Eds. (Springer-Verlag, New York, 1971), p. 259; M. Degre, *Proc. Soc. Exp. Biol. Med* **142**, 1087 (1972); B. J. Leonard, E. Eccleston, D. Jones, *Nature (Lond.)* **224**, 1023 (1969).
33. B. J. Leonard and E. Eccleston, *Proceedings of the European Society for the Study of Drug Toxicity* **13**, 274 (1972); A. D. Steinberg, S. Baron, N. Talal, *Proc. Natl. Acad. Sci. U.S.A.* **63**, 1102 (1969).
34. P. A. Young, J. J. Taylor, M. C. Yu, E. Eyerman, *Nature (Lond.)* **228**, 1191 (1970); M. C. Yu, P. A. Young, W. A. Yu, *Am. J. Pathol.* **64**, 305 (1971).
35. A. K. Field, C. W. Young, I. H. Krakoff, A. A. Tytell, G. P. Lampson, M. M. Nemes, M. R. Hilleman, *Proc. Soc. Exp. Biol. Med.* **136**, 1180 (1971); D. A. Hill, S. Baron, H. B. Levy, J. Bellanti, C. E. Buckley, G. Cannellos, P. Carbone, R. M. Chanock, V. DeVita, M. A. Guggenheim, E. Homan, A. Z. Kapikian, R. L. Krischstein, J. Mills, J. C. Perkins, J. E. Van Kirk, M. Worthington, in *Perspectives in Virology*, M. Pollard, Ed. (Academic Press, New York, 1971), p. 197.
36. J. Vilcek and M. H. Ng, *Advan. Protein Chem.*, in press.
37. W. A. Carter, L. Marshall, P. O. P. Ts'o, unpublished observations.
38. P. M. Pitha, L. W. Marshall, W. A. Carter, *J. Gen. Virol.* **15**, 89 (1972); E. De Clercq, R. D. Wells, R. C. Grant, T. C. Merigan, *J. Mol. Biol.* **56**, 83 (1971).
39. K. Amako and S. Dales, *Virology* **32**, 201 (1967).
40. A. T. Haase, S. Baron, H. Levy, J. A. Kasel, *J. Virol.* **4**, 490 (1969).
41. H. B. Levy and W. A. Carter, *J. Mol. Biol.* **31**, 561 (1968).
42. R. K. Ralph, *Advan. Virus Res.* **15**, 61 (1969).
43. P. H. Duesberg and C. Colby, *Proc. Natl. Acad. Sci. U.S.A.* **64**, 396 (1969); C. Colby, C. Jurale, J. R. Kates, *J. Virol.* **7**, 71 (1971).
44. J. J. Lucas and H. S. Ginsberg, *Biochem. Biophys. Res. Commun.* **49**, 39 (1972).
45. R. M. Franklin, *Proc. Natl. Acad. Sci. U.S.A.* **55**, 1504 (1966).
46. W. E. Stewart II, E. De Clercq, A. Billiau, J. Desmyter, P. De Somer, *ibid.* **69**, 1861 (1972).
47. E. De Clercq, W. E. Stewart II, P. De Somer, *Infect. Immunol.* **7**, 167 (1973).
48. W. E. Stewart II, E. De Clercq, P. De Somer, *J. Gen. Virol.* **18**, 237 (1973).
49. W. Braun and M. Nakano, *Science* **157**, 819 (1967); R. Winchurch and W. Braun, *Nature (Lond.)* **223**, 843 (1969); A. F. Woodhour, A. Friedman, A. A. Tytell, M. R. Hilleman, *Proc. Soc. Exp. Biol. Med.* **131**, 809 (1969); W. Turner, S. P. Chan, M. A. Chirigos, *ibid.* **133**, 334 (1970); H. Cantor, R. Asofsky, H. B. Levy, *J. Immunol.* **104**, 1035 (1970); J. R. Schmidtke and A. G. Johnson, *ibid.* **106**, 1191 (1971); T. J. Chester, E. De Clercq, T. C. Merigan, *Infect. Immun.* **3**, 516 (1971); D. Collavo, B. Finco, L. Chieco-Bianchi, *Nat. New Biol.* **239**, 154 (1972).
50. H. M. Friedman, A. G. Johnson, P. Pan, *Proc. Soc. Exp. Biol. Med.* **132**, 916 (1969); J. H. Dean, W. C. Wallen, D. O. Lucas, *Nat. New Biol.* **237**, 218 (1972); T. A. McNeill, *Immunology* **21**, 741 (1971).
51. D. Waddell, T. C. Merigan, J. Wilbur, S. Walker, *Clin. Res.* **5**, 312 (1967).
52. R. E. Cone and A. G. Johnson, *J. Exp. Med.* **133**, 665 (1971); *Cell Immunol.* **3**, 283 (1972); B. N. Jaroslow and L. Oritz-Oritz, *ibid* **3**, 123 (1972).
53. K. Y. Huang, R. M. Donahue, F. B. Gordon, H. B. Dressler, *Infect. Immunol.* **4**, 581 (1971).
54. E. De Clercq and W. E. Stewart II, in *Selective Inhibitors of Viral Functions*, W. A. Carter, Ed. (Chemical Rubber Co., Cleveland, 1973), p. 81.
55. W. E. Stewart II, in *Selective Inhibitors of Viral Functions*, W. A. Carter, Ed. (Chemical Rubber Co., Cleveland, 1973), p. 1.
56. D. C. Dumonde, R. A. Wolstencroft, G. S. Panayi, M. Mathew, J. Morley, W. T. Howson, *Nature (Lond.)* **224**, 38 (1969).
57. M. C. Raff, *ibid.* **242**, 19 (1973).
58. G. A. Granger, *Ser. Haematol.* **5**, 8 (1972).
59. W. A. Carter, J. S. Horoszewicz, P. O. P. Ts'o, in preparation.
60. D. Baltimore, *Bacteriol. Rev.* **35**, 235 (1971); *Trans, N.Y. Acad. Sci.* **173**, 327 (1971); W. H Mitchell, in *Selective Inhibitors of Viral Functions*, W. A. Carter, Ed. (Chemical Rubber Co., Cleveland, 1973), p. 60.
61. We happily acknowledge the insight of Dr. Eugene Sulkowski whose comments sharpened the definition of a number of our ideas. Professor P. De Somer and Drs. A. Bardbourne and W. E. Stewart II also gave constructive review. The research of W.A.C. cited here was supported by NIH grant A1-11292-07; by a Center grant in Viral Chemotherapy (CO 14801-01); by the Jane Coffin Childs Fund for Medical Research (286); and, in part, by contract NO1-CM33726 with the Chemotherapy Branch, National Cancer Institute. E.DeC. was supported by a grant from the Belgian Fonds voor Geneeskundig Wetenschappelyk Onderzoek

Health Care and Education: On the Threshold of Space

Audio and video satellite communications are being used experimentally for health care and education in Alaska.

Albert Feiner

It is not universally agreed that there is an absolute shortage of physicians, but it is so agreed that there exists a maldistribution of medical services that leaves many millions of Americans with minimal or no primary health care. The problem must be attacked from two directions if the situation is to be alleviated: physicians must be trained so that their undergraduate and postgraduate experiences will be rooted in rural America, and acceptable substitutes must be found for the physical presence of highly qualified physicians and teachers of medicine. The Department of Health, Education, and Welfare (HEW) has examined both approaches to the problem and recently, at the Lister Hill National Center for Biomedical Communications, a part of the National Library of Medicine, scientists have been exploring the possibility of using advanced telecommunications techniques to deliver health care and medical education to populations where these commodities are scarce.

