audio signals to the end user and the supervision and control of the unattended Earth station.

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Project Delphi—Technical Aid to the Developing Nations by Consulting Services Satellite

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Lack of skills and emigration of available skills are formidable obstacles to economic growth in developing nations. To see if space technology can help overcome these obstacles, mission requirements for enhancing international technical cooperation in the United Nations Second Decade of Development were examined. This led to a preliminary feasibility study of a satellite video-telephone system serving 9000 experts in developed and developing nations by 1980. A model of a one million square-mile developing region containing seven nations, 10 centers of excellence, and 70 field centers was assumed. Each of four such regions could be served by a 12-GHz, 3500-lb synchronous satellite with a solar array power of 12.5 kw. Each satellite also would link its developing region to two advanced centers in developing nations. The most difficult problem is obtaining adequate allocation of the synchronous-orbit spatial/spectra resource for the developing nations.

Introduction

A NUMBER of space systems has been identified as potentially useful to the developing nations: communications satellites, weather satellites, resource survey systems, educational television systems, etc. However, most of them are impractical until some solution to the shortage of technical skills and low product output in developing nations is found. In 1967, two-thirds of the world's population lived in countries where the per capita output was less than $100 per year.[1] Roughly half of the developing nations that are members of the World Bank have a growth rate of 1% or less.[2] Furthermore, the growth goals of the United Nations Second Decade of International Development of 3.5–4.5% in per capita income[3] are suspect because they depend on the advanced nations investing 1% of their own GNP in economic aid, a target missed by a wide margin in the First Decade of Development.

A "Consulting Services Satellite" would make available aid more effective by providing a two-way television link between personnel at field and regional centers in the developing nations and consultants at institutions in the advanced nations. This approach would be consistent with the trend that has been appearing towards the end of this decade; e.g., whereas the United States AID program declined a total of $250 million in economic assistance in 1967, the total for technical cooperation was slightly higher than the previous year.[4] Similarly, the U.N. Development Program, which is largely concerned with technical assistance in the early phases of projects, has shown a steady growth in the latter half of this decade, reaching $200 million in 1969.[5] It also has been suggested that science and technology "will have to become one of the major preoccupations of the United Nations, and the stimulation of the transfer of technology one of its principal actvities."[6] However, there is a growing shortage of experts that can provide assistance, and the problem is aggravated by a net flow of skilled personnel from the developing nations to the advanced nations. Between 1949 and 1964, 73,500 scientists and engineers established permanent residence in the United States, and in the latter part of this period Asia and South America were contributing 27% of this flow.[7] Moreover, training programs in the developing nations will fall short of the need for technical and scientific personnel by tens of thousands, if satellites are used extensively there for meteorology, communication and education,[8] and other proposals, such as nuclear reactor projects for bringing water to desert areas, would make similar demands on meager reservoirs of skill.

A New Work Environment

To encourage skilled people to stay in their own country and to encourage the ones who have emigrated to go back, a new climate has to be created. The Consulting Services Satellite (CSS) could revolutionize the environment and work of people in the developing nations. What is often needed is "intermediate technology"[9,10] rather than advanced technology. Furthermore, important elements to be transferred are the research and educational methods and attitudes of the West—"with their emphasis on problem solving through experimentation, analyses and tests, and their objectivity,

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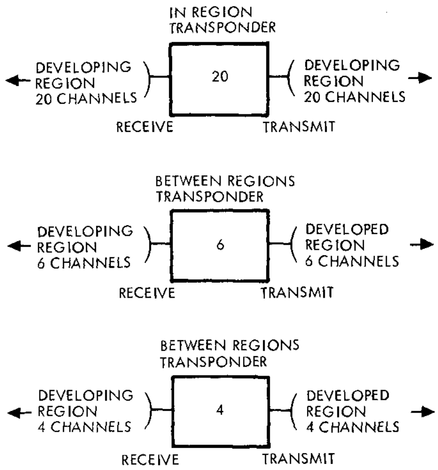

Fig. 1 30 Satellite transponder channels would provide technical assistance to area comparable to the Central American Common Market.

pragmatism, and optimism," to quote Roger Revelle, Chairman of the Center for Population and World Resources at Harvard University.[11] The video-telephone link can give the sense of immediacy of attention and directness of contact. Interest and enthusiasm can be vividly transmitted.

