupang	60
Makasar	240
Palu	60
Manado	60
Pontianak	60
Bandjarmasin	120
Samarinda	60
Ambon	60
Djajapura	60
Seven additional cities located in provinces not represented	60/City

assigned to demand access telephony. The satellite capacity in the FDM/FM mode is then reduced primarily by the removal of a single channel; in addition, further circuit reduction is applied to balance the traffic flow between various cities, particularly at Djakarta and Surabaja. The majority of the satellite capacity is assigned to those cities not connected to the microwave-troposcatter system on Java and Sumatra.

Since the cities in the microwave-troposcatter network are primarily on the islands of Java and Sumatra, the major function of the satellite telephony network is to connect the outer island provinces to the major cities on these two islands. This is accomplished by direct satellite connection to either Djakarta or Surabaja and then by microwave connection to the ultimate destination, should it be different from either of these two cities.

3.3.2.1 Dedicated Channels

The satellite telephony network is described in matrix form in Table 15 and is illustrated in Figure 2. The 13 province capitals, beginning with Banda Atjeh and ending with Djajapura, are the principal cities to be connected to the microwave network. The projected voice channel requirements for each city, as indicated by Table 14, are shown in parentheses. These voice channels may also be regarded as the number of transmitted voice channels at each city.

The majority of the voice channels assigned to each city are transmitted on a single carrier in FDM/FM format. The greater part of these are terminated in either Djakarta or Surabaja. In most cases, the terminations are divided equally between these cities since the requirements in Table 14 indicate an equal number of channels for these two cities.

TABLE 15.

TELEPHONY TRAFFIC PLAN

	Djakarta	Surabaja	Banda Atjeh	Panan-baru	Bandjar-masin	Pontianak	Samar-inda	Makasar	Palu	Kendari	Manado	Mataram	Kupang	Ambon	Djajapura	Demand Assigned
Djakarta		488	48	24	36	12	12	72	12	12	12	12	12	24	24	12
Surabaja	488		48	24	36	12	12	72	12	12	12	24	24	12	12	12
Banda Atjeh (120)	48	48														12
Pakanbaru (60)	24	24														3
Banjarmasin (120)	36	36				12	12									12
Pontianak (60)	12	12			12		12									3
Samarinda (60)	12	12			12	12										3
Makasar (240)	72	72							12	12	12					15
Palu (60)	12	12						12		12						3
Kendari (60)	12	12						12	12							3
Manado (60)	12	12						12								6
Mataram (60)	12	24														6
Kupang (60)	12	24														6
Ambon (60)	24	12														6
Djajapura (60)	24	12														6
Padang																6
Palembang																6
Bengkulu																6
Semarang																6
Jogjakarta																6
Denpasar																6
Palangkaraja																6
Total Channel Terminations	800	800	96	48	96	48	48	180	48	48	36	36	36	36	36	150

However, commercially available multiplex/demultiplex equipment comes in channel groupings which are multiples of 12. Consequently, an even division of channels at cities terminating in Djakarta and Surabaja was not possible in all cases.

In addition to connection of the outer-island cities with the microwave link, a certain number of dedicated intra-island circuits are provided within Kalimantan and Sulawesi. This eliminates the need for double-hop transmission on intra-island calls, a procedure which would double the number of voice channels required and cause a delay in transmission.

For each dedicated voice channel group assigned to one of the outer island cities and terminating in either Djakarta or Surabaja, a group of equal size must be assigned in the opposite direction for completion of the voice circuits. In addition, 488 voice circuits are provided between Djakarta and Surabaja directly. These serve as a backup to the microwave link between the two cities.

The sum of the entries in each column of Table 15 gives the number of dedicated circuits terminated in each city, which is also the number of voice channels that must be supported by the transmitted carrier at the city. Each total is a multiple of 12, and so is compatible with currently available multiplex/demultiplex equipment. Since most of these totals are less than the single-carrier transponder capacity, it is necessary in those cases that the transponders be operated in a frequency division multiplex (FDM) mode.

3.3.2.2 Demand Assigned Channels

While the FDM/FM format is the standard mode of telephony transmission, it is inflexible in that the voice channel assignments are fixed between pairs of cities. This can be seen from Table 15, where the only single-hop inter-island connections provided are those between the outer islands and Java. Furthermore, if a particular link should become saturated because of an atypically heavy load demand, there is no way of alleviating the situation, even if there should be excess circuits on other links. To provide a single-hop connection between any pair of ground terminals, as well as to provide backup capability for temporarily saturated links, a limited number of demand assigned circuits has been included in the system.

Demand assignment of circuits can assume several forms. The present discussion is confined to FDMA systems, which are best suited to low density traffic applications. More particularly, attention is confined to systems that operate on a single message per carrier basis. A fully variable demand assignment (FVDA) system is one in which each terminal is capable of transmitting or receiving on any available frequency. In such a system, voice channels are assigned in pairs to form voice circuits or trunks, in the order in which they are requested. Because of the great flexibility of such a system, the number of circuits required to handle a given peak traffic load can be as low as one-third of that needed in a system of dedicated circuits.

The order wire operation of an FVDA system is fairly complex, and the required speed of operation is probably too great to be handled manually. Moreover, the cost per voice circuit is quite high. For these reasons, it was decided that the demand assignment portion of the Indonesian telephony network would initially sacrifice some flexibility in exchange for simplicity and reduced system cost. The type of system selected operates in a variable origin demand assignment (VODA) mode. Each terminal has the capability to transmit on any available frequency, but can receive on only a limited number of preassigned frequencies. The terminal initiating a call scans a tunable receiver to find an unused receive frequency of the opposite terminal. If successful, it signals the other terminal on this frequency and indicates on which of its receive frequencies it wishes the second terminal to transmit. The signaling operation is simple enough to be carried out manually.

The number of receive frequencies assigned to each city is shown in the last column of Table 15. For the most part, these numbers are one-fourth the difference between the total required number of circuits and the number provided by means of dedicated circuits.

In addition to the demand assigned circuits provided to the outer-island cities to complement the dedicated circuit capability, twelve demand assigned channels are added to the capability of both Djakarta and Surabaja. Furthermore, six demand assigned channels are provided at each of seven smaller cities that also have microwave capability. The latter circuits not only act as a backup to the microwave links, but they also provide potential connections to cities not otherwise accessible via satellite. Since the cities given this added capability would in any case be provided with a terminal for NTV and ETV reception, the additional cost attributable to telephony is smaller than it would be if the terminal were constructed solely to provide the latter service.

A total of 150 demand assignment voice channels are provided in the system. Either digital or analog modulation methods could be employed for these channels. Although digital modulation would permit a greater number of voice channels to simultaneously access a satellite transponder, FM transmission has been chosen to minimize system costs. A single satellite transponder can support at least 300 frequency modulated carriers.

3.3.2.3 Satellite Channel Arrangement

As mentioned earlier, the number of voice channels supported by the carrier transmitted from each ground terminal is shown in the bottom row of Table 15. The occupied bandwidth and required satellite power for each of these carrier types is shown in Table 16. These figures are based on a ground station antenna diameter of 35 feet and a receiver noise temperature of 200°K.

Several possible arrangements of these carriers within the four FDM/FM satellite channels are possible. One such arrangement is shown in Figure 10. In each channel, the occupied bandwidth is less than the nominal 36 MHz useful bandwidth.

TABLE 16.
BANDWIDTH AND POWER REQUIREMENTS
OF DEDICATED FDM/FM SIGNALS

Voice Channels Per Carrier	Number of Carriers	Single Carrier Bandwidth, MHz	Single Carrier EIRP, dBW
36	5	3.63	20.4
48	5	4.37	21.1
96	2	7.35	23.1
180	1	12.88	25.2
800	2	36.00	35.0

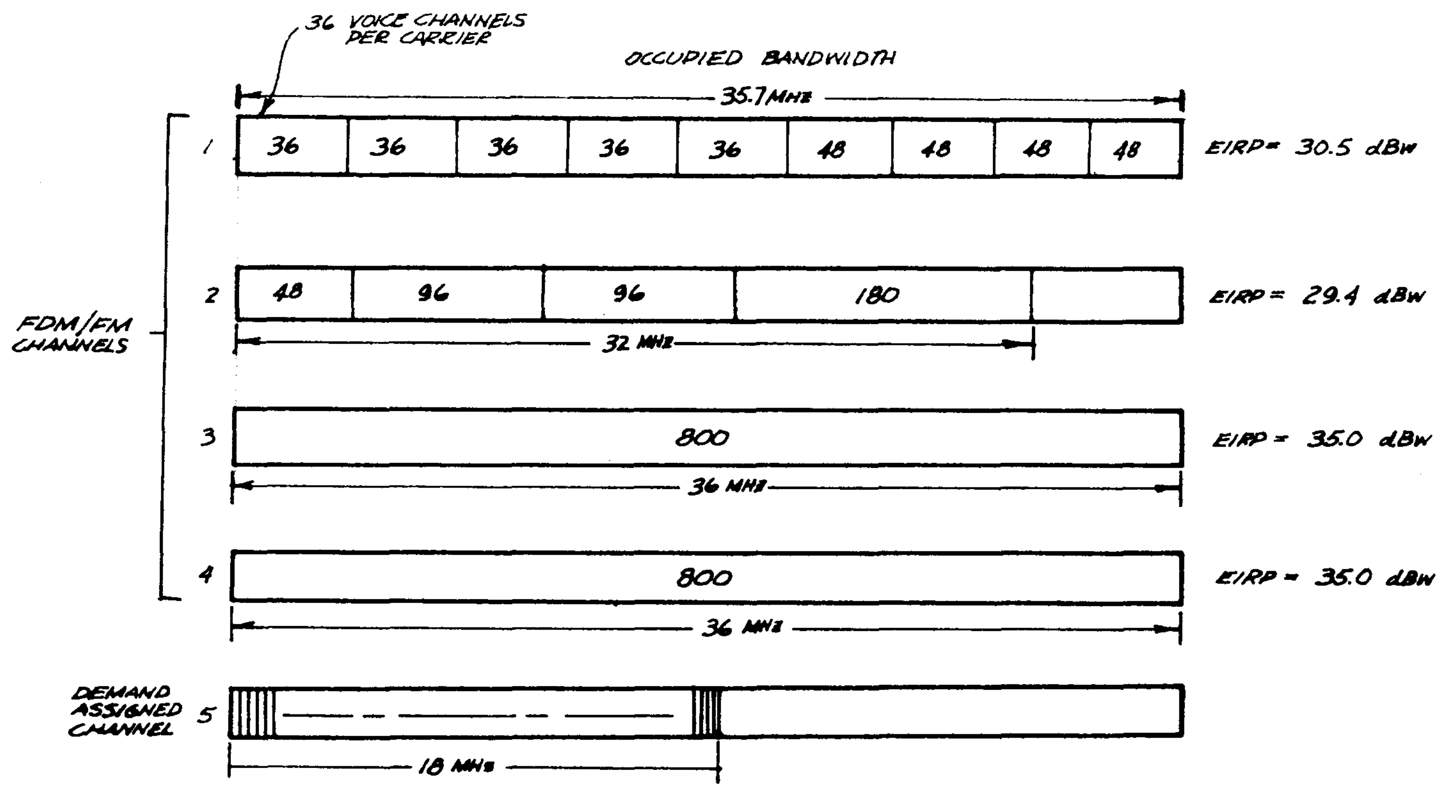


FIGURE 10. CHANNEL ALLOCATIONS

Each transponder that is operated in multicarrier fashion must be backed off from saturation to avoid excessively large intermodulation products. In the HS 347 spacecraft, the TWT operating point varies with the received signal level. Proper link design will result in a maximum EIRP backoff of about 4.4 dB from the single-carrier saturated value of 35 dBW. For the channel arrangement of Figure 10, therefore, the minimum power margin is approximately 1 dB.