Mr. Feiner is director of technology evaluation and management at Practical Concepts Inc., 1030 15th Street, NW, Washington, D.C. 20005. He was formerly director of the Lister Hill National Center for Biomedical Communications, National Library of Medicine, Bethesda, Maryland.

The ATS-1 Medical Network

Since 1971, the Advanced Technology Satellite (ATS-1) launched by the National Aeronautics and Space Administration (NASA) has been used in a program for delivering health care to rural populations in Alaska (*1*). The Tanana Service Unit in central Alaska an area about the size of Texas, was chosen as the first experimental site because of the nature of the terrain and climate and because the Indian Health Service, a sister organization at HEW, has responsibility for the well-being of all Alaskan Indians. The majority of the native population is scattered in some 200 villages over the length and breadth of the state. Seven health service units, each with a service unit hospital, serve these villages. The major hospital to which patients are referred is located in Anchorage. Primary health care in the villages is administered by a community health aide who has received up to 16 weeks of training by the Public Health Service (PHS). The health aide's tools are a basic drug kit, a manual, and a high-frequency (hf) radio that may be used to contact a PHS physician on a daily schedule and in times of emergency. The hf radio is plagued by ionospheric interference that causes periods of "blackout" (no communications) which can last for days. This unreliability has caused much stress among patients as well as health aides and has resulted in very infrequent use of the radio.

Earth stations for satellite communications have been installed in some 26 villages, most of them in the Tanana District. The ATS-1 communication satellite (Fig. 1) is used to relay voice consultation between health aides and the PHS physicians at Tanana. A single simplex narrow-band channel is used, which means that only one person at a time may talk. The phased antenna array, located at the bottom of the satellite, coupled with its solid state transmitter, provides about 200 watts of effective radiated power at very high frequencies. The signals are received on the ground by a helical antenna located at the residence of the community health aide.

When the satellite communication system had been in operation for 1 year, results of the program were analyzed (*2*). Villages with satellite communication stations showed a 400 percent increase in radio contacts compared to those same villages (and to villages not included in the program) prior to the installation of the earth stations, a difference which is statistically significant despite the fact that only 13 villages were involved in the analysis. As would be expected, the number of satellite-conducted discussions with physicians increased correspondingly. Although this increase does not in itself guarantee that better health care was provided, both health aides and doctors were convinced that the quality of care did improve.

In this same area of Alaska a number of experimental educational programs have also been initiated. A lecture has been transmitted from the medical school at the University of Washington, Seattle, to medical students in basic genetics at the University of Alaska; approximately 22 nurses in small clinics throughout Alaska regularly "attended" a 3-month course on coronary care; and the National Education Association has sponsored a three-credit course by the University of Alaska for teachers in rural areas of Alaska.

The ATS-6 Satellite and Goals of Current Experiments

Because the experiments with the ATS-1 satellite have been so successful, the Health Resources Administration and the Health Services Administration are now cooperating with the Lister Hill National Center for Biomedical Communications to sponsor two advanced series of experiments with the ATS-6 satellite (designated ATS-F before it went into orbit) that was launched at the end of May 1974 (*3, 4*). In these experiments the advantages of wide-band communication services such as video consultation are being explored. The key characteristics of the ATS-6 satellite (*4*) are compared with those of ATS-1 (*5*) in Table 1. In ATS-6, the available bandwidth has been increased by more than two orders of magnitude, while the effective isotropic radiated power has been increased by three orders of magnitude. Another advantage of ATS-6 is its operating frequency, which has been raised from 140 to 2500 megahertz, a frequency considerably less susceptible to ionospheric disturbances. Figure 2 shows the ATS-6 and gives an idea of its large size.

Table 1. A comparison of the ATS-1 and ATS-6 satellites. In designing the earth stations for these satellites, one of the primary objectives was to make the hardware simple and inexpensive.

Characteristic	ATS-1	ATS-6
Frequency (Mhz)	140	2,500
Bandwidth (Mhz)	0.1	30
Power (watts)	200	200,000
Coverage	Whole earth	Restricted
Communication capability	Audio and data	Video, audio, and data

Before I discuss the details of the actual experiments now being conducted, it would be well to explain briefly why these experiments are being performed and the promise they hold for alleviating some pressing health problems.

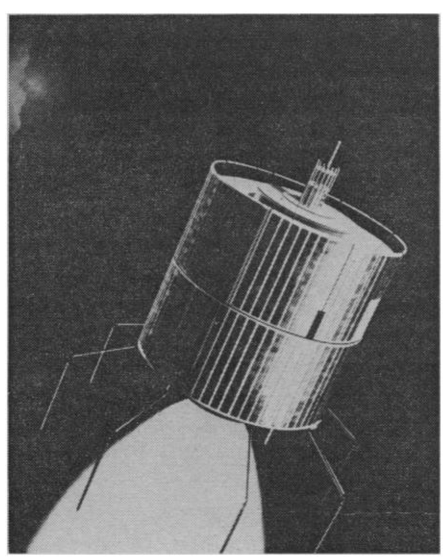

Fig. 1. The ATS-1 communication satellite. Protruding from the bottom of the satellite are antenna elements whose radiations are phased so that the energy is concentrated toward the earth as the satellite spins about its axis.

The Indian Health Service operates a number of programs designed to provide better health care to populations living in the more remote areas of the United States. Local health aides and paramedical personnel are sent in to these areas and, to compensate for their somewhat limited training, they are given the support of highly trained physicians who are located in more populated areas and who consult with the paraprofessionals by radio. While such voice consultation enhances the paraprofessional's abilities, in many instances the physician does not receive enough information to enable him to provide complete instructions for the care of a patient's problems. Medical decisions must often, therefore, be delayed until the status of the patient changes, or the patient must be transported to a hospital or medical center. Transportation to a medical facility is not only costly, but it may also cause trauma or family hardship; it might frequently be avoided if the physician had adequate information.

Telemedicine, under controlled conditions, has been demonstrated to be an effective tool for providing the additional information required by physicians giving support to paramedical personnel (*6*). The ATS-6 satellite will provide the opportunity for testing the new technologies in an environment where remoteness and harsh climate have a major effect on communication and transportation, and it will therefore have a much greater impact on the delivery of health care. Information will be gathered on the effectiveness of sophisticated technological support for minimally trained paraprofessionals and on the ability of these people to use the technology effectively and with confidence (*7*).