The CSS also could overcome some of the practical disadvantages in present technical aid programs. For example, the people willing to embark on technical assistance missions may be "people who have not succeeded in finding satisfactory niches at home."[12] Problems also have arisen from their high standard of living compared with that of the people they are working with.[13] A video telephone system could tap a reservoir of talent that is simply unavailable to most other forms of technical assistance while minimizing contrasts of standards of living. The system would conform to the rules for technical assistance evolved by the Rockefeller Foundation,[14] particularly in its ability to operate over an extended time, the essential participation by the developing nations, close involvement, quality assistance and the possibility of operating programs on a broad front. It would have many specific uses; e.g., it could greatly increase the utility of Earth Resources Satellite information that President Nixon offered the world community in his 1969 speech before the 24th Session of the U.N. General Assembly.

A CSS system can most easily be built up on a regional basis. Accordingly, the system examined was designed around the establishment of regional centers of excellence such as have been proposed on a number of occasions.[15–17] Two other types of centers are required: field centers in each developing nation, and advanced centers in the developed world. The complete system—made up of these centers, the satellite, launch operations, orbital operations, maintenance and logistics, link scheduling, nonvideo data transmission, recruiting, translating, and so forth—is referred to as Project Delphi. The project would use other media in addition to television, but the video phone is the most novel element and is the one described in the following sections.

Systems Concepts

To allow a preliminary assessment of the technology required for a mission of this type, the following assumptions were made. In day-to-day operation, field centers (FC's) communicate primarily with consultants at regional centers (RC's, centers of excellence) in their local region of developing nations. On a less frequent basis, the experts at the RC's communication with experts at advanced centers (AC's) in the developed nations. In addition, conference calls linking an FC, RC, and an AC will be required, and FC's will wish to be able to receive information directly from AC's.

To keep the satellite and launch vehicle costs down, the electrical performance of the field center should be as good as possible. However, to avoid balance of payments problems the field center cost should be kept down. Also a rugged and compact design, with as few mechanically sensitive components as possible, is necessary. As a desirable goal, the cost of the FC communications terminal is set at $50,000. This assumes quantity manufacture of key components. For simplicity, the system models assume that the same terminal (with additional channel capacity) is used at the field, regional and advanced centers. This would also make it a simple matter to set up the nucleus of a regional center and allow it to grow as skills and resources become available to it.

An operational agency is assumed to control the satellite and to manage the system from an operations center, which will have more sophisticated communications equipment than the other centers.

The system is designed to handle monochrome television pictures of passable but not excellent quality. The communications channels that result are also capable of handling many forms of data. They could be used, for example, to provide direct access from field centers to regional computer facilities or to computer centers in the advanced nations. As such, the channels could be used for data reduction or computer-assisted instruction.

Two types of systems have been examined. One is a generalized system that could be a building block for worldwide coverage. The other is a small system such as might result from cooperation between one advanced nation and a small regional group of developing nations. To keep costs low the small system is configured so that it can act as a pilot experiment for the large system and can begin operation in 1975.

Pilot System

The Pilot System is assumed to be typified by that which could be installed if a technical assistance project were set up via synchronous satellite between the U.S. and the Central American Common Market: Costa Rica, El Salvador, Guatemala, Honduras, and Nicaragua. These five countries can be served by an elliptical beam with a projected area of 0.5 million square miles. A typical time for initial operation of such a system would be 1975. The CSS is assumed to have a spot beam directed to one advanced center (AC) in the eastern United States (to minimize time-zone differences) and a second beam illuminating the developing region. (An AC in Europe could be brought into the system by addition of another antenna on the spacecraft.)

Each developing country will have two FC's, and the region as a whole will have four RC's, which might typically be concerned with agriculture, education, family planning, health, public administration, and community action. The average consultation in any part of the system may take 2 hr, and an average working week may be 48 hr. Thus one video channel is able to carry 48 hr of one side of a consultation each week. Two channels can handle 24 full consultations/week.

Users of the FC's are assumed to average one visit per week to the terminal to consult with the particular RC of interest to them. Thus, there are 24 users per FC and 240 field users throughout the region. They require some 480 hr of consultation from the RC's, or 120 hr/RC. If each specialist at an RC spends 10 hr/wk consulting with RC's, each RC will require 12 consultants.

Each consultant at an RC is assumed to communicate once a week with his counterpart at the advanced center. He is also assumed to take part in conference calls involving an RC, and FC, and the AC. If one in five FC calls is a conference call, there will be 48 conference calls per wk (they reduce the two-way calls by the corresponding amount), and it is convenient to assume that each of the 48 regional consultants takes part in one conference call once per wk. To complete the conference call, the field center call is relayed to the AC by the RC; this avoids the need to broadcast all FC channels into the advanced nation.