The fifth telephony channel is utilized for the VODA signals. For frequency modulation, the RF bandwidth per carrier is 114 MHz. Thus, slightly in excess of 300 carriers can be accommodated in the 36 MHz channel bandwidth. From a power standpoint, a single transponder can support slightly less than 300 carriers. This number can be more than doubled, however, through the technique of voice switching (i.e., turning off the ground transmitter during pauses in conversation). There is ample room for system growth with the initially chosen total of 150 demand assigned voice channels.

3.3.3 An ETV Approach for Indonesia

Several sources of information have been used to establish a rationale for the ETV service proposed. The three major documents applied are the "Statistical Pocketbook of Indonesia, 1964-1967," the "1969-1973 Five Year Plan (REPELITA)," and the "Area Handbook for Indonesia - 1970." Each source has been used to provide an understanding of the structure of Indonesian education, the characteristics of the current number of facilities, students, and teachers, and information for future development plans in the educational sector.

As indicated in these sources, progress is being made in bringing education to the primary school population. Through development of facilities and teachers, primary education now reaches 75 percent of the student population. Although complete coverage is not available, pupils at the primary level do have a better opportunity for schooling compared to all other age classifications. This is particularly illustrated in Table 17. Both the number of schools and student population are shown in the table for each of the six major educational sectors.

The increasing demand for education is particularly reflected at levels other than primary (basic) schools. Since compulsory education was enacted for children between 6 and 12, the number of facilities and teachers has grown in that sector to accommodate a very large percentage of the potential student population at the primary level. Available information indicates that more than 15 million children are included in this school program in both the public and private school systems. Secondary school facilities are far fewer and, because of the lack of available teachers, only a relatively few students who graduate from the primary schools can extend their education.

A possible approach to solving this problem is to implement a broader teacher education program and to redistribute teachers from sectors outside of basic and general education into the secondary level. This plan could be initiated through an ETV system approach. It is proposed that ETV facilities be provided at all teachers' colleges and universities in Indonesia to augment the existing system. ETV programs

TABLE 17.

SCHOOL AND STUDENT DISTRIBUTION

Type	Number of Schools	Number of Students
Basic Education	61,678	16,000,000
General Education	5,291	1,000,000
Teacher Colleges	412	61,000
Technological Schools	670	243,000
Vocational Schools	1,036	150,000
Universities	24	111,000

generated in Djakarta could be transmitted to all of the schools via the communications satellite. A much smaller number of instructors would then be required at these schools, making the teachers available for transfer into the secondary level. Another important feature of the satellite ETV approach is that several sessions may be held each day, reaching an increasingly larger number of students via ETV. The investment in this service is minimal since facilities at the 436 teacher colleges and universities already exist.

The approach described here can also be applied to the other sectors, namely, the technological and vocational schools. The REPELITA has stated the need for better trained people. The ETV system could be used to improve opportunities for a greater number of students at the 1,706 existing technological and vocational schools. In this way, the development program would be enhanced by a broader emphasis on general mechanical and electrical engineering, automobile repair, factory supervision, small business management, basic economics, and civil administration. Thus, the four sectors selected for introduction of ETV are the universities, teachers' colleges, technological education, and vocational education schools. The latter three total 2,118 schools and 454,349 students, while there are 110,677 students in the 24 universities and institutes.

3.3.3.1 <u>ETV Terminal Distribution</u>

Many of the schools that would receive ETV would also be in the cities that are provided with multiservice ground stations. Each of these stations has the capability to receive the ETV signal from the satellite and rebroadcast via VHF to the schools in the urban centers. There are other schools in both the urban and rural areas of the country that would require colocation of ETV terminal equipment, including television monitors, at the schools.

In order to estimate the number and deployment of ETV terminals, a population distribution model was developed (see Appendix A). The result is used as a guideline in proportioning the urban and rural schools receiving the ground terminal equipment. The estimated school distribution model is shown in Table 18. The number of schools at each of the educational sectors identified in Table 18 is classified into urban and rural categories for each province. To definitize the ETV approach, the following collective assumptions have been made:

1) Schoolhouse ETV terminals are located at each school in the rural population.

2) Monitors are provided at each rural school house in proportion to the average number of students and on a two-shift basis.

3) Schools in urban centers that are also in the VHF coverage area will be supplied with television receivers. Ten percent of the schools in the urban areas are assumed to be reached by VHF rebroadcast.

   a) Universities and institutes are supplied with three television receivers per school.

TABLE 18.

ESTIMATED URBAN AND RURAL SCHOOL DISTRIBUTION

Province	Number of Schools									
	Basic Education		General Education		Teachers' Colleges		Technical Education		Vocational Education	
Atjeh	220	830	15	70	1	6	2	9	4	14
N. Sumatra	875	1,350	60	115	5	9	8	14	12	22
W. Sumatra	230	756	20	65	2	5	3	8	5	12
Palu	306	810	20	70	1	6	3	9	5	13
Djambi	356	820	20	70	1	6	3	9	5	13
S. Sumatra	815	1,500	60	130	5	10	8	16	12	25
Bengkulu	70	420	10	35	1	3	2	4	2	7
Lampung	315	740	20	60	2	5	3	8	5	12
W. Java	2,200	9,100	160	795	12	62	23	97	37	150
S. T. Djakarta	2,050	-	170	-	13	-	21	-	32	-
Central Java	2,240	10,800	160	935	13	72	23	115	36	180
S. T. Jogjakarta	185	-	20	-	1	-	2	-	3	-
East Java	2,820	11,600	200	1,000	16	76	31	122	45	190
W. Kalimantan	466	460	30	40	3	3	4	5	7	7
C. Kalimantan	436	430	40	36	3	3	4	5	7	7
S. Kalimantan	305	195	20	15	2	1	3	2	4	3
E. Kalimantan	325	295	20	25	2	2	3	3	4	5
N. Sulawesi	316	540	20	45	1	4	2	6	4	9
C. Sulawesi	120	900	15	80	1	6	2	10	4	15
S. Sulawesi	600	1,450	50	130	4	10	7	15	11	23
S. E. Sulawesi	70	650	5	60	1	6	2	7	2	11
Bali	452	1,150	30	100	6	7	7	10	10	15
W. Nusatenggara	25	68	20	80	2	3	4	6	6	10
E. Nusatenggara	25	68	20	80	2	3	4	6	6	10
Maluku	110	324	10	25	1	2	2	3	3	5
W. Irian	120	370	10	25	1	2	2	3	3	4
	16,052	45,626	1,220	4,071	102	310	178	492	274	762
	61,678		5,291		412		670		1,030	

b) Other schools will be supplied with receivers on the same basis as the monitor distribution identified by item 2.

The estimated total number of ETV terminals, monitors, and receivers required for the model described are summarized for each province in Table 19. The results are based on the figure of 30 students per television monitor. A requirement of two to six monitors was derived based on existing student populations. To simplify matters, an average of four monitors per school (ETV terminal) or four receivers for schools within the VHF coverage pattern is assumed.

To illustrate the use of Table 19, an example of the ETV system capability for Atjeh province can be considered. It is assumed that there is a single university at Banda Atjeh. The university of Sjau Kuala would be supplied with three television receivers. Also in Banda Atjeh, a school of teacher training, for example, would be supplied with four receivers, since the system model includes a multiservice ground terminal with VHF rebroadcast capability located in this city. The Atjeh province estimate of schools in the urban area shows one teacher college, two technological education schools, and four vocational education schools. Since it was assumed that only one (10 percent) school would be covered by VHF, the remaining six schools are located in other cities in Atjeh province and thus are supplied with ETV receive terminals. The number of monitors supplied at all six terminals is 24. Again, referring to Table 18, the total number of schools in the rural area, including the

TABLE 19.
DISTRIBUTION OF ETV FACILITIES

Province	Number Receiving ETV by				Totals		
	VHF/Urban		Schoolhouse ETV Terminal		ETV		
	University	School	Urban	Rural	Terminals	Monitors	Receivers
Atjeh	1	1	6	29	35	140	7
N. Sumatra	1	3	22	45	67	268	15
W. Sumatra	1	1	9	25	34	136	7
Riau	1	1	8	28	36	144	7
Djambi	1	1	8	28	36	144	7
S. Sumatra	1	2	23	51	74	296	11
Bengkulu	0	1	4	14	18	72	4
Lampung	0	1	9	25	34	136	4
W. Java	2	7	65	309	374	1,496	34
S. T. Djakarta	1	66	0	0	0	0	267
Central Java	1	7	65	367	432	1,728	31
S. T. Jogjakarta	1	6	0	0	0	0	27
East Java	1	9	83	389	471	1,888	39
W. Kalimantan	1	2	12	15	27	108	11
C. Kalimantan	1	2	12	15	27	108	11
S. Kalimantan	1	1	8	6	14	56	7
E. Kalimantan	1	1	8	10	18	72	7
N. Sulawesi	1	1	6	19	25	100	7
C. Sulawesi	1	1	6	31	37	144	7
S. Sulawesi	1	2	20	48	68	272	11
S. E. Sulawesi	1	1	4	22	26	104	7
Bali	1	3	20	32	52	208	15
W. Nusatenggara	1	1	11	19	30	120	7
E. Nusatenggara	1	1	11	19	30	120	7
Maluku	1	1	5	10	15	60	7
W. Irian	0	1	5	9	14	56	4
TOTAL	24	124	430	1,564	1,994	7,976	568

three educational sectors described above, numbers 29. Hence, 29 ETV terminals, each with four monitors, are located throughout the Atjeh province countryside. A total of 116 monitors is required in the rural area. Table 19 tallies the ETV terminal requirements in Atjeh, showing that 35 schools outside the VHF coverage area would be supplied with terminals, whereas a university and school within the city would receive ETV via VHF transmission. The total number of monitors and receivers required in Atjeh is 140 and 7, respectively.