The effectiveness of several configurations of health professionals and technology will be compared. At Fort

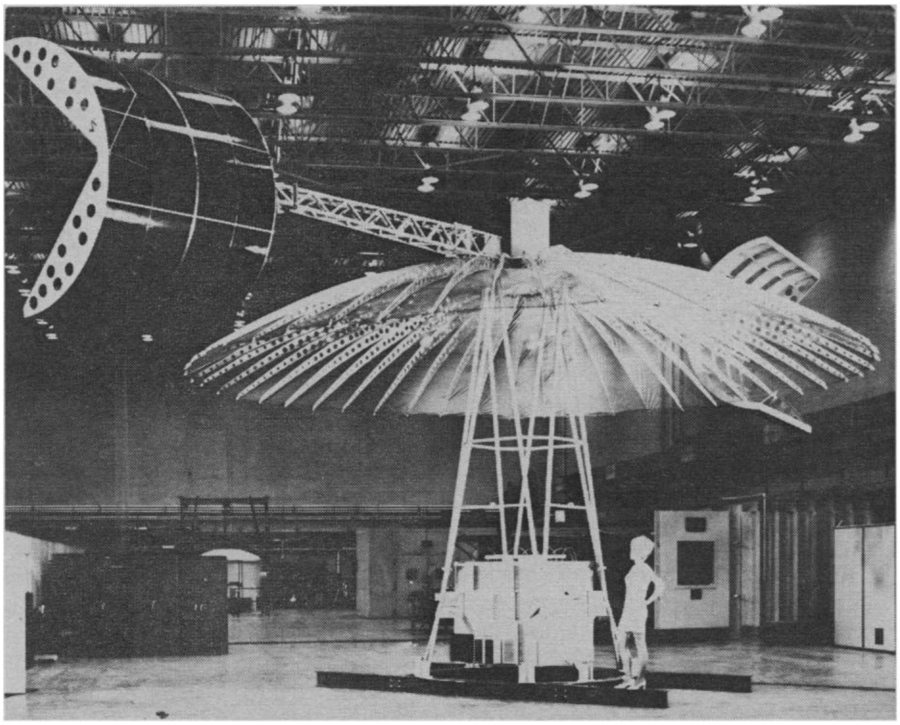

Fig. 2. The ATS-F communication satellite before launching. After its successful launching in May 1974, it became known as ATS-6 (*4*). At the top are the two solar panels (at the ends of the metal booms) which supply energy to the electronics (15.7 m tip to tip). Below the booms is the 9.1-m parabolic reflector antenna which receives signals from earth stations and also retransmits signals to the earth. At the bottom is the box which contains the antenna feeds (on top), electronics, and satellite stabilizing gyros.

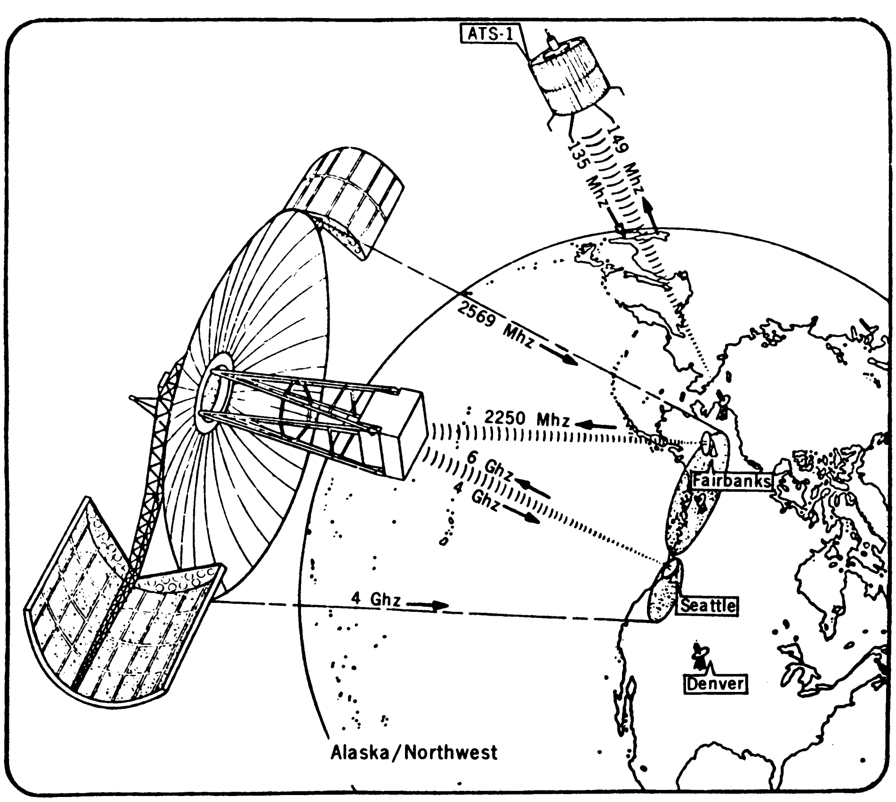

Fig. 3. Coverage provided by the ATS-1 and ATS-6 satellites. The ATS-1 satellite can relay signals to or from anywhere on the North American continent; ATS-6 coverage is restricted to the shaded areas (footprints). The larger footprint represents the S-band coverage and includes the panhandle and central regions of Alaska. The smaller footprint represents the C-band coverage which includes Omak and Seattle, Washington.

Yukon a registered nurse will consult with physicians at the Tanana Health Service Unit Hospital by video and audio communication. Telemetry—for example, electrocardiograms—can be sent at the physician's request and current patient medical records made available at both sites to assist in diagnosis and formulation of the treatment plan. At the clinic in Galena a health aide, or other professional, will have the same technological support as the registered nurse at Fort Yukon. In still another setting, a health aide will have access only to audio consultation with the physician and to medical record information.

The Indian Health Service has stated that the purpose of these experiments will be to gather data to help test the following hypotheses concerning the improvement of patient care. Telemedicine, when used in conjunction with a good medical record system [in this instance the Indian Health Service's Health Information System (HIS)], will (i) affect patient movement in such a way that only those patients requiring physician services will be transported to hospitals while those retained in the villages will still receive adequate treatment; (ii) enable treatment of problems to begin at a lesser degree of severity; (iii) reduce the average time between detection and treatment of a problem; (iv) reduce the percentage of patients lost to diagnostic, therapeutic, or follow-up programs; (v) reduce the number of visits by specialists to remote villages; (vi) provide, by means of educational programming, a better understanding of health, health care, and the health delivery system among the native population; and (vii) enable patients to receive higher levels of consultation than would otherwise be possible and will in this way increase the sense of security of the native population.

Telemedicine as a substitute for the physical presence of a physician represents one aspect of alleviating the problem of delivering good health care to people in rural areas. However, it is also desirable to train physicians in the rural areas where they are needed, because studies have shown that where a physician receives his education has a major influence on where he will choose to set up practice (*8*). In the northwestern United States, Wyoming, Alaska, Montana, and Idaho do not have a medical school within their borders. For several years, in a program sponsored by the Health Resources Administration at the University of Washington, Seattle, attempts have been made to expand medical education into those states that have no medical school. Known as WAMI, an acronym obtained by taking the first letters of the states of Washington, Alaska, Montana, and Idaho, this program is designed to test the feasibility of providing young, aspiring physicians in the states without medical schools an opportunity to study medicine equal to that of their peers in other states (*9*).

In the ATS-6 experiments, the teaching staff at the University of Washington School of Medicine in Seattle will be communicating with students and teachers at the University of Alaska in Fairbanks. Curriculum experiments will be conducted, and studies will be made of administrative conferencing (for example, joint development of curriculum via video and audio interaction, interviewing applicants for admission to the University of Washington School of Medicine by faculty at both the remote and on-campus sites), and of computer-aided evaluation of student performance.