Each of the 10 FC's is assumed to have a single channel for communicating with the RC's, which in turn require 10 channels to communicate with the FC's. These 20 channels are represented by the first line in Fig. 1. The 48 conference calls per wk require two channels to relay the FC signal to the AC. In addition, the AC and the RC's each require two channels for their contribution to the conference call. The FC's can pick up the AC contribution as it is in the beam illuminating the developing region. The RC contribution needs to be fed into the beam to the AC and into the beam to the developing region. In the latter, it will make use of the normal channel for communicating with the FC in question. Thus, there are 6 channels in total in the second line of Fig. 1. Finally, for the 48 calls per wk between the RC and the AC that are not conference calls, two additional sets of two channels each are required. The total pilot system requires 30 channels (30 transponders, Fig. 1).

If the reduced bandwidth requirements of television signals that are of acceptable rather than excellent quality are taken into account, the bandwidth requirements of this pilot Consulting Services Satellite are about the same as those of Intelsat IV, a communication satellite now operating. The power requirements are, of course, higher.

Phase I System

For the Phase I System, no specific region of the world has been considered. An antenna bandwidth of about 3° at the synchronous consulting services satellite is assumed. The resulting circular zone over the Earth of about 2700-km-diam (10^6 sq miles) served by such an antenna is considered to be a typical region. To simplify calculations, the region is assumed to contain seven countries. This is about the number of countries that have managed to achieve regional agreements of one sort or another in Europe. Changes in satellite antenna design can provide different areas of coverage, and these need not be circular.

Since some development will have taken place by the time the Phase I system is implemented, it is assumed that each country will have 10 FC's (making 70 FC's per region) and that each region will have 10 RC's. The idea that ten regional centers of excellence might serve a particular region is suggested by the categories used to break down the ten-yr World Plan of Action being prepared by the U.N. Advisory Committee on the Application of Science and Technology to Development (ACAST). This plan is intended to come into action in 1971 and be coordinated with the Second Development Decade. Its subplans cover: 1) natural resources, 2) food and agriculture, 3) industry, 4) transport and communications, 5) housing, 6) health, 7) science and education, and 8) population, in addition to general policies. Data processing can be added as a ninth category. The Governing Council of the United Nations Development Program (UNDP) recently had added the question of setting up and operating a system of automatic data storage, processing, and retrieval to the UNDP study of the capacity of the UN System to carry out an expanded development program.[18] In addition, there is significant potential in computer-assisted instruction for the developing nations. Also, there is a constellation of activities such as finance, retail trade, insurance, and administration that could constitute a tenth category

It is assumed that the Phase I of the Delphi Project, operational by 1980, will involve four developing regions and two advanced regions. The satellite is assumed to be in synchronous orbit and capable of linking regions distributed over a third of the earth's surface, outside of the polar regions. That is, it is capable of linking countries with up to 8 hr difference in time zones. However, 4 hr of time-zone difference is expected to be the normal maximum. Each developing region is assumed to communicate with two developed regions.

As envisaged, the Phase I system would involve 70 field centers/developing region, working 50 hr/wk with each user having an average of 2 hr/wk. Thus the system would serve 25 users/field center, or a total field staff of 7000 in 4 regions. If one assumes that the consultations between the field users and the RC's are equally divided between the 10 different groupings of skill, then each RC will handle 175 consultations/wk. Again, if a regional consultant deals with FC's for 10 hr a week, there will be an average of 35 consultants at an RC.

The staff requirements at the AC's can be derived from the rate at which staff at the RC's will wish to communicate with the developed world. If an average for a regional consultant of one 2-hr session every 2 weeks is the minimum desirable, this implies a total of 700 consultations/wk (1400 staff in the RC's) with 350 allotted to each of the two AC's associated with a particular developing region. Since it may be desirable to have as many different specialists within a skill as possible, then an average consulting staff of 350 for each of the two AC's will be assumed. The total manpower in the Phase I system will then be 7000 + 1400 + 700 = 9100. This number can be compared to the 1967 total of 7865 AID-financed technicians world wide, contract and U.S. Government employees,[4] and to the 8200 experts that the U.N. Development Program had in the field in 1968.[5]

The average weekly activity in the Phase I system will comprise 1400 hr of AC-RC consultations, 14,000 hr of FC-RC consultations, and 1400 hr of three-way conferences.

As each one-way video channel is subject to frequency translation in the satellite, each requires two channels in the radio spectrum—one at the up-link frequency, the other at the down-link frequency. Channels in the radio spectrum are referred to as rf channels in the following.

Pilot System

For the Pilot system, (Fig. 1), 10 rf channels are required in the advanced region (4 up, 6 down) and 50 in the developing region (26 up, 24 down). That is, the large bandwidths are required over the developing regions: five times more spectrum than the advanced region. A similar pattern appears in the Phase I system, except that the proportional increase in activity in the developing regions raises the ratio to ten to one.