A final breakdown by sector of educational services provided is given in Table 20. The ETV system presented herein covers a total of 578 schools in the cities and 1,564 schools in the countryside of Indonesia. Approximately 1,994 schoolhouses would be supplied with ETV receive terminals. A total of 8,544 television receivers and monitors would be located at the educational facilities offering education to more than 600,000 students during this introductory phase. As will be shown in the ensuing sections, the average revenue requirement could be as low as U. S. $5.60 per student year for the ETV service.

3.4 Financial Anslysis

The financial data contained in this section include a development of all capital investment, operating expense, and revenue estimates associated with a satellite program. The cost estimates are based upon quantity procurements in 1971 U. S. dollars. The major financial characteristics for the program discussed herein are presented in Table 21.

TABLE 20.

TYPICAL EDUCATIONAL MODEL CHARACTERISTICS

Sector	Method of Distribution			Number of Receivers and Monitors	
	Schools With VHF Rebroadcast	Schools With ETV Terminal			
	Urban	Urban	Rural	Urban	Rural
University	24	-	-	72	-
Teacher College	36	66	310	408	1,240
Technological Education	36	142	492	712	1,968
Vocational Education	52	224	762	1,098	3,048
Subtotal	148	430	1,564	2,288	6,356
TOTAL	2,142 Schools			8,544	

TABLE 21.

MAJOR FINANCIAL CHARACTERISTICS

DEPRECIATION

- o Satellites, launch vehicles, and insurance - 7-year life from date of launch.
- o All ground equipment, including central station, multiservice stations, ETV terminals, and VHF rebroadcast stations - 15-year life from date of installation.
- o Regional service centers - 15-year life from date of installation.

OPERATIONS & MAINTENANCE EXPENSES

- o See Table 24. Annual 3% inflation factor is included in projections.
- o Model period - 9 years; 2 years preoperational, 7 years operational.
- o Taxes - Assume Indonesian Government would assess a tax of 45%.
- o Return Objective - 10% on average net investment.
- o Working Capital - U.S. $1.0 million fund provided continuously over operational program period.

FINANCING

- o U.S. $7.9 million interest-free Government loan. Lump sum repayment by end of 5th year.
- o U.S. $70.7 million in debt (U.S. $36.8 million retired over 7 years and U.S. $33.9 million retired over 15 years). Interest is calculated at 7%. Two-year grace period assumed requiring 0.5% commitment fee. Assumes combination of development and commercial bank loans from various countries.

3.4.1 Investment

The capital investment requirements fall into three major categories: Space segment, ground segment, and general system investment. The space segment investment is a function of both the number of satellites and launch vehicles (at U.S. $7.5 million each) required to support the program and the amount of insurance included.

Generally speaking, most commercial satellite programs provide for an in-orbit spare to assure service continuity and to avoid revenue losses that would occur should there be a catastrophic failure. In this study, I have chosen to postulate a fully redundant space segment configuration and to include launch failure premiums to cover both planned launches to demonstrate the financial extreme of a fully insured program. Alternatively, a spare satellite could be maintained on the ground for launch within a 30 to 90 day period. Such planning is based upon the fact that an in-orbit satellite failure would be characterized by a gradual subsystem degradation. For this case, the replacement can be launched well before substantial traffic or revenue losses occur. It is important to recognize that this approach is dependent upon NASA maintaining a sufficient stock of suitable Thor Delta vehicles. In any event, several space segment configuration choices are available to meet the needs and desires of the Indonesian Government.

In order to provide a financially conservative projection, the model presented here assumes an initial procurement and launching of two satellites and a 25 percent insurance premium for the space segment. Such an assumption produces an initial space segment investment of U.S. $37.5 million and, as shown in Table 22, a total program investment of U.S. $77.7 million. If the initial program considers procurement of two satellites and a single launch without insurance, the resulting investment would be reduced to U.S. $62.7 million. The total ground segment portion of the investment is U.S. $36.6 million.

The program investment is phased over a 9-year period as shown in Table 23. The preoperational period is referred to as Phase I. During this time, the space segment is developed and brought into service. In addition, sufficient earth station equipment is provided to meet all telephony requirements through the first three years of operation. Phase II covers the first three years of program operation. During Phase III, additional master and multiservice station equipment is added to meet the total telephony circuit requirements.

The ground segment portion of the initial capital investment as shown in Table 23 amounts to U.S. $27.5 million. Approximately 760 of the ETV terminals and the associated TV monitors are scheduled for operation at the initiation of service. The remaining 1,234 terminals are installed during Phase II. Also, certain earth station capital investment additions are scheduled for the third and sixth year of operation to coincide with circuit requirement projections (Figure 11c). Therefore, the initial ground segment capital investment includes all facilities

TABLE 22.
MAJOR INVESTMENT ASSUMPTIONS
$ U.S. MILLIONS

Element	Quantity	Price
SPACE SEGMENTS		
Satellite	2	$ 15.0
Launch Vehicle	2	15.0
Launch Insurance	-	7.5
Total Space		$ 37.5
GROUND SEGMENT		
Master Station	1	$ 3.9
Multiservice Stations	25	17.3
VHF Rebroadcast	26	4.6
ETV Terminals	1,994	6.3
TV Monitors/Receivers	8,544	1.5
Regional Service Centers (Including spare parts inventory and maintenance equipment)	26	3.0
Total Ground		$ 36.6
PROGRAM MANAGEMENT/ SYSTEMS ENGINEERING		2.9
TRAINING (Preoperational)		0.7
TOTAL SYSTEM		$ 77.7

TABLE 23.

INVESTMENT SCHEDULE

$ U.S. MILLIONS

Element	Quantity	Phase I		Phase II			Phase III				Total
		Years									
		-2	-1	1	2	3	4	5	6	7	
		Preoperational		Operational							
				Launch							
SPACE SEGMENT											
Satellite + Insurance	2	$ 7.5	$ 15.0								$ 22.5
Launch Vehicle	2	7.5	7.5								15.0
Total Space		$15.0	$ 22.5								$ 37.5
		$37.5									
GROUND SEGMENT											
Master Station	1	$ 0.9	$ 2.0			$0.4			$0.6		$ 3.9
Multiservice Station	25	6.5	7.5			1.3			2.0		17.3
VHF Rebroadcast	26	2.3	2.3								4.6
ETV Terminals	1,994	1.2	1.2	$1.3	$1.3	1.3					6.3
TV Monitors/Receivers	8,554	0.3	0.3	0.3	0.3	0.3					1.5
Service Centers	26	1.0	2.0								3.0
Total Ground		$12.2	$ 15.3	$1.6	$1.6	$3.3			$2.6		$ 36.6
		$27.5		$6.5							
PROGRAM MANAGEMENT/SYSTEMS ENGINEERING		$ 1.1	$ 1.8								$ 2.9
TRAINING		$ 0.1	$ 0.6								$ 0.7
Total Investment by Year		$28.4	$ 40.2	$1.6	$1.6	$3.3			$2.6		$ 77.7

necessary to provide long distance telephony, national television distribution into each of the 26 major cities and educational television at 760 schools. Furthermore, provision is made for the establishment of 26 regional service centers equipped with a full complement of spare parts and test equipment. The investment for most of the spare parts and test equipment is included in the price for the individual earth stations, but such equipment would probably be housed in the service centers consistent with the system maintenance plan.

The general system investment consists of nonrecurring expenditures required to support training and system management and engineering efforts. Such expenditures are capitalized and depreciated to match expenses and revenues and to equitably allocate the recovery of such costs to both the initial and subsequent users of the system. The amounts of capitalization estimated for such activities are based upon an evaluation of training and staff engineering efforts necessary to support construction and to provide a field support staff capable of maintaining a continuing operation. Accordingly, the capitalized engineering management expenditures amount to U.S. $2.9 million, or roughly, the equivalent of 50 professional man-years; the capitalized training costs approximate one-half of a year's direct operations wage and salary expenses.

3.4.2 Depreciation and Amortization

All depreciation and amortization of the investment described in the preceding section is calculated on a straight-line basis over the projected lifetime of the applicable unit of property. Specifically, in-orbit satellites are depreciated over 7 years from the date of operation, while the launch insurance is amortized from the date of the last scheduled launch.

The earth station and regional service center depreciation period is 15 years. This period represents a composite lifetime of the various station components. The replacement of equipment having shorter lifetimes is covered in the annual operations and maintenance expense projections. Under actual operating circumstances, some replacement costs would probably be capitalized and the deplaced equipment retired, but the inclusion of such a statistical refinement would only add complexities to the financial model and would not materially affect the results.

The amortization period of the capitalized engineering and training expenses has been set at 7 years to coincide with the service duration of the initial satellite. It is also possible to adopt a longer amortization period and recover the investment on the basis of system usage to offload the major portion of the recovery to periods of high utilization.

3.4.3 Operations and Maintenance Expenditures

In order to develop valid estimates of annual operating expenses, three surveys were conducted. The first survey concerned the number and average wage of personnel required to operate earth stations now in use in various areas of the world. The results summarized in Table 24

TABLE 24.

ANNUAL OPERATIONS AND MAINTENANCE EXPENSE ASSUMPTIONS

$ U.S.

CENTRAL STATION

$ 16	Men
1,500	Salary
$ 24,000	
24,000	Overhead @100%
$ 48,000	Total Direct
97,500	Miscellaneous expenses, including spares @ 2.5% initial investment ($3.9M)
$145,500	Total

MULTISERVICE STATIONS

$ 25	Stations
10	Men per Station
250	Men
$ 1,500	Salary
$375,000	
375,000	Overhead @ 100%
$750,000	Total Direct
547,500	Miscellaneous Expenses
$1,297,500	Total

ETV TERMINALS

2,000	Terminals
4	Days/Year Servicing
8,000	
250	Man-Days/Year
32	Men
$ 1,500	Salary
$ 48,000	
48,000	Overhead @ 100%
$ 96,000	Total Direct
125,000	Transportation Expense
$221,000	
546,000	Spares at 7% of Investment
$767,000	Total

CENTRAL MAINTENANCE DEPOT

$ 30	Men
1,500	Salary
$ 45,000	
45,000	Overhead @ 100%
$ 90,000	Total Direct
55,000	Depot Maintenance
$145,000	Total

REGIONAL SUPPLY DEPOTS

$ 25	Depots
4	Men per Depot
100	Men
$ 1,500	Salary
$150,000	
150,000	Overhead @ 100%
$300,000	Total Direct
18,750	Depot Maintenance
$318,750	Total

indicate that the master station should have a staff of 16 permanently assigned personnel while each of the multiservice stations would be staffed by ten personnel. Thirty people are assigned to the master maintenance depot, which would house all major spare parts and test equipment. Each of the remaining 25 regions would have small-parts supply depots with a permanent staff of four men per depot. A mobile field maintenance staff of 32 men is provided to service each unattended ETV terminal twice a year. The total manpower requirement for system support amounts to 428 people. Since there may be other items of expense peculiar to the Indonesian environment and because an entirely new category of trained personnel may be involved, an average annual gross wage of U.S. $1,500 per person is used.