In relation to basic science education, attempts will be made to determine the following: (i) whether satellite-mediated teaching is academically effective, is acceptable to students and local and peripheral faculties, evokes meaningful student-faculty interactions, is effective in reducing the sense of isolation experienced by students and peripheral faculty, and assists local and peripheral faculty in clarifying educational objectives. (ii) In the computer-aided evaluation of student performance, will the satellite communication system facilitate the expansion and standardization of selected areas of the curriculum at the peripheral institutions, and will the accessibility and reliability of the system be sufficient to permit effective student interaction and faculty evaluation of progress made in specified areas of learning?

In studies of undergraduate clinical education and of continuing medical education, faculty at the University of Washington and students in clerkships under the tutelage of clinicians at Omak, Washington, will participate. Students will make case presentations, and these will be followed by conferences and critiques. Case presentations concerning patients requiring specialist intervention will also be made by Omak clinicians.

Attempts will be made to determine whether the students will gain meaningful experience from preparing formal cases and presenting them by way of satellite communication for analysis and critique; and whether such a system will permit adequate evaluation of the students' knowledge and progress in the care of patients. The experiments will also indicate whether case presentations via satellite are able to enhance the practitioners' ability to provide service, and whether the communication system can contribute materially to the continuing education of the participating faculty.

Technical Requirements for ATS-6 and Network Coordination

It was early in 1972 that the health agencies of HEW joined with the Office of Education to participate in the satellite communication experiments. The design of the experiments was in large part dictated by the coverage that the ATS-F satellite would provide when launched (*4*). To achieve the very high power densities required for operation with small earth stations, the power of the satellite transmitters is concentrated by means of a 9.1-meter antenna. This results in the ground coverage being restricted to a small area or "footprint." In fact, two elements of the satellite's S-band feed array are used to provide two 1° footprints which, when the satellite is pointed at the southwestern United States, cover almost the entire height of the country. NASA modified the ATS-F repeater and installed two 15-watt solid state transmitters to provide coverage in two footprints simultaneously. This permits TASO I quality television (no noise discernible in the picture) to be received by earth stations with antennas as small as 2.1 m. The operating center frequencies of the two spot beams are 2566.7 and 2667.5 Mhz. The bandwidth provided is 30 Mhz at each frequency.

Both health care delivery and medical education experiments must take

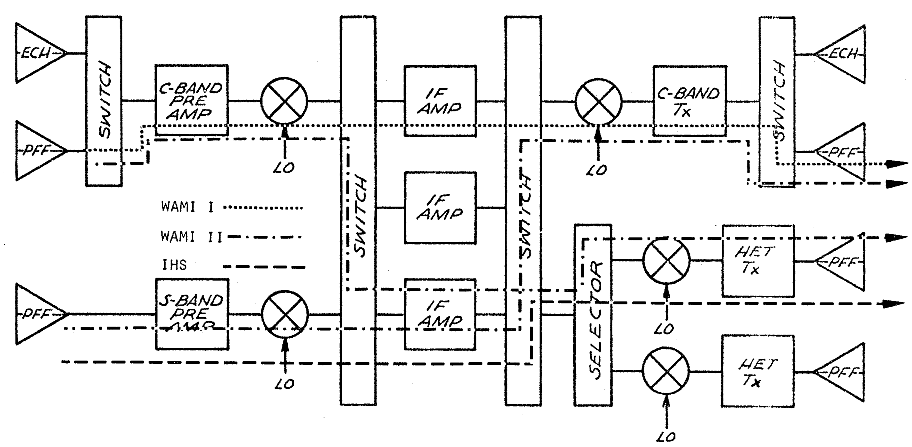

Fig. 4. Block diagram of the repeater configuration (signal flow) for the health experiments. Dotted lines indicate the flow for WAMI-I (undergraduate and continuing medical education); dots and dashes represent the flow for WAMI-II (basic science instruction); and dashed lines show the signal path for the Indian Health Service health care delivery experiment. The ATS-6 satellite will accept (left) both S-band and C-band signals. The S-band signals are received on an element of the primary focus feed (PFF) associated with the 9.1-m antenna. C-band signals can be received either on a PFF element or in the earth coverage horn (ECH). The repeater configuration can be commanded from the ground to route any input to any output or any combination simultaneously. The exception is that the C-band (4 Ghz) transmitter (right) cannot feed both C-band PFF and ECH simultaneously. In the Indian Health Service health care delivery experiment the signals are received at S-band on an element of the PFF, are amplified, mixed with the local oscillator (LO) and brought down to an appropriate intermediate frequency (IF), translated up to 2566.7 Mhz, and retransmitted into the same S-band footprint. The basic sciences portion of the education experiments can be two-way interactive involving both C-band and S-band paths (WAMI-II). Video, audio, and other signals originating from the students and faculty at the University of Alaska are received on the narrow-beam PFF (S-band), brought down to a suitable intermediate frequency, and switched to the C-band transmitter where they are radiated at 4 Ghz via the 9.1-m antenna to faculty at the University of Washington. Simultaneously, video, audio, and the other signals originating from Seattle are received on the narrow-beam PFF (C-band), brought down to intermediate frequency, switched over to the S-band transmitter, and radiated at 2566.7 Mhz via the 9.1-m dish to students and faculty at Fairbanks. For undergraduate clinical and continuing medical education, all interactions take place within the single narrow-beam C-band footprint. Signal flow is simply into the satellite 6-Ghz PFF and out the 4-Ghz PFF (WAMI-I).

place in real time. Visual as well as audio interactions are conducted between students and faculty and physicians and other health professionals. Video and audio signals are transmitted from all participating sites (except the medical center at Anchorage) from one small earth station (3-m antenna) directly to the other small earth stations. It was recommended by NASA that the signals from the ground to the satellite (uplink) be centered at 2247.5 Mhz, because the ATS-F satellite was already equipped to receive at this frequency for another experiment involving the relay of signals from low-orbiting satellites. This frequency presented problems because it is located in a band assigned for military use. Through the cooperation of the Office of Telecommunications Policy, the Executive Office of the President, the Department of Defense, and other members of the Intragovernmental Radio Advisory Committee a compromise was worked out. For the duration of the ATS-6 experiments, July 1974 through June 1975, the earth stations in Alaska will be permitted to transmit at 2247.5 Mhz on a noninterfering basis with the military services, and the two earth stations in Washington, Seattle and Omak, will use the commercial bands at 6 and 4 gigahertz. This unusual arrangement resulted in an unexpected dividend permitting simultaneous two-way television interactions between Seattle and Fairbanks for the basic science portion of the medical education experiment (Fig. 3).