Phase I System

The channel requirements of a Consulting Services Satellite depend on how the system is implemented. One approach is to consider the developing region as the building block of the system and to design the satellite for intraregional communications and for linking a region to two advanced centers. As the developing regions can in most cases be served by separate beams, the same set of rf channels can be used by each region. The satellites serving each region will, of course, have to be separated by the beamwidths of the ground antennas. In this case, however, the spectrum requirements in the developing world stay constant as further satellites are added.

The developed world can also share regions of the spectrum for communicating with the developing world, again provided that there is adequate beam separation. Problems would arise if a global system were rapidly implemented, but here the assumption is made that expansion of the Phase I system will be in terms of the more advanced technology available in the 1980's—possibly very much narrower beams and wider

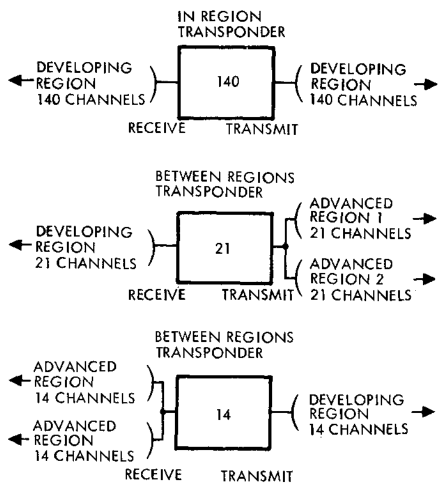

Fig. 2 175 Satellite transponder channels would provide technical assistance to a million square mile developing region of the Phase I system.

bandwidths. The Phase I Regional Satellite would use beam switching to enable a developing region to communicate with two advanced regions.

These simplifying assumptions mean, of course, that the spectrum requirements of the Phase I system are those of a single regional satellite. The system has the disadvantage that conference calls involving more than one advanced center will be difficult to set up; but such centers will have alternate communications paths available.

For a single satellite serving one developing region with 70 FC's and two developed regions, 175 video channels are required, as shown in Fig. 2. This figure shows that 35 rf channels (14 up, 21 down) are required in the spectrum of the advanced region and 315 rf channels (161 up, 154 down) are required in the spectrum of the developing regions.

If each rf channel carries a 16-MHz FM television carrier, the bandwidth required in the spot beam to and from the developed nation is 630 MHz, allowing for the insertion of guard bands. In the developing region, the bandwidth required is 5770 MHz, including guard bands. The wide bandwidth is much less of a problem in a developing nation than in an advanced region because of the frequent absence of terrestrial services competing for the spectrum. In addition, many developing nations are grouped around the equator and receive synchronous satellite signals at an angle much closer to the zenith than is the case in Europe or North America. They sit, in fact, in unique cones of space when viewed from synchronous orbit and have very large spectrum resources available within each cone.

The spectrum needs will decrease in the future when more advanced antenna techniques become available. Phased array antennas with many very narrow beams will be particularly relevant to this system. If the beams can be narrowed to serve a particular developing country there is the possibility that countries not immediately adjacent to each other could use the same set of frequencies. Other developments that will be relevant to the system will be the emergence of the technology for operation at millimeter wavelengths and possibly the use of laser communication.

The requirements for the satellite are similar to those for broadcast satellites for which several satellite concepts have already been developed. The chief difference is the large number of television channels relayed by a regional satellite in the Phase I system and the lower power requirements per channel. The technological requirements can be characterized as beyond the present state of the art but achievable by 1980. The system would require a fraction of the technical effort expended on the development of nuclear weapons, of ICBMs, or of the Apollo manned lunar system.

System Management

For simplicity, the operation of a conceptual single-region organization is described here. It is assumed that there is an International Council deciding matters of general policy.

System Development and Operation

A System Development Division of the Operating Agency is responsible for the technical expertise of the agency. It includes research laboratories for staff capable of managing technical innovations for the system and acting as consultants for technical problems as they arise. It also contains design and development staff capable of providing technical specifications for the system and its elements (space and ground segments) and technical direction of subsequent contractor effort. This division would be responsible for the total systems analysis and systems engineering task.

A System Operations Division would be responsible for launch and orbital control of the spacecraft and would monitor the technical performance of the spacecraft. It would also be responsible for ground facility design (as distinct from the ground equipment design), for routine installation, maintenance, testing and logistics functions, and for metering communications link usage.