In addition to the direct salary expenses, a second survey indicated that a 100 percent overhead rate would be appropriate to account for fringe benefits and other general and administrative costs.

The last major item of operating expenses concerns spare parts consumption. As noted earlier, all such expenditures have been treated as operating expenses when, under actual operating circumstances, some amount would probably be capitalized. The overall level of expenditure for spare parts is very much a function of individual component mean-time-to-failure estimates, but experience from several operating stations indicates that an annual percentage of initial investment produces valid estimates. Accordingly, all ground station facilities have annual spare parts expenses amounting to 2.5 percent. The ETV terminals have a higher, more conservative rate of 7 percent, partly because the TV monitors do not have a well-documented maintenance history.

3.4.4 Revenue Requirements

For the purpose of calculating rates for the major service categories, cost allocations were made and revenue requirements were developed using a 10-percent after-tax return on average net investment. In calculating the average annual net investment, the mid-year convention was used. That is, all capital additions were assumed to occur at mid-year, and all depreciation was assumed to be recovered on a linear basis.

The development of revenue requirements per service category is based upon cost allocations. The cost allocations attempt to charge each service category (telephony, ETV, and NTV) with the investment and operating expenses peculiar to that service as shown in Table 25.

All common costs are allocated on the ratio of the resulting investments. More specifically, the space segment is allocated on the ratio of the number of satellite channels; i.e., the eight channels distribution ratio is telephony - 5/8, ETV - 2/8, and NTV - 1/8. The ground segment allocations consider the amount of investment required at each facility for each category of service and then the common costs (building, antenna, etc.) are assigned based on the resulting ratio. As an example, the investment for the 25 multiservice earth stations is allocated as shown in Table 26.

TABLE 25.

COST ALLOCATIONS

Element	Total Investment Allocation $U.S. Million	Service Allocation		
		Telephony	NTV	ETV
Space Segment				
Satellite & Launch Vehicle	$ 37.5	$ 23.6	$ 4.5	$ 9.4
System Engineering/ Program Management	2.9	1.7	0.3	0.9
Training	0.7	0.4	0.1	0.2
Ground Segment				
Master Station	3.9	3.6	0.1	0.2
Multiservice Station	17.3	15.9	0.5	0.9
VHF Rebroadcast	4.6	-	1.6	3.0
ETV Terminals	6.3	-	-	6.3
TV Monitors	1.5	-	-	1.5
Regional Service Centers	3.0	1.7	0.2	1.1
Total Ground	$ 36.6	$ 21.2	$ 2.4	$ 13.0
Total System	$ 77.7	$ 46.9	$ 7.3	$ 23.5
	Annual Operations And Maintenance Allocations			
Master Station	$ 145,500	$ 132,405	$ 4,365	$ 8,730
Multiservice Station	1,297,500	1,193,700	38,925	64,875
ETV Terminals	767,000	-	-	767,000
Regional Service Centers	463,750	268,975	32,463	162,312
Total	$2,673,750	$1,595,080	$75,753	$1,002,917

TABLE 26.

ALLOCATION OF INVESTMENT

FOR 25 MULTISERVICE EARTH STATIONS

Cost Allocation	Service Category, $ U.S. Thousands			
	Telephony	NTV	ETV	Total
o TV Only	-	269.7	539.6	809.3
o Telephony Only	9,860.7	-	-	9,860.7
o Basic Terminal	4,161.4	120.6	241.2	4,523.2
o Redundancy	1,965.8	57.0	114.0	2,136.8
Total	15,987.9	447.3	894.8	17,330.0

On this basis, all investment costs associated with the ETV terminals are logically allocated entirely to the TV service category. All operations and maintenance expenses at the main and regional supply depots are allocated on the basis of the total system ground investment associated with each service category, since these facilities will generally support all services.

3.4.5 Income Taxes

The revenue requirement profiles include a 45 percent federal tax rate. The taxes are applied to the net operating revenues (gross revenues less depreciation and operating expenses). The taxes calculated in the operating results statement are similarly applied to net operating revenues, but after deducting interest expense. Further, during the initial years of operation, when operating expenses exceed gross revenues, the net operating losses have been carried forward to the subsequent year as a tax credit. However, as will be seen, the amounts involved are not significant, and if Indonesian tax laws are somewhat different from the methods described, the operating results should not be materially affected.

3.4.6 Revenue Requirement Analysis

Table 27 provides complete revenue requirements profiles, per category of service, for each year of the program. As can be seen, the total revenue requirements are highest during the first year of operation and decline thereafter. This decline is due to the fact that only small capital investment is required after the program has been initiated and the average undepreciated investment decreases quickly with the rapid recovery of investment. Such a decline in revenue requirements is

TABLE 27.

REVENUE REQUIREMENTS SCHEDULE
$ U.S. MILLIONS

Item	YEARS							Total
	1	2	3	4	5	6	7	
TELEPHONY								
Depreciation	4.9	4.8	4.9	5.0	4.9	5.0	5.0	$ 34.5
O&M	1.6	1.7	1.7	1.7	1.8	1.9	1.9	12.3
Return	4.0	3.6	3.2	2.7	2.3	2.0	1.5	19.3
Tax	3.3	2.9	2.6	2.3	1.8	1.6	1.2	15.7
Total	13.8	13.0	12.4	11.7	10.8	10.5	9.6	$ 81.8 Average Year $11.7M
NTV								
Depreciation	0.8	0.8	0.9	0.9	0.9	0.9	0.9	$ 6.1
O&M	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.7
Return	0.7	0.6	0.5	0.4	0.3	0.2	0.2	2.3
Tax	0.6	0.5	0.4	0.4	0.3	0.1	0.1	2.4
Total	2.2	2.0	1.9	1.8	1.6	1.3	1.3	$ 12.1 Average Year $1.7M
ETV								
Depreciation	2.1	2.3	2.3	2.3	2.4	2.4	2.4	$ 16.2
O&M	1.0	1.0	1.0	1.1	1.1	1.1	1.2	7.5
Return	1.9	1.9	1.8	1.6	1.3	1.1	0.9	10.5
Tax	1.6	1.5	1.5	1.3	1.1	0.8	0.7	8.5
Total	6.6	6.7	6.6	6.3	5.9	5.4	5.2	$ 42.7 Average Year $6.1M

(Continued)

Continuation of TABLE 27. REVENUE REQUIREMENTS SCHEDULE, $ U.S. MILLIONS.

Item	YEARS							Total
	1	2	3	4	5	6	7	
TOTAL SYSTEM								
Depreciation	7.8	7.9	8.1	8.2	8.2	8.3	8.3	$ 56.8
O&M	2.7	2.8	2.8	2.9	3.0	3.1	3.2	20.5
Return	6.6	6.1	5.5	4.7	3.9	3.3	2.6	32.7
Tax	5.5	4.9	4.5	4.0	3.2	2.5	2.0	26.6
Total	22.6	21.7	20.9	19.8	18.3	17.2	16.1	$ 136.6
								Average Year $19.5M

characteristic of satellite systems throughout the world and is one of the major reasons why averaging periods of between 5 and 10 years are commonly used for rate making purposes. Another reason for averaging is that frequently system utilization during the early years is low, and averaging over 1 or 2 years would produce unreasonably high rate levels. Therefore, this analysis averages all costs and usage over the initial 7 years of operation, and an average annual telephony circuit revenue requirement of U.S. $15,268 and a national television channel revenue requirement of U.S. $1.7 million is produced. The educational television revenues are similarly calculated, but also include recognition of the planned ETV expansion during the first three years of operation. Table 28 summarizes the annual revenue derivation for each service offered. As shown in the table, the first year rate for ETV is U.S. $2.6 million, growing to U.S. $7.6 million in the fourth year and to U.S. $7.7 million in the sixth year, and remaining at that level for the rest of the program.

3.4.7 System Usage

The anticipated usage of the system can be viewed on two different bases. First, there are the broad telephony and television requirements informally provided to Hughes by the Indonesian Government. Second, there are usage projections which can be derived by extending the World Bank telecommunications study data.

As noted earlier, the satellite model is designed to accommodate the first set of requirements, and appropriate revenue requirement estimates have been calculated. With the revenue requirement per circuit year identified, it is important to verify if such a demand level could

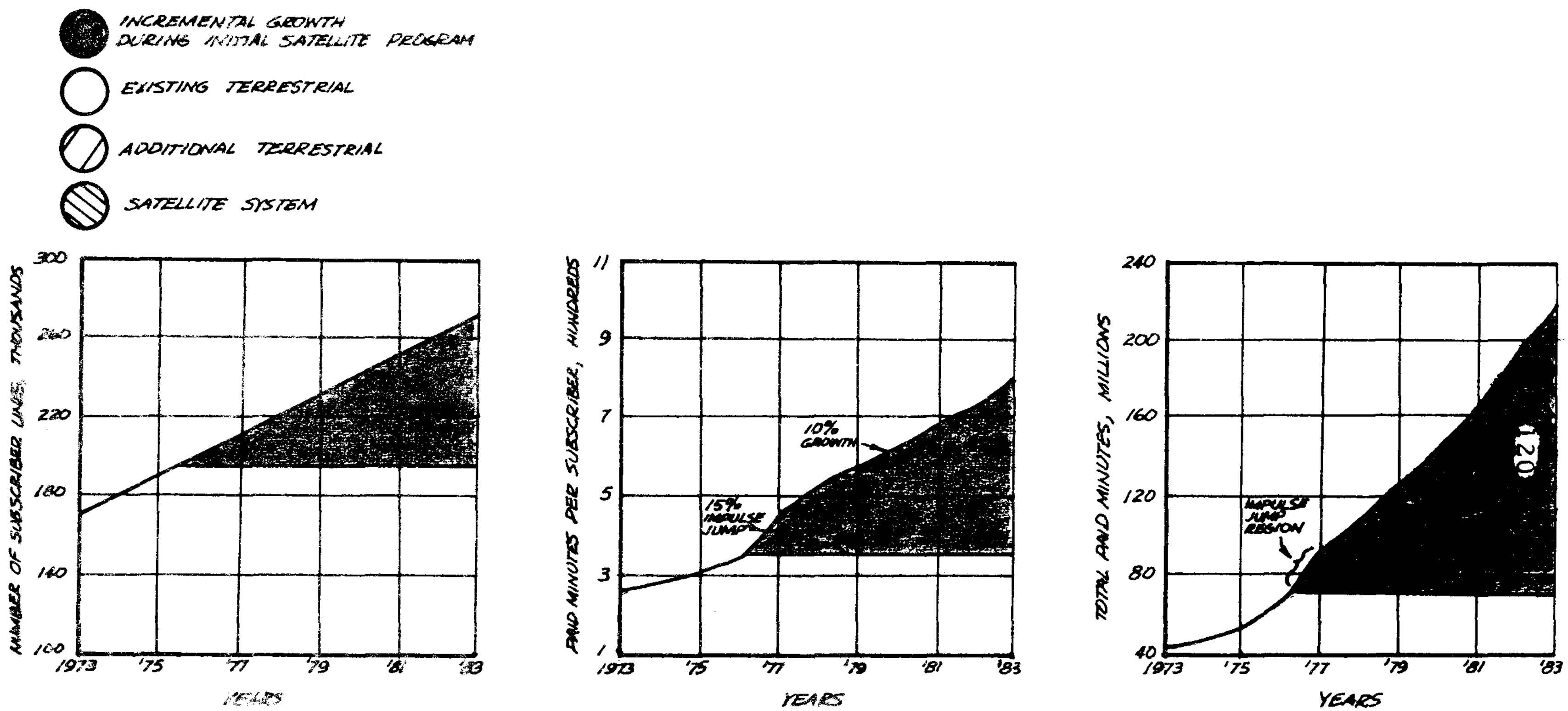
TABLE 28.
REVENUE DEVIATION
$ U.S. MILLION