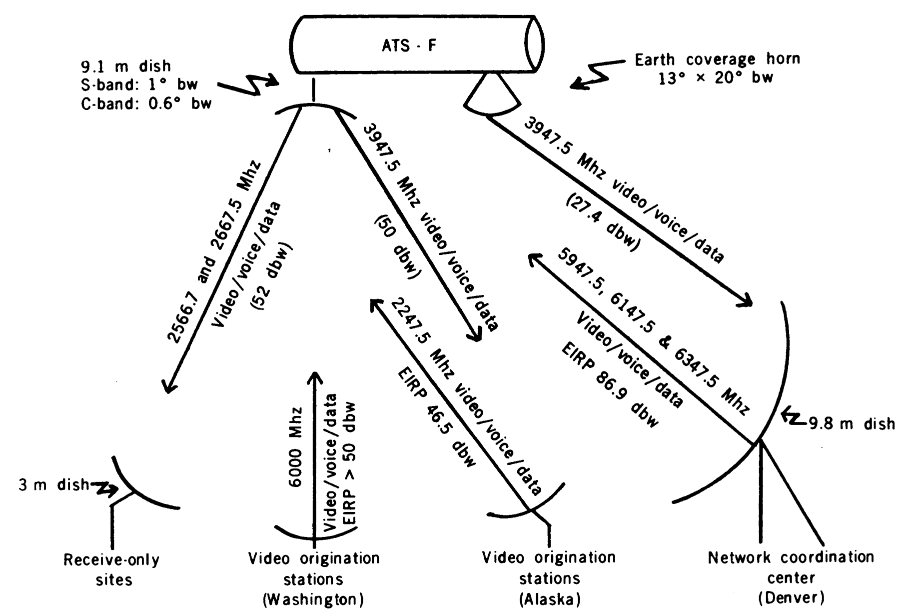

Fig. 5. The ATS-6 network for the health care delivery and education experiments; bw, beamwidth; dbw, decibels relative to 1 watt; EIRP, effective isotropic radiated power.

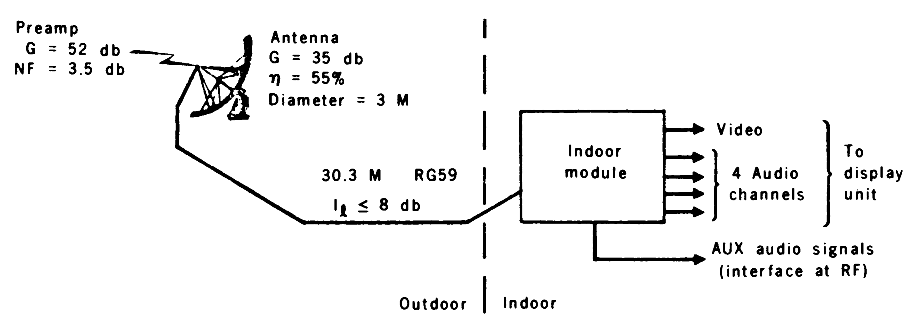

Fig. 6. Block diagram of "receive-only" station; G, gain; NF, noise figure; η, efficiency; I_l, insertion loss.

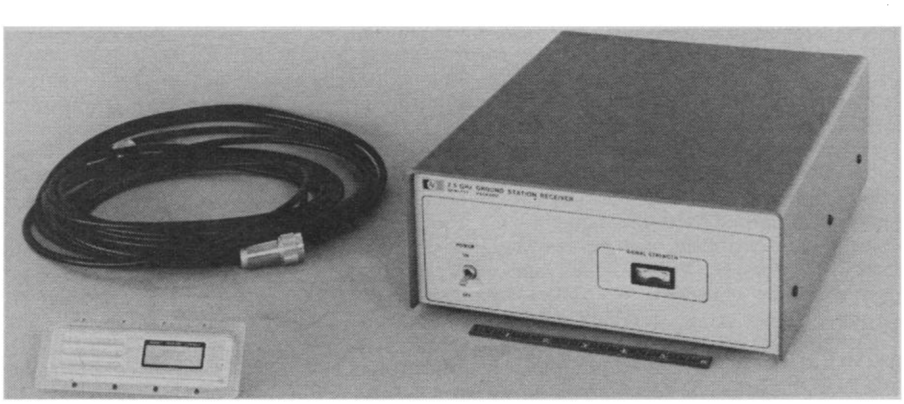

Fig. 7. The receiving equipment for a "receive-only" station. The unit on the left is mounted on the antenna, and the indoor unit is shown on the right. No operator adjustments are permitted on the antenna-mounted electronics, and only an on-off switch for power is provided on the indoor unit. A simple meter indicates to the health personnel whether the unit is working or not.

The satellite S-band transmission frequency is at 2566.7 Mhz, which is the lower of the two available frequencies. To prevent failure of a transmitter from causing loss of critical coverage, either transmitter can be switched to either footprint. The resulting frequency change can be accommodated in the earth station receiving equipment. The smaller footprint, which represents the 4-Ghz coverage, is also obtained by using the 9.1-m parabola. The ATS-1 provides full earth coverage and is used in conjunction with the ATS-6. Figure 4 shows an abbreviated block diagram of the repeater configuration to be used for the health and education experiments.

To coordinate the variety of health and education experiments, HEW established an ATS-F User Policy Committee which is chaired by the director of the Office of Telecommunications Policy of HEW, and includes representatives from all the participating organizations. All the representatives maintained that the technology should support high-priority objectives and that the health professionals in the field should require no on-site assistance to operate the system. None of the "operators," from health aides to physicians and teachers, would have had experience with this kind of technology. Therefore, at the request of NASA, all experiments were to be coordinated from "operational day 1" by a single entity that was also to be the sole interface with NASA. The experiments are now being coordinated (this includes positive control of all transmitters) at a Network Coordination Center (NCC) located at Denver and managed by the Federation of Rocky Mountain States (the NASA interface) under contract to HEW. Schedule changes, preemption, individual station performance monitoring, and reporting are some of the functions assigned to the NCC.

The network, which began operation in July of this year, consists of the complement of capabilities and associated hardware for ATS-6 operation depicted graphically in Fig. 5. All the earth stations but one are "comprehensive stations," that is, they are capable of receiving and originating video, voice, and data via the ATS-6 and ATS-1 satellites. The Alaska Native Medical Center at Anchorage has almost all of the capabilities of the others, but cannot initiate video transmissions; this we call an "intensive station." For education experiments other than health education there are "intensive stations" and a number of "receive-only stations" where video and voice transmissions from the ATS-6 will be monitored. The NCC at Denver receives and monitors transmissions of all experiments, regardless of the direction of the ATS-6 transmissions. This is accomplished by using a large ground-based antenna (9.8 m) and by working through the satellite's earth coverage horn. The single exception, noted previously, occurs when the earth stations at Omak and Seattle are in operation. There is a single C-band transmitter aboard ATS-6 and when it is operating in the narrow-beam mode, no signals are transmitted from the earth coverage horn.

Table 2. Characteristics of the video receivers that are used at receive-only, intensive, and comprehensive stations; db, decibels; PK, peak.

Characteristic	Measurement
	Antenna unit
Noise figure	< 4.2 db (3.5 db is desired)
3-db bandwidth	2600 ± 150 Mhz
Gain	56 db, nominal
Flatness	± 0.5 db at 2566.7 ± 12.5 Mhz; ± 0.5 db at 2667.5 ± 12.5 Mhz
	Indoor unit
Center frequency (selectable)	2566.7 or 2667.5 Mhz
3-db bandwidth	24.5 Mhz
Input power range	—45 to —25 db
Video	
Output	1 to 1.3 volts PK to PK ± 0.75 db; 10 hertz to 4.2 Mhz
Difference gain and phase	< 8 percent and 5°
Energy dispersal	30 hertz triangular; 1 Mhz PK to PK
Audio	
Subcarriers	4.66, 4.83, 5.06, 5.36 Mhz
Output	0 ± 3 db, 30 hertz to 10 khz
Distortion	< 5 percent at 1 khz

Health Care Delivery Experiments

The individual experiments are being conducted within the network context and there is almost no intervention from the NCC. The Indian Health Service's health care delivery experiment is being conducted with five earth stations. The small clinics at Fort Yukon (population 630) and Galena (population 425) are comprehensive stations, the examining rooms being outfitted with television equipment and capable of transmitting and receiving video and audio signals as well as physiological data. Health professionals (aides or paramedical personnel) present patients to the viewing physicans at the PHS Hospital in Tanana. This station is also a comprehensive one. Medical specialists in Fairbanks and at the Alaska Native Medical Center in Anchorage are available for consultation. Fairbanks is a comprehensive medical station, but the Alaska Native Medical Center is an intensive station and is not capable of originating video, although patients can be "seen" there. All sites can receive information about medical records via the ATS-1 satellite. Medical records of patients are retrieved from the Indian Health Service's data bank in Tucson, Arizona.