Consulting Operations

A Consulting Operations Division is responsible for recruiting of consultants, scheduling of consultations, translation services, computer services, monitoring and user liaison, and information services. Recruiting would be aided by word-of-mouth through the Delphi system and by the publicity that the system itself would receive. Requirements reporting would be processed through the system with the regional centers playing a major coordinating role. The chief difference of both requirements reporting and recruiting in the Delphi system compared with present methods of technical aid will be that the process can be much faster, but the possibility of short time assignments means that many more requests for assistance and many more responses to recruiting will have to be processed.

To make the scheduling task manageable, it will be necessary to break it into small segments. For example, any one RC in Phase I might allot certain times of each week for each of the seven countries it serves. Each of the FC's in one country would then work out between themselves, with the aid of the RC, how they will time share the frequency channel that the RC has allotted to them. Correspondingly, the advanced centers will work out a basic sequence for working with each of the RC's during the course of two weeks. The consultants within each RC will need to coordinate their own schedules.

This division will have to keep track of forecast and actual schedules and make available spare channel capacity to users who appear at very short notice or are willing to be on call. Spare channels will also be used by the division for conducting the various communications activities required in its operations of the system.

This division also will carry out other types of user liaison, sometimes invoking the aid of other divisions. In this case it will be dealing with such things as handling suggestions and complaints about the terminal equipment, advising on scheduling policies, and obtaining installation, test or maintenance assistance as required. The division will also monitor the general activity in the system both in terms of the type of use to which it is put and in terms of the technical performance of the system, although this last aspect will be largely a matter for the System Operations Division.

Financial Control

The Financial Control Division is concerned with such matters as paying consultants or agencies providing consultant services, providing a suitable accounting to agencies financing the system through various kinds of aid funds, and billing each user country against its allotted aid budget. The country, in turn, can take the total aid budget that it has for consulting services and parcel it out as it sees fit to its own nationals making use of the field centers. Thus each user has a limited budget in terms of channel time and consultant fee, but is free to use it as he sees best. He can make use of a few long consultations or a greater number of shorter ones, depending on his particular needs.

Cost-Effectiveness

The annual operating costs of the Delphi Phase I system would be less than those of a terrestrial microwave system operating over the same area and with the same interconnections. Comparison of the Delphi system with a traditional system of sending people overseas that provides regular contact for 7000 field workers cannot be made without a more specific geographical model and data on acceptable attrition rates for itinerant specialists. However, it is desirable for field technical assistance to be held at least to the present level and preferably higher, while the Delphi system taps a manpower pool that is not currently available for overseas assignment.

This last feature is difficult to quantify in a cost-benefit analysis, but it is of vital importance. Thus, in discussing the return on investment that can be anticipated from a nuclear desalination plant (1000 Mwe, serving 490,000 acres, population of about 400,000), Prof. Richard L. Meier notes that the uncertainties are not related to technology but to the human factor: "Means must be found for achieving continuous cooperation between different kinds of specialists and to react very quickly to emergencies."[19] The Delphi system does enable such reaction, because it will be a simple matter to install a videophone terminal in such a complex, which is a natural site for a regional center.

In a similar way there are real benefits in being able to transmit lectures from a university in the developed world to one in the developing world (and vice versa), with a discussion period at the end. Or to transmit the details of a surgical operation, or demonstrate a new instrument or experimental technique in any of the sciences, or discuss a machine-tool feed problem, a new crop species, the interpretation of real weather or oceanographic charts, the development of a real curriculum and teaching aids, the significance of a real magnetic anomaly in relation to topography, and a host of other topics where the transfer of information is still archaically slow when it depends on the transport of people, materials and facilities around the world.

Concluding Remarks

Another major benefit of Project Delphi that is difficult to quantify is its integrating effect. In discussing the key areas for international cooperation during the next decade, the Chairman of the Preparatory Committee for the Second United Nations Development Decade, Mr. Phillippe de Seynes, emphasized the need to inject an element of organization, supervision and planning into the fragmentary development activities of the first 20 yr.[20] By integrating the activities of advanced and regional centers of excellence through a comprehensive communication system, Project Delphi would provide powerful assistance towards development the concerted effort required. Although the key areas for international cooperation identified by de Seynes exceed the scope of Project Delphi system—international trade, regional economic integration of developing nations, financial resources for development, science and technology, human development, expansion and diversification of production, and plan formulation and implementation, Project Delphi would have a powerful impact on most of these areas because of its utility to the key people involved.

Project Delphi is, of course, no substitute for capital aid; it will make demands for such aid more articulate and make such aid as is granted more effective. Hopefully, it will help develop the infrastructure within a nation and within groups of nations for the fruitful exploitation of world resources by the world community as a whole.

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