Item	YEARS							Total
	1	2	3	4	5	6	7	
TELEPHONY								
Average Annual Circuit Requirement	200	350	515	715	945	1,205	1,421	5,351
Revenue @ $15,268/average Circuit Year	3.1	5.4	7.9	10.9	14.4	18.4	21.7	$ 81.8
NTV								
Average Annual Revenue from Provision of National Commercial TV	1.8	1.8	1.7	1.7	1.7	1.7	1.7	$ 12.1
ETV								
Annual Revenue to be Contributed by Various Government Agencies	2.6	4.0	5.5	7.6	7.6	7.7	7.7	$ 42.7
Total System Revenue	7.5	11.2	15.1	20.2	23.7	27.8	31.1	$ 136.6

reasonably be anticipated and if the resulting costs would be competitive with current rates. Accordingly, using the World Bank telecommunications study data, telephony and telegraph growth projections were formulated. The projections are derived through extrapolating new subscriber line connections and toll calling rates per subscriber.

The World Bank data indicated that there would be 177,060 connected subscribers by the end of 1973 and that this represents an annual growth rate of 5.3 percent for the period 1968 to 1973. Thus, a 5 percent subscriber line growth rate was applied to the period 1973 to 1982, producing a total of 274,700 connections by the end of the period (see Figure 11a). In addition, the World Bank report indicated that during 1970, each subscriber line would produce an average toll usage of 180 paid minutes (3 erlangs) for that year, and that this calling rate would increase by 15 percent per annum. Therefore, the calling rate per subscriber was grown annually at a 15 percent level from 1973 through the end of 1975.

During 1976, with the introduction of satellite service throughout the country, a calling rate impulse jump of 15 percent was introduced, and a 10 percent annual growth rate was applied to the remaining six years of the study, as shown in Figure 11b. The resulting projections in Figure 11c indicate that the long distance telephony demand reflecting the combined growth in subscriber lines and calling rates would amount to 96.6 million paid minutes in 1976, growing to 223.4 million paid minutes in 1982.



a) Projected Growth in Subscriber Lines

b) Number of Annual Paid Minutes per Subscriber

c) Total Number of Annual Paid Minutes

FIGURE 11. INCREMENTAL GROWTH DURING INITIAL SATELLITE PROGRAM (1973 THROUGH 1982)

These usage projections represent the total telephony demand to be satisfied by both terrestrial and satellite facilities. With respect to the terrestrial facilities, the World Bank data indicates that as of 1969, there were 1,203 long distance circuits. An estimate of the circuit distribution by facility type is made based upon the actual channel miles. The facilities include radio telephone (38.7 percent), open wire (43.4 percent), microwave (13 percent), and VHF (4.6 percent). By 1973, an additional 991 microwave circuits would be added. Taking into consideration the low capacity, quality, age, and high costs associated with the radio telephone and open wire circuits, it is assumed that these facilities would be retired with the introduction of satellite service. Thus, the projected requirements would be served via a combination of 1,202 microwave and VHF terrestrial circuits and the satellite facilities.

In order to convert the telephony usage requirements from paid minutes into long distance circuits, a measure of service quality, in terms of acceptable holding time, had to be adopted. The conversion factor selected was that commonly used in other domestic and international systems, namely, three erlangs or 180 paid minutes per day, requiring one full period telephony circuit.

It is important to note that the three erlangs conversion factor is only significant in that it determines the level or quality of service in terms of holding time and dictates the number of circuits, and therefore, the amount of investment required for terminating equipment. Thus, when given the estimated amount of traffic in terms of total paid minutes, the revenue potential is established, and the selection of a conversion factor should have little effect on this potential, unless service quality is severely impaired.

On this basis, the total circuit demand is established, as shown in Table 29. The table demonstrates how this circuit demand would be satisfied by the satellite and terrestrial facilities. As indicated in this table, a requirement for additional terrestrial facilities during the program is anticipated. These requirements would be for short haul circuits along established terrestrial routes between cities not included in the satellite system. It would be possible to meet these requirements by adding earth stations at these locations, as opposed to over-building the existing microwave, but such provision was not made in order to conform with the 22-city guideline.

The above methodology does not entirely conform with the commonly accepted traffic forecasting and facility planning techniques. However, the approach is necessary because applicable historic traffic data were unavailable. This is true because nationwide telecommunications facilities do not exist to demonstrate calling patterns nor to establish precise use communities of communications interest. The growth projections presented in the table must be viewed as a very conservative basis upon which to estimate telecommunication demand for a country growing as rapidly as Indonesia. The projections include provision for both long and short haul terrestrial growth (68 percent), as well as long haul satellite growth (32 percent) over the period 1976 to 1982. As noted in the technical discussion, the satellite system would be capable of handling greater traffic, but the system design and financial appraisal attempts to

TABLE 29.

PROJECTED CIRCUIT REQUIREMENTS

Year	Existing Terrestrial Circuits	New Terrestrial Circuits	Satellite Circuits	Total Circuits
1976	1,202	88	200	1,490
1977	1,202	162	350	1,714
1978	1,202	253	515	1,970
1979	1,202	349	715	2,266
1980	1,202	459	945	2,606
1981	1,202	590	1,205	2,997
1982	1,202	824	1,421	3,447
Total Circuit Years	8,414	2,725	5,351	16,490

stay within the guidelines given. This approach presents a very conservative view of financial viability.

By applying the above growth assumptions, it can be seen from Figure 11a that the number of subscriber lines would increase by 79.4 thousand over the period 1976 to 1982. This increase, combined with the growth in the per subscriber line calling rate, results in an average of 152.7 million paid minutes of telephony service during each of the initial 7 years of system operation. Of this amount, 49.5 million paid minutes would be carried via the satellite facilities, requiring the number of circuits shown in Table 29.

Based on this level of use and considering the telephony average annual revenue requirement to be U.S. $11.7 million, a revenue requirement of U.S. $0.23 per paid minute is produced. This revenue requirement applies to all satellite circuits in the system irrespective of destination because the cost of satellite communications is distance insensitive. Also, since the average satellite circuit distance is 1,500 km, the U.S. $0.23 is comparable to the existing U.S. $1.05 urgent rate for all circuits over 750 km. To complete the comparison, additional local switching and distribution costs should be added to the satellite costs. These costs, based upon ITU and World Bank statistics, should amount to an additional investment of approximately U.S. $65.9 million, producing an incremental average annual revenue requirement of U.S. $11.2 million. The amount of this incremental revenue requirement assignable to toll service could be assumed to be 45 percent (World Bank data) or U.S. $5.0 million per year. Two-thirds of the U.S. $5.0 million is allocated to the satellite service, the remaining 1/3 being allocated to terrestrial service. Thus, the comparison would be based on a total average revenue requirement of U.S. $15.0 million. An average calling rate of U.S. $0.30 per paid minute is established by dividing the U.S. $15 million by the 49.5 million paid minutes defined above.

As previously described, the satellite program has been designed to provide a single channel of high quality color television into each of 26 major cities. Based on the cost allocation assumptions, the total cost of this service would amount to U.S. $1.7 million per year or U.S. $65,000 per city per year. Currently, PERUMTEL receives annual revenues of approximately U.S. $600,000 for national television service into four cities or U.S. $150,000 per city. Thus, the satellite program would provide service into 22 additional locations at less than one-half the cost per city.

The educational television portion of the program has been designed primarily to complement various projects carried in the current 5-year program. It is thought that the in-field teacher training and many vocational projects for which funds have already been allocated could be accomplished more efficiently through the selective use of television. This is also true of projects designed to bring standardization of techniques to the various colleges, such as medicine, law, and engineering, located throughout Indonesia. The capacity would exist to undertake many projects designed to upgrade the overall educational and achievement levels at a total annual cost of approximately U.S. $5.0 million or U.S. $5.60 per student year. It should be noted that the average annual ETV revenue requirement allocation is calculated in Table 27 at U.S. $6.1 million, including U.S. $1.2 million for income tax and U.S. $1.5 million for return that the Government would in theory be charging itself.

3.4.8 System Financing

The financial profile presented herein assumes that approximately 90 percent (U. S. $70.7 million) of the program's capital requirements will be funded by debt supplied by various international banking institutions. The remaining capital is assumed to be provided by the Indonesian Government. Other mixes of debt financing could be considered with total debt amounting to almost 100 percent of the system's capital costs.

There are many banking institutions that could be considered as potential debt financing sources for the system. The most prominent institution is the International Bank for Reconstruction and Development (World Bank), which is already financing a telecommunications project in Indonesia. In addition, there is the Agency for International Development and Overseas Primate Investment Corporation, the Asian Development Bank, and various export-import banks.

The cost of debt is a very important factor affecting the overall cost of the system, and such costs vary significantly between the development banks and the more commercially oriented banks. However, since the program appears to have the potential for being virtually self-liquidating, favorable financing terms and conditions can be anticipated.

The financial projections of the system model are based upon financing assumptions that must be considered as being more austere than will probably be the case. These assumptions are based on a 7 percent interest rate which is thought to be reasonable, but assume only a 2-year grace period and very rapid repayment over periods of 7 and 15 years. The repayment periods are related to the expected lifetime of the space and ground facilities, respectively. Nonetheless, even with such financially conservative assumptions, the total costs of the system are well within the projected revenue potentials.