The health care system is operated as follows: Tanana physicians contact villages and clinics via ATS-1 to discuss medical problems with the health professionals in the same way that they had been doing for the past 2 years. Patients in the clinics who might benefit from visual consultation are scheduled for video time with the ATS-6 satellite. Emergencies may preempt scheduled video consultations. Patients are visually presented at comprehensive medical stations and appropriate management is recommended by the Tanana physician. Specialists in Fairbanks and Anchorage are consulted if necessary. During the presentation of a patient, physiological information, such as that obtained by an electrocardiograph, may be sent simultaneously via any or all of the four aural channels associated with the television picture. Talk-back from the Tanana physician or other specialists to the presenting clinics is accomplished via ATS-1 since simultaneous two-way transmission through ATS-6 is not possible in this mode. If the physician at Tanana deems it appropriate, he can terminate video transmission from the clinic and assign the ATS-6 channel to Fairbanks or use it himself to demonstrate some technique that would help

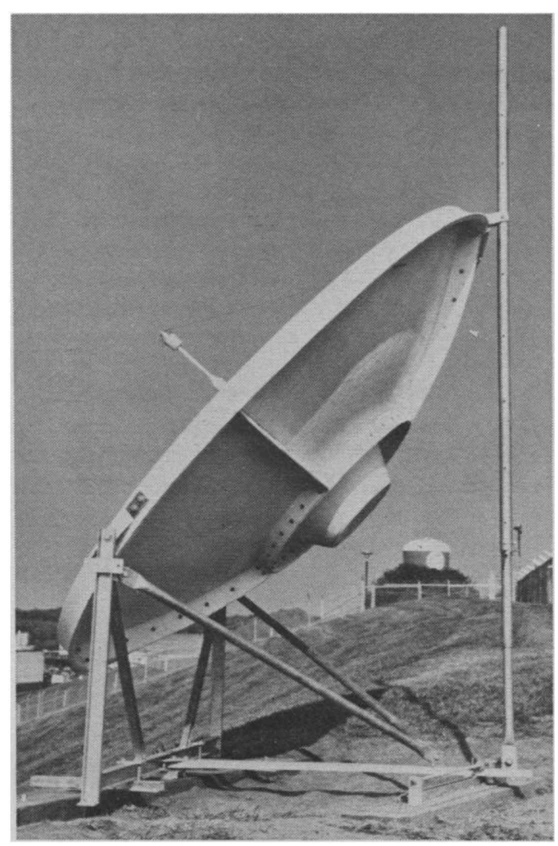

Fig. 8. Antenna for receiving signals transmitted by the ATS-16 satellite. [Courtesy of Westinghouse Electric Corporation]

the health professionals at the clinics to better manage their patients. During this period, the clinic talk-back mode is via the ATS-1. Upon termination of a consultation, the attending health professionals prepare a report to be mailed to Tucson where it is used to update the stored medical records. In the interest of privacy, the video and audio signals associated with all consultations are scrambled. Only the presenting clinic and consulting staffs are able to unscramble the information. The signal path through the ATS-6 repeater is shown as a dashed line in Fig. 4. All interactions for this experiment take place in Alaska. Three hours per week of video (ATS-6) communications and 3 to 4 hours per day of audio and data communications (ATS-1) are available.

Medical Education Experiments

Two aspects of medical education are being investigated: basic science instruction, and undergraduate clinical education and continuing medical education. Students and peripheral faculty at Fairbanks, Alaska, and local faculty at the University of Washington, Seattle, are participating in the basic science program. Because both S-band and C-band portions of the satellite repeater can be activated simultaneously, it will be possible to compare the advantages of using one-way television and voice talk-back interaction with those of using simultaneous two-way television interaction.

For the studies of undergraduate clinical education, third and fourth year medical students at remote sites receive local instruction from clinicians at Omak and television instruction from the medical faculty at Seattle. Students are required to give both formal, prepared presentations of patients and spontaneous presentations of new patients. The former presentations are of complex cases prepared in detail over a period of time. The latter presentations are followed by verbal discussions of the history and physical condition of the patients, the results obtained by laboratory analyses, and diagnostic impressions and tentative treatment plans. In addition to student presentations, the clinical faculty at Omak can make presentations of selected patients from Omak. Difficult cases can be discussed with specialists in Seattle who can confer with them by video and audio communication. Both clinicians and students then make decisions on patient care based on the consultative input. If desired, the patient can also interact. Signal flows to and from the ATS-6 satellite are shown for both the medical and education experiments in Fig. 4.

Satellite Earth Stations

The ATS-6 earth stations were specifically designed to meet the needs of both the health and education programs. The ATS-6 User Policy Committee established the types of characteristics of terminals to be developed and detailed specifications were written jointly by the Lister Hill National Center for Biomedical Communications, NASA, and the Federation of Rocky Mountain States. It was realized from the outset that the stations should be designed so that they could be operated solely by the health professionals and teachers without the help of on-site technicians. The system would be far too costly if each earth station had to have a full-time technician. A building-block approach was used so the receive-only, intensive, and comprehensive stations could be assembled from a relatively few low-cost components. The hardware is (i) solid state throughout; (ii) has no high voltages; (iii) has relatively few circuit boards, so that first-level maintenance will consist of plugging in boards until the defective one is found; (iv) has very few switches and adjustments; and (v) has simple go, no-go indicators for critical voltages and signal levels, for example.

The simplest stations, those for receive-only, are equipped with an antenna, a simple mount with restricted motion in two planes, a dish-mounted,