3.4.9 Operating Results

Based upon the previously stated system costs and usage estimates, the net operating income would total U.S. $59.3 million for the initial 7 years of operation (Table 30). Such revenues would produce an 18 percent pretax return on the average net investment for the same period, and after deducting Government income taxes and interest expenses, the overall return would amount to 6.7 percent.

Of significance is the amount of capital recovery and debt repayment scheduled during the initial 7 years (Table 31). The capital recovery indicates that U.S. $56.8 million of the U.S. $77.7 million capital investment would be recovered, leaving U.S. $20.9 million of undepreciated ground investment to be recovered through operations in subsequent years. The commercial debt principal repayment would amount to U.S. $46.1 million of the total debt of U.S. $70.7 million. The remaining debt associated with the ground segment is to be repaid from revenues generated from the follow-on operations. In conjunction

TABLE 30.

OPERATING RESULTS
$ U.S. MILLION

Item	YEARS							Total
	1	2	3	4	5	6	7	
REVENUES	7.5	11.2	15.1	20.2	23.7	27.8	31.1	$ 136.6
OPERATING EXPENSES								
Depreciation	7.8	7.9	8.1	8.2	8.2	8.3	8.3	56.8
Operations & Maintenance	2.7	2.8	2.8	2.9	3.0	3.1	3.2	20.5
Total Operating Expenses	10.5	10.7	10.9	11.1	11.2	11.4	11.5	$ 77.3
NET OPERATING INCOME	(3.0)	0.5	4.2	9.1	12.5	16.4	19.6	$ 59.3
Return on Investment	(4.5%)	0.8%	7.8%	19.1%	31.8%	50.6%	76.9%	18.1%
Interest Expense	1.9	3.9	3.5	3.4	3.0	2.3	1.9	$ 19.9
Net Earnings	(4.9)	(3.4)	0.7	5.7	9.5	14.1	17.7	39.4
Government Tax (45%)	-	-	-	-	3.4	6.3	8.0	17.7
After Tax Return on Investment	(7.4%)	(5.7%)	1.3%	11.9%	15.5%	24.1%	38.0%	6.7%

TABLE 31.

SOURCE AND APPLICATION OF FUNDS
$ U.S. MILLION

Item	YEARS -2	-1	1	2	3	4	5	6	7	Total
Beginning Cash Balance	0	0	0	0	0.1	0.2	5.8	3.8	8.9	$ 0
Source of Funds										
Operating Net Income			(3.0)	0.5	4.2	9.1	12.5	16.4	19.6	59.3
Depreciation			7.8	7.9	8.1	8.2	8.2	8.3	8.3	56.8
Commercial Debt										
Space	14.1	22.7								36.8
Ground	11.1	13.7	2.0	4.9	2.2					33.9
Government Funding	3.4	3.9	0.1	0.1	0.4	—	—	—	—	7.9
Total Sources	28.6	40.3	6.9	13.4	15.0	17.5	26.5	28.5	36.8	$194.7
Application of Funds										
Property	28.4	40.2	1.6	1.6	3.3	0	0	2.6	0	$ 77.7
Working Capital			1.0	1.0	1.0	1.0	1.0	1.0	1.0	7.0
Repayment of Debt										
Space			2.0	5.2	5.2	5.2	5.2	5.2	5.2	33.2
Ground			0.7	1.6	1.8	2.1	2.2	2.2	2.3	12.9
Government							7.9			7.9
Interest Expense										
Space	0.1		0.9	2.3	1.9	1.6	1.2	0.8	0.5	9.3
Ground	0.1	0.1	0.7	1.6	1.6	1.8	1.8	1.5	1.4	10.6
Government Tax (45%)	-	-	-	-	-	-	3.4	6.3	8.0	17.7
Total Application	28.6	40.3	6.9	13.3	14.8	11.7	22.7	19.6	18.4	$176.3
Ending Cash Balance	0	0	0	0.1	0.2	5.8	3.8	8.9	18.4	$ 18.4

with the repayment of debt would be the payment of almost U.S. $20 million in interest expense. Such debt and interest payments have been developed based upon very short repayment periods and grace periods of only 2 years. A financially less conservative debt service schedule would serve to enhance the financial characteristics of the system. In addition, the U.S. $7.9 million Government loan is to be entirely paid by the fifth year of operation, and an annual provision for U.S. $1.0 million of working capital is included.

The amount of additional Government income taxes to be generated by the system would be approximately U.S. $18 million, and an additional U.S. $10 million in direct wages and salaries would flow directly into the Indonesian economy. Further, over 425 workers are to be trained in various technical skills.

Finally, over U.S. $18 million of retained earnings are to be available to apply to system expansion or replacement, or lower rates could be introduced during the initial service period.

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APPENDIX A
RF BANDWIDTH AND POWER REQUIREMENTS

The following baseband parameters are defined:

N = Number of voice channels/carrier

B_b = Baseband bandwidth

F_L = Load factor - i.e., rms value, relative to test-tone rms, of standard white-noise simulation of N-channel baseband.

F_P = Peaking factor - i.e., ratio of peak-to-rms value for N-channel baseband

R_N = Peaking factor for Gaussian noise.

The values of these parameters were determined in the following manner:*

$$B_b = (12 + 4N) \text{ kHz}$$

$$20 \log F_L = \begin{cases} -1 + 4 \log_{10} N & N \le 240 \\ -15 + 10 \log_{10} N & N > 240 \end{cases}$$

$$20 \log F_P = \begin{cases} 7 - 4 \log_{10} N + R_N & N \le 56 \\ R_N & N > 56 \end{cases}$$

*The formulas for F_L were adopted at the 9th CCIR Plenary Session in Los Angeles in 1959. The expressions for F_P are recommended by N. A. Zellerman in an article based on the work of Holbrook and Dixon, entitled, "A Review of the Factors Affecting System Loading in FDM Carrier Systems," paper G-1D.3, Globecom, 1965.

R_N = 10.7 dB, which corresponds to the "peak" value being exceeded slightly less than 0.1 percent of the time.

It is further assumed that the combined thermal and IM noise allocation for each trunk is 8,000 pWp or 39.0 dBpWp. The corresponding unweighted noise allocation, allowing 2.5 dB for psophometric weighting and 4.0 dB for pre-emphasis, is 45.5 dBpW. Thus, for a 1 mW test-tone, the required test tone-to-noise ratio (TT/N) is 90–45.5 = 44.5 dB.

The expression for TT/N in terms of the system parameters can be written

$$\frac{TT}{N} = \frac{C_t}{N_T} \; \frac{2(\Delta F + B_b)}{B_v} \left(\frac{\Delta F}{F_P \, F_L \, B_b} \right)^2$$

where

$\frac{C_t}{N_T}$ = Carrier-to-total noise ratio in RF bandwidth

ΔF = Peak carrier deviation

B_v = Voice-channel bandwidth = 3.1 kHz

With F_P, F_L, and B_b determined in terms of N, TT/N specified as 44.5 dB, and C_t/N_T fixed at the FM threshold of 10 dB, the above equation can be used to find ΔF for any value of N. The Carson-rule RF bandwidth is then given by $2(\Delta F + B_b)$.

Although the ratio C_t/N_T is fixed at 10 dB, the carrier-to-thermal noise ratio (C_t/N) generally must exceed this value because of IM products generated in the TWT. The IM spectrum depends on the composite input to the TWT. For present purposes, it is assumed that the baseband of each input signal comprises the same number of voice channels. By using the carrier-to-IM ratios for different numbers of carriers found in Reference 16, it is found that the required value of C_t/N increases with the number of carriers; for a 12-voice-channel baseband (which corresponds to the maximum number of carriers considered), C_t/N must be 11.3 dB. Whenever the baseband is large enough to permit no more than two carriers in the 36 MHz transponder bandwidth, the IM products fall out-of-band and, as a result, the required value of C_t/N assumes the minimum value of 10 dB.

With C_t/N established, the required carrier power, C, can be determined. For a 300°K ground receiver temperature, the thermal noise, N, in the RF bandwidth, B_{RF}, of a single carrier is

$$N = -228.6 + 24.8 + B_{RF} \quad \text{dBw}$$

with B_{RF} expressed in dB-Hz. The required carrier power is

$$C = C_t/N + N \quad \text{dBw}$$

The required EIRP per satellite channel can be expressed as

$$EIRP = C + L_S - G_R$$

where L_S is the path loss and G_R is the receive antenna gain. The free-space loss at 4 GHz for an elevation angle of 80 degrees (the minimum value for Indonesia) is 195.64 dB, while the atmospheric attenuation is 0.04 dB. Addition of a 2-dB weather margin results in a total path loss of 197.7 dB. G_R is taken as 50.2 dB, corresponding to a 35-ft. antenna.

APPENDIX B
DEMOGRAPHIC MODEL OF INDONESIA

In designing a domestic communications satellite system for any country which provides not only telephony, but educational television and national television distribution as well, it is exceedingly important to determine the distribution of population in that country. The necessity of knowing the rural and urban population concentrations becomes apparent when one attempts to implement, for example, an educational television system which reaches the greatest percentage of country population in the most cost-effective approach.

This annex presents the governing assumptions and analyses which were made in constructing a demographic model for the Republic of Indonesia. The resulting model is used to implement a system for educational television and national television distribution. The population data are also valuable in sizing telephone traffic requirements in various parts of the country.

General Population Characteristics

All population figures used in the analysis were based on the 1961 census for Indonesia. Some of the basic figures, broken down on an island-by-island basis, are summarized in Table 1. A list of the 57 largest cities with their corresponding population is shown in Table 2.

No attempt was made to update the 1961 census figures to a 1971 estimate. It is assumed that population will grow in the same proportion,

TABLE 1.

INDONESIA'S POPULATION IN THE 1961 CENSUS
(Statistical Pocket Book of Indonesia, 1961, Djakarta)

Island	Area (Sq. Mi.)	% of Total Area	Population In '000	% of Total Population	Density Per Sq. Mi.
Java/Madura	48,842	6.5	63,059	64.9	1,291
Sumatra	183,000	24.6	15,739	16.2	86
Sulawesi	71,695	9.6	7,079	7.2	98
Kalimantan	189,106	25.4	4,102	4.2	21
Moluccas	32,300	4.3	790	0.8	24
West Irian	162,965	21.9	758	0.7	4
Other Islands	55,976	7.7	5,558	6.0	98

TABLE 2.