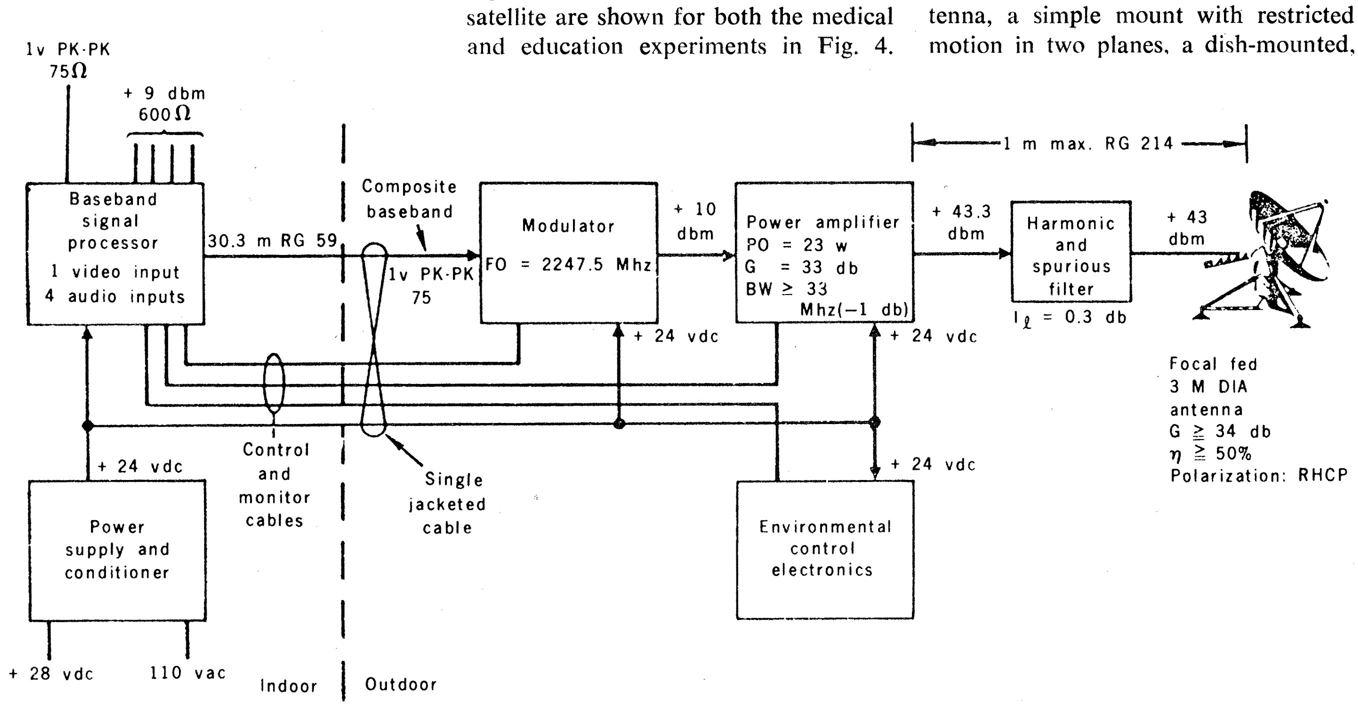

Fig. 9. Block diagram of a transmit-only station for use at comprehensive stations. The indoor unit accepts a television baseband signal and up to four audio-channel bandwidth signals, provides four subcarriers to be frequency modulated by the four aural bandwidth channels, and sums them with the video signal to provide a composite baseband signal. The composite baseband signal is fed to the antenna-mounted unit where it is modulated onto the radio-frequency carrier and amplified in a transistor power amplifier. The amplified signal is filtered and goes to the antenna feed for transmission to ATS-6; PK-PK, peak to peak; dbm, decibels relative to 1 milliwatt: vdc, volts direct current; vac, volts alternating current; Ω, ohms; FO, frequency output; PO, power output; BW, bandwidth; RHCP, right-hand circular polarization.

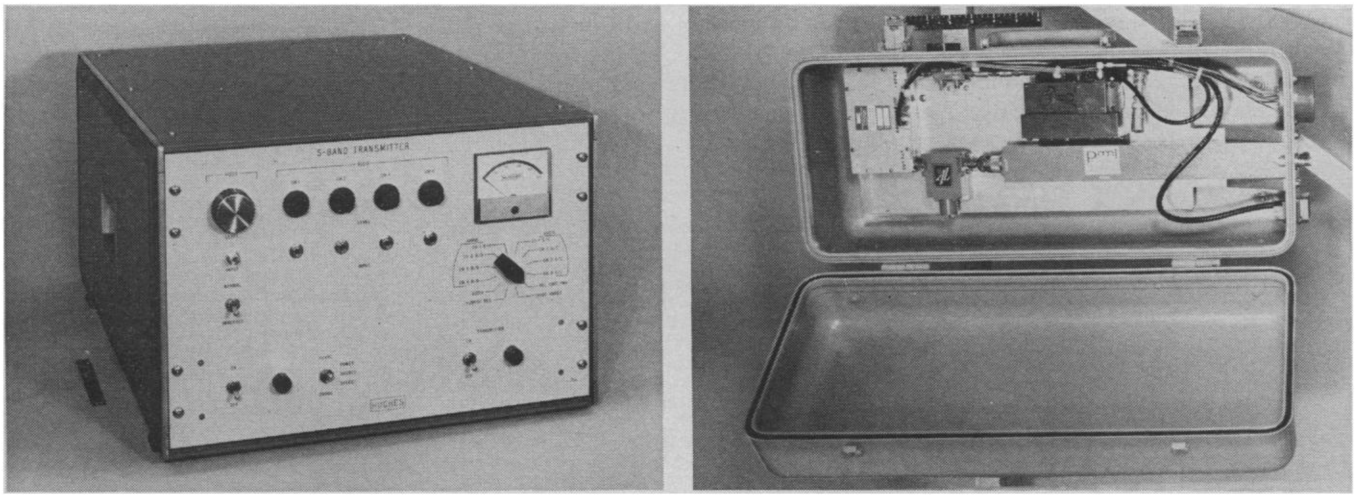

Fig. 10. The indoor electronics unit (left) and the outdoor antenna-mounted unit (right) for transmitting signals to the ATS-6 satellite.

low-noise radio-frequency amplifier, and an indoor unit containing the demodulator. The receiver output consists of one video plus four audio channels (Fig. 6). The four audio channels are used for voice, physiological information, or data such as that for the computer-aided evaluation program. The antenna and mount are produced by Prodelein, the solid state electronics by Hewlett-Packard, and the system integrator is the Westinghouse Electric Corporation (*10*). Some 150 such receive-only stations have been produced by Westinghouse. The receiving equipment is shown in Fig. 7 and other data are given in Table 2.

The antenna (Fig. 8) is a fiber glass dish which comes in four large segments and a central hub. The primary focus feed (seen at the left of the dish) receives the energy which has been transmitted from ATS-6 and concentrated by the dish. It is a helix mounted at the end of a transmission line guyed to the parabola at four points. The mount consists basically of simple-angle and tubular metal structures. To allow for coarse changes that may have to be made in the angle of elevation, depending on the orientation of the satellite's antennas, the top of the antenna can be bolted to any of the holes in the vertical tube. Each hole shown represents a change of 10°. Fine adjustments over 15° range are made by the hand crank which screws the central portion of the vertical tube along a threaded portion of the lowest section which is bolted at its base. Adjustment in the *x*-axis (azimuth), required only at installation, is accomplished by rotating the entire structure about a bolt through the center of the base between the two forward uprights supporting the dish. Mounts to be used in Alaska for health experiments will be motorized because it is not deemed practical, or desirable, to have health personnel going out in the bitter cold of winter. Although during an experimental interaction the antenna does not have to be moved, during the course of a year the direction of the antenna will have to be changed to compensate for the position of the satellite in its figure eight (motion viewed from a fixed location on the earth) as defined by the inclination of the orbit.

The intensive stations have the equipment for receive-only plus that for the VHF (very high frequency) transmit-receive station (*11*) now being used with the ATS-1 satellite. This enables the users to receive video and associated audio and data channels and to talk back using the audio and data channels of the VHF station.