LARGEST CITIES

(The International Atlas, Rand-McNally & Co., 1969, New York)

City	Location/Island	Population
Ambon	Maluku	55,263
Balikpapan	Kalimantan	88,534
Banda Atjeh	Sumatra	40,067
Bandjarmasin	Kalimantan	212,683
Bandung	Java	1,025,000
Banjuwangi	Java	72,467
Blitar	Java	61,979
Bogor	Java	146,907
Bukittinggi	Sumatra	51,587
Denpasar	Bali	56,587
Djakarta	Java	2,922,000
Djember	Java	94,089
Djombang	Java	68,963
Garut	Java	76,244
Gorontalo	Sulawesi	71,232
Gresik	Java	38,998
Jogjakarta	Java	308,530
Kediri	Java	158,682
Krawang	Java	49,567
Kudus	Java	74,911
Madiun	Java	122,801
Magelang	Java	91,636
Makasar	Sulawesi	367,882
Malang	Java	332,023
Manado	Sulawesi	127,614
Martapura	Kalimantan	44,608
Medan	Sumatra	466,370
Modjokerto	Java	50,308
Padang	Sumatra	143,615

TABLE 2. (Continued)

City	Location/Island	Population
Padangsidempuan	Sumatra	46,496
Pakanbaru	Sumatra	69,147
Palembang	Sumatra	458,661
Pangkalpinang	Sumatra	58,540
Parepare	Sulawesi	62,683
Pasuruan	Java	62,872
Pekalongan	Java	100,261
Pematangsiantar	Sumatra	112,687
Ponorogo	Java	59,952
Pontianak	Kalimantan	146,547
Probolinggo	Java	68,378
Purwakarta	Java	45,610
Purwokerto	Java	80,556
Salatiga	Java	53,706
Samarinda	Kalimantan	68,095
Semarang	Java	487,006
Sukabumi	Java	78,806
Surabaja	Java	1,050,000
Surakarta	Java	363,167
Tandjungkarang-Telukbetung	Sumatra	132,312
Tasikmalaja	Java	125,525
Tegal	Java	89,953
Djambi	Sumatra	108,834
Tjiandjur	Java	62,546
Tjilatjap	Java	55,333
Tjimahi	Java	64,226
Tjirebon	Java	153,405
Tulungagung	Java	62,069

thus obviating the necessity of projection to current population figures since only relative demographic data are required.

Since over 92 percent of Indonesia's population lives on only four islands - Java, Sumatra, Kalimantan, and Sulawesi - the demographic analysis will be conducted only for these four main islands. The relatively low percentage of the country's population assumed by the remaining islands together with a scarcity of existing population data does not make feasible an extension of the analysis to these other islands.

Only 15 percent of the population of Indonesia lives in urban communities. This requires a demographic model which will give a good estimation of rural population density. A detailed development of this model, including all governing assumptions, is presented in the next section.

In addition to the 1961 census population figures given in Tables 1 and 2, cartographic data were obtained from the 1969 Rand-McNally International Atlas. The above reference may be consulted for the maps with the associated sector identification. The city population key considers six classes of cities. For those cities which were not listed in Table 2, a nominal population was assumed as being representative of the "average" population of a city in that classification. The city classifications and their associated symbols are shown in Table 3, together with the assumed nominal population. A nominal population for those cities with a population greater than 100,000 was not assumed since actual populations are given for these cities in Table 2.

TABLE 3.

NOMINAL POPULATION ASSUMPTIONS

Symbol	Population Range	Assumed Nominal Population
●	0 - 10,000	5,000
○	10,000 - 25,000	15,000
⊙	25,000 - 100,000	50,000
⊡	100,000 - 250,000	--
▣	250,000 - 1,000,000	--
■	> 1,000,000	

It is essential in the model to determine not only the population in the urban centers (i.e., villages, towns, and cities over 10,000), but also the countryside population and, most important, the countryside population density. This is particularly important for a country such as Indonesia, where approximately 85 percent of the people live in small villages and in the countryside. For the demographic model to be a valid one in such applications as constructing an educational television network, the areas of highest countryside population concentration must be identified.

The demographic model treats the four main islands by dividing the land mass into sectors; all analysis was done on a sector-by-sector basis for each island. The extraction of the urban population from the total, thus leaving the rural population, was done in two steps. First, the appropriate selected cities which appeared on the list in Table 2 were taken out of the total population for the island. Consider, for example, the island of Sulawesi. Four cities appeared on the list - Gorontalo, Manada, Makasar, and Parepare. These four cities accounted for 629,411 of the total island population of 7,079,000. This left remaining a portion of the urban population (towns and small cities) and the village and countryside population. Next, the remaining number of cities from each of the three classifications - 0-10,000, 10,000-25,000, 25,000-100,000 - were tallied for each sector. These cities were then assigned the nominal population, as shown in Table 3 and were summed to establish what was referred to as the "total town population." Extracting the population of the selected cities and the total town population for each sector left the countryside population for the island.

Since the countryside population is not evenly distributed over the entire island, it is necessary to weight the countryside population. Weighting was done on the basis of the village and urban population concentration within a sector. Large metropolitan areas were excluded from the urban population since they would unfairly weight the remaining sector area. That is, the entire countryside population was distributed in proportion to the total town population in a sector. This yields a weighted countryside population on a sector-by-sector basis.

Because land mass occupying each sector varies, it is necessary to obtain a weighted countryside population density. Land mass occupation of a sector was estimated to the nearest one-fifth of a sector. Dividing this area into the countryside population per sector gives the desired population density.

Java/Madura - Total Population, 63,059,000; Area, 48,842 Sq. Mi.

TABLE 4.

SELECTED CITIES

Selected Cities	Population
Bandung	1,025,000
Banjuwangi	72,467
Blitar	61,979
Bogor	146,907
Djakarta	2,922,000
Djember	94,089
Djombang	68,963
Gresik	38,998
Jogjakarta	308,530
Kediri	158,682
Krawang	49,567
Kudus	74,911
Madiun	122,801
Magelang	91,636
Malang	322,023
Modjokerto	50,308
Pasuruan	62,872
Pekalongan	100,261
Ponorogo	59,952
Probolinggo	68,378
Purwakarta	45,610
Purwokerto	80,556
Salatiga	53,706
Semarang	487,006
Sukabumi	78,806
Surabaja	1,050,000
Surakarta	363,167
Tasikmalaja	125,525
Tegal	89,953
Tjiandjur	62,546
Tjilatjap	55,333
Tjimahi	64,226
Tjirebon	153,405
Tulungagung	62,069
Total Selected City Population	8,682,232

TABLE 5.

TOTAL TOWN AND WEIGHTED COUNTRYSIDE POPULATION

Sector	No. of Villages (●)	No. of Towns (○)	No. of Small Cities (⊙)	Total Town Population (000's)	Weighted Countryside Population (000's)
B-C/1-2	1	0	0	5	56.5
A-B/2-3	3	3	0	60	678
B-C/2-3	17	7	4	390	4,410
C-D/2-3	12	7	3	315	3,560
D-E/2-3	8	9	2	275	3,110
E-F/2-3	3	3	4	260	2,940
F-G/2-3	2	6	0	100	1,130
G-H/2-3	5	7	2	230	2,605
H-I/2-3	2	2	1	90	1,017
B-C/3-4	2	1	0	25	283
C-D/3-4	7	4	1	145	1,640
D-E/3-4	9	5	1	170	1,923
E-F/3-4	12	13	2	355	4,015
F-G/3-4	16	6	3	455	5,150
G-H/3-4	7	6	5	375	4,240
H-I/3-4	16	11	4	445	5,030
I-J/3-4	9	7	2	250	2,830
J-K/3-4	3	1	1	80	905
F-G/4-5	1	0	0	5	56
G-H/4-5	4	3	0	65	735
H-I/4-5	3	4	0	75	848
I-J/4-5	4	5	1	145	1,640
J-K/4-5	5	0	0	25	283
TOTAL	153	121	37	4,415	--

TABLE 6.

RURAL, URBAN, AND TOTAL POPULATION

Sector	Weighted Rural* Population (000's)	Area (Sq. Mi.)	Rural Population Density	Urban** Population (000's)	Total Population (000's)
B-C/1-2	56	930	60	5	61
A-B/2-3	678	1,863	363	60	738
B-C/2-3	4,410	3,725	1,183	3,538	7,948
C-D/2-3	3,520	3,725	956	1,655	5,215
D-E/2-3	3,110	1,863	1,666	428	3,538
E-F/2-3	2,940	930	3,160	450	3,390
F-G/2-3	1,130	1,863	606	662	1,792
G-H/2-3	2,605	1,863	1,396	230	2,835
H-I/3-4	5,030	3,725	1,356	2,207	7,237
I-J/3-4	2,830	1,863	1,518	318	3,148
J-K/3-4	905	930	972	80	985
F-G/4-5	56	930	60	5	61
G-H/4-5	735	930	792	127	862
H-I/4-5	848	1,863	454	137	985
I-J/4-5	1,640	1,863	879	239	1,879
J-K/4-5	283	1,863	152	97	380
H-I/2-3	1,017	930	1,092	90	1,107
I-J/2-3	848	930	910	75	923
B-C/3-4	283	930	304	25	308
C-D/3-4	1,640	2,790	588	145	1,785
D-E/3-4	1,923	3,725	518	296	2,219
E-F/3-4	4,015	3,725	1,080	491	4,506
F-G/3-4	5,150	4,650	1,108	1,272	6,422
G-H/3-4	4,240	4,650	912	558	4,798

*Countryside population

**Includes total town population and selected cities.

Sulawesi

Population Total - 7,079,000

Area - 71,695 Square Miles

TABLE 7.

SELECTED CITIES

Selected Cities	Population
Gorontalo	71,232
Makasar	367,882
Manado	127,614
Prepare	62,683
Total Selected City Population	629,411

TABLE 8.

TOTAL TOWN AND WEIGHTED COUNTRYSIDE POPULATION

Sector	No. of Villages (●)	No. of Towns (○)	No. of Small Cities (⊙)	Total Town Population (000's)	Weighted Countryside Population (000's)
A-B/1-2	3	0	0	15	68
B-C/1-2	16	0	0	80	363
C-D/1-2	13	0	0	65	295
D-E/1-2	12	2	0	90	400
A-B/2-3	15	1	0	90	408
B-C/2-3	20	1	0	115	522
C-D/2-3	9	0	0	40	182
A-B/3-4	12	2	1	140	636
B-C/3-4	25	0	1	175	795
C-D/3-4	2	0	0	10	45.4
A-B/4-5	8	5	1	165	750
B-C/4-5	12	2	1	140	636
C-D/4-5	2	1	0	25	113
TOTAL	149	12	4	1,150	--

TABLE 9.

RURAL, URBAN, AND TOTAL POPULATION

Sector	Weighted Rural* Population (000's)	Area (Sq. Mi.)	Rural Population Density	Urban** Population (000's)	Total Population (000's)
A-B/1-2	68	3,810	18	15	83
B-C/1-2	363	7,625	48	80	443
C-D/1-2	295	3,810	77	136	431
D-E/1-2	408	3,810	107	217	625
A-B/2-3	408	3,810	107	90	498
B-C/2-3	522	7,625	69	115	637
C-D/2-3	182	7,625	24	40	222
A-B/3-4	636	7,625	82	140	776
B-C/3-4	795	11,400	70	175	970
C-D/3-4	45	3,810	12	10	55
A-B/4-5	750	3,810	197	596	1,346
B-C/4-5	636	3,810	167	140	776
C-D/4-5	113	7,625	15	25	138

*Countryside population

**Includes total town population and selected cities.

Sumatra

Total Population - 15,739,000

Area - 183,000 Square Miles

TABLE 10.

SELECTED CITIES

Selected Cities	Population
Banda Atjeh	40,067
Medan	466,370
Padang	143,615
Padangsidempuan	46,496
Pakanbaru	69,147
Palembang	458,661
Pangkalpinang	58,540
Pamatangsiantar	112,687
Tandjungkarang-Telukbetung	132,312
Djambi	108,834
Total Selected City Population	1,636,729

TABLE 11.

TOTAL TOWN AND WEIGHTED COUNTRYSIDE POPULATION

Sector	No. of Villages (●)	No. of Towns (○)	No. of Small Cities (⊙)	Total Town Population (000's)	Weighted Countryside Population (000's)
A-B/1-2	10	0	0	50	222
B-C/1-2	14	1	1	135	600
C-D/1-2	3	0	0	15	66
B-C/2-3	12	0	1	110	487
C-D/2-3	20	0	5	350	1,550
D-E/2-3	3	1	0	30	133
C-D/3-4	13	1	1	130	576
D-E/3-4	19	3	0	110	487
E-F/3-4	10	2	0	80	354
C-D/4-5	2	0	0	10	44
D-E/4-5	19	9	2	330	1,460
E-F/4-5	21	4	0	165	732
F-G/4-5	7	0	0	35	155
D-E/5-6	10	1	1	115	510
E-F/5-6	27	8	2	355	1,570
F-G/5-6	22	3	1	205	910
E-F/6-7	2	5	0	85	377
F-G/6-7	16	10	1	280	1,240
TOTAL	229	48	15	2,590	--

TABLE 12.

RURAL, URBAN, AND TOTAL POPULATION

Sector	Weighted Rural* Population (000's)	Area (Sq. Mi.)	Rural Population Density	Urban** Population (000's)	Total Population (000's)
A-B/1-2	222	3,810	58	90	312
B-C/1-2	600	11,400	53	135	735
C-D/1-2	67	3,810	18	15	82
B-C/2-3	487	7,625	64	110	597
C-D/2-3	1,550	11,400	141	929	2,479
D-E/2-3	133	3,810	35	30	163
C-D/3-4	576	7,625	76	176	752
D-E/3-4	487	19,100	26	179	666
E-F/3-4	354	7,625	46	80	434
C-D/4-5	44	3,810	12	10	54
D-E/4-5	1,460	15,250	96	474	1,934
E-F/4-5	732	19,100	38	274	1,006
F-G/4-5	155	3,810	41	35	190
D-E/5-6	510	7,625	67	115	625
E-F/5-6	1,570	19,100	82	355	1,925
F-G/5-6	910	19,100	48	723	1,633
E-F/6-7	377	7,625	49	85	462
F-G/6-7	1,240	15,250	81	412	1,652

*Countryside population

**Includes total town population and selected cities.

Kalimantan

Total Population - 4,102,000

Area - 189,106 Square Miles

TABLE 13.

SELECTED CITIES

Selected Cities	Population
Balikpapan	88,534
Bandjarmasin	212,683
Martapura	44,608
Pontianak	146,547
Samarinda	68,095
Total Selected City Population	560,467

TABLE 14.

TOTAL TOWN AND WEIGHTED COUNTRYSIDE POPULATION

Sector	No. of Villages (●)	No. of Towns (○)	No. of Small Cities (⊙)	Total Town Population (000's)	Weighted Countryside Population (000's)
D-E/1-2	5	0	0	25	41
E-F/1-2	21	0	0	105	172
A-B/2-3	9	3	1	140	230
B-C/2-3	9	2	0	75	123
C-D/2-3	9	0	0	45	74
D-E/2-3	12	0	0	60	98
E-F/2-3	16	0	0	80	131
F-G/2-3	4	0	0	20	33
A-B/3-4	6	0	0	30	49
B-C/3-4	17	4	0	145	238
C-D/3-4	13	0	0	65	106
D-E/3-4	14	1	0	85	139
E-F/3-4	10	1	0	65	106
B-C/4-5	8	2	0	70	115
C-D/4-5	8	0	1	90	148
D-E/4-5	16	2	2	210	345
E-F/4-5	7	0	0	35	57
TOTAL	184	15	4	1,345	--

TABLE 15.

RURAL, URBAN, AND TOTAL POPULATION

Sector	Weighted Rural* Population (000's)	Area (Sq. Mi.)	Rural Population Density	Urban** Population (000's)	Total Population (000's)
D-E/1-2	41	7,625	5.4	25	66
E-F/1-2	172	19,100	19.0	105	277
A-B/2-3	230	7,625	30.0	140	370
B-C/2-3	123	7,625	16.1	75	198
C-D/2-3	74	11,400	6.5	45	119
D-E/2-3	98	15,250	6.4	60	158
E-F/2-3	131	15,250	8.6	80	211
F-G/2-3	33	3,810	8.7	20	53
A-B/3-4	49	3,810	12.8	176	225
B-C/3-4	238	19,100	12.5	145	383
C-D/3-4	106	19,100	5.6	65	171
D-E/3-4	139	19,100	7.3	85	224
E-F/3-4	106	7,625	13.9	222	328
B-C/4-5	115	7,625	15.1	70	185
C-D/4-5	148	11,400	13.0	90	238
D-E/4-5	345	15,250	22.6	467	812
E-F/4-5	57	3,810	15.0	35	92

*Countryside population

**Includes total town population and selected cities.

Development of Demographic Data for a Typical Sector

Consider the island of Sulawesi with a total population of 7,079,000 and an area of 71,695 square miles.

The island contains four cities from the largest cities list (Table 2) - Gorontalo, Makasar, Manado, and Parepare. These four cities have a combined population of 629,411, which constitutes almost 9 percent of the island population. According to the coding used in Table 8, Sulawesi has 149 villages, 12 towns, and 4 small cities. Assigning the nominal population assumptions (see Table 3) to these cities leads to the following urban population breakdown:

Selected city population $\cong$ 629,000

Village population - 5,000 x 149 = 745,000

Town population - 15,000 x 12 = 180,000

Small city population - 50,000 x 4 = 200,000

thus,

$$\text{Total urban population} = 745{,}000 + 180{,}000 + 200{,}000 + 629{,}000$$
$$= 1{,}754{,}000$$
$$= 24.8 \text{ percent island population.}$$

Subtracting the urban population leaves the rural, or countryside population. Hence,

$$\text{Countryside population} = 7{,}079{,}000 - 1{,}754{,}000$$
$$= 5{,}325{,}000$$

The countryside weighting factor is therefore

$$F_{C/S} = \frac{\text{Countryside population}}{\text{Total town population}} = \frac{5,325,000}{1,150} = 4.54$$

For a particular sector, then, the countryside population is just,

Countryside population = 4.54 x total town population.

Consider sector C-D/1-2. It has a total town population of 65,000 (see Table 8). The weighted rural population for that sector is merely 4.54 x 65,000 = 295,000. To the nearest one-fifth of a sector, the area of C-D/1-2 is 3,810 square miles. This leads to a rural population density of 77 people/square mile. The urban population is found by summing the total town population (65,000) and the selected city population (71,232 for Gorontalo). This yields the figure shown in Table 9, 136,000. The total sector population is then 136,000 + 295,000 = 431,000.

APPENDIX C
SATELLITE/TERRESTRIAL SYSTEM COMPARISONS

In order to illustrate the cost-effectiveness of the Indonesian satellite system proposed, it is necessary to draw a comparison with an equivalent terrestrial microwave system. While a detailed technical/economic comparison would entail a comprehensive analysis beyond the scope of work intended, it is appropriate to outline some of the elements required by a terrestrial system to provide the required telephony and television services. A cursory economic comparison is made on the basis of system investment and operations and maintenance costs.

System Model

The intra-island transmission of television and telephony is accomplished via line of sight microwave relay, part of which is already existing on Java and Sumatra. As in the satellite system, VHF rebroadcast is used to distribute the television signals at the 26 major city locations. VHF rebroadcast stations are also used for ETV distribution. With little information regarding the exact locations of schools, no attempt is made to precisely locate these stations, and an average of two VHF stations per province is assumed. The terrestrial net requires additional inter-island transmission paths. The channel capacity requirements for both the telephony traffic and three television channels require installation of submarine cable to interconnect a number of the islands.

The following items represent the guidelines for developing the terrestrial system investment model. The additions required are:

1) NTV and ETV

   - Add new terminal facilities at 14 cities not on the existing microwave net.
   - Add TV capability and three-channel VHF rebroadcast at all 26 cities.
   - Augment existing repeater stations for three-channel TV and install 115 additional repeater stations to complete microwave link.
   - Interconnect islands with submarine cable.
   - Deploy 52 two-channel VHF stations for educational TV only.

2) Telephony

   - Add microwave equipment at all new terminals.
   - Add multiplex equipment to both new and existing terminals.

Financial Considerations

The terrestrial investment summary is shown in Table 1. Comparison of the above terrestrial investment with the satellite system reveals the cost-effectiveness of the satellite system for this particular application for the country of Indonesia. Furthermore, the operations and maintenance costs of the terrestrial system will be much greater than those for the proposed satellite system. This arises from the fact that

TABLE 1.

TERRESTRIAL SYSTEM
CAPITAL INVESTMENT SUMMARY

Item	Quantity	$ U.S. Millions
System Management		7.0
Major Terminals at Provincial Cities	26	9.2
VHF Rebroadcast Stations		
Two-Channel	52	11.5
Three-Channel	26	6.5
Repeater Stations		
Augmentation of Existing Net	81	5.0
New Stations	115	31.5
Submarine Cable	5	32.4
Additional TV Micro-wave Equipment for Cities On-Line		1.5
TV Receivers	8,544	1.5
Regional Service Centers	26	3.0
Total System Investment		$ 109.1

the many microwave relays requiring regular maintenance are often located in rough, unaccessible terrain and are subjected to the harsh natural elements characteristic of the Indonesian geographical environment. These costs typically run 16 percent to 20 percent of the ground investment each year.

On the basis of this analysis, then, it is apparent that the satellite system represents the most cost-effective approach to telecommunications expansion for the Republic of Indonesia.