The comprehensive stations have the same equipment as the intensive stations plus that for a transmit-only station; thus, the user can send as well as receive video, audio, and other signals. The comprehensive stations provide energy dispersal of the transmitted radio-frequency carrier in order to ensure that the satellite effective isotropic radiated power does not exceed the maximum power densities on the earth permitted by international agreement. The transmit-only station (Fig. 9) uses the same dish and mount as described previously. The electronics are manufactured by the Hughes Aircraft Company which is also the system integrator (*12*). The equipment includes an indoor and an outdoor unit. Key characteristics of this terminal are shown in Table 3. The indoor electronics unit is shown in Fig. 10 (left). Inputs for the video and four aural channels are provided on the front of the unit with associated

Table 3. Characteristics of a transmit-only station used at comprehensive stations; EIRP, effective isotropic radiated power; dbw, decibels relative to 1 watt; vac, volts alternating current; mph, miles per hour.

Characteristic	Measurement or particular
Transmission frequency	2247.5 Mhz
Instantaneous bandwidth	30 Mhz between 1-db points
Antenna diameter	10 feet
EIRP	≥ 46.5 dbw
Primary power	115 ± 10 vac, 50 to 60 hertz, or 28 ± 2 volts, battery
Antenna adjustment and accuracy	
Elevation	0° to 70° ± 0.5° accuracy
Azimuth	± 20°, ± 0.5° accuracy
Static pointing accuracy	≤ 0.1°, winds to 20 mph; ≤ 0.5°, winds to 60 mph; survive winds to 120 mph
Composite baseband	Video plus four audio subcarriers
Frequency stability (long term)	≤ 1 part in 10^3 per year
Signals	
Video	30 hertz to 4.2 Mhz
Audio	Four each 30 hertz to 10 khz
Audio subcarrier frequencies	4.66, 4.83, 5.06, 5.36 Mhz
Energy dispersal	30 hertz triangular, synchronous with frame frequency
Transportability	Small van
Installation	Two men, one work day

gain controls. A multiposition switch and easy-to-read meter constitute the means by which proper performance is ascertained. The antenna-mounted unit is shown in Fig. 10 (right). The transmitter consists of four power transistors in parallel. The largest element in the box is the filter for suppression of spurious and harmonic signals. Anything that is wrong with the transmitted signal can be detected by the NCC at Denver and the sender notified or, in extreme cases, the transmitter turned off by the NCC.

Conclusion

The studies described herein represent some of the most sophisticated social and technical experiments ever attempted in education and health care delivery. It is hoped that the lessons learned from them will bring us much closer to the goal of providing good quality health care and education in areas that are away from metropolitan centers.

References and Notes

1. A. Feiner, "An experimental satellite medical network for scarcity areas," paper presented at the 8th Annual Meeting of the American Institute for Aeronautics and Astronautics, Washington, D.C., 28 October 1971.
2. H. E. Hudson and E. B. Parker, *N. Engl. J. Med.* **289**, 1351 (1973).
3. National Aeronautics and Space Administration, *The HEW-NASA Health-Education Telecommunications Experiment, Summary Description* (Goddard Space Flight Center, Greenbelt, Md., November 1973), pp. 11–18.
4. ———, *The ATS-F Data Book* (Goddard Space Flight Center, Greenbelt, Md., rev. ed., May 1974).
5. ———, *ATS-VHF Experiments Guide, Revision 1, ATS Project* (Goodard Space Flight Center, Greenbelt, Md., January 1972).
6. For example, see K. T. Bird and M. E. Kerrigan, "Telemedicine: A new health information exchange system," paper presented at the 1970 Medical Services Conference sponsored by the American Medical Association, Boston, Mass., 28 November 1970; R. L. H. Murphy, D. Barber, A. Broadhurst, K. T. Bird, *Am. Rev. Respir. Dis.* **102**, 771 (1970); J. Hayes, *Biomed. Commun.* **1**, 18, 48 (1973); B. K. Thorne, *Dartmouth Alumni Mag* (April 1973).
7. Indian Health Service, "Master Plan: ATS-F Alaska Health Service Experiment" (unpublished report, Indian Health Service, Washington, D.C., 1973).
8. J. Hadley, "Physician specialty and location decisions: A literature review," *Discuss. Pap. Ser. No. 10* (internal report prepared for the National Center for Health Services Research and Development, May 1973).
9. R. Kobernick, *Health Sci. Rev.* (University of Washington, Seattle, Summer 1973).
10. R. N. Smith, HEW/HET Receive-Only Terminal Systems Description, a report for use by ATS-F experimenters (Westinghouse Electric Corp., Baltimore, Md., June 1974).
11. D. S. Allen, "Medical Telecommunications Experiments for Alaska via Satellite" (a report prepared at Stanford University, 15 March 1973, under contract NIH 71-4718 with the Lister Hill National Center for Biomedical Communications).
12. Hughes Aircraft Company, "ATS-F S-band Transmitter Description," a report prepared under contract with the Department of Health, Education, and Welfare (Hughes Aircraft Company, Los Angeles, Calif., 1974).

NEWS AND COMMENT

Green Revolution (II): Problems of Adapting a Western Technology

The Green Revolution was conceived by its creators as a primarily technical intervention for increasing food production. Most critiques have focused on the economic impact of the Green Revolution practices (*Science*, 20 December, p. 1093), but the technical nature of the process has also come under strong, if less vociferous, questioning. The package of agricultural practices that constitute the Green Revolution is essentially a Western technology, and its problems—such as dependence on high energy inputs—are if anything more formidable in a Third World setting.

Probably the most serious aspect of the high yielding varieties (HYV's) is that they are genetically more uniform than the native strains they replace, and hence more vulnerable to epidemics. The semidwarf wheats developed at CIMMYT (the International Maize and Wheat Improvement Center in Mexico) are among the varieties that represent "extreme potential genetic vulnerability," says a committee of the National Academy of Sciences (NAS). In the first few years of the Green Revolution, large areas of cropland in India and Pakistan were sown to a few varieties of CIMMYT wheat. What was probably a quite serious risk at that time has been considerably diminished by the introduction of many new varieties of wheat. It is quite unlikely that a single strain of glume blotch, root rot, Karnal smut, or other disease that wheat is heir to would strike down all varieties simultaneously. The only way this could happen is if the dwarfing gene that all the HYV wheats have in common should have linked with it a gene conferring susceptibility to some pathogen. That this should be so is fairly improbable, except that it has already happened once. The epidemic of southern corn blight that destroyed a fifth of the U.S. crop in 1970 was caused by a genetic linkage of this nature. Damage from the southern corn blight was as limited as it was because of the skill and number of American plant breeders.

"If a thing like that should happen in places like India or Nigeria, it would really be a disaster," says J. M. de Wet of the Crops Evolution Laboratory at the University of Illinois. A serious responsibility devolves upon aid givers and promoters of the Green Revolution to see that local research institutions can cope with such a threat: "The outbreak of any major disease which wipes out the harvest of thousands of farmers is far more likely to be blamed on the producers and spreaders of the miracle seed than on Fate," observes Clifton R. Wharton, president of Michigan State University.

The Green Revolution strains are generally more vulnerable to pests than are traditional varieties. This is partly because of the practice—now largely abandoned—of transplanting HYV's developed in one area of the world to another, without first adapting them to local conditions. "It is futile to think that we in America or Mexico can sit down and put together a strain of cultivated crop that will be equally suitable all over the world," says de Wet: "Local farmers may have good results with it for one or two seasons, but then the introduced variety may become susceptible to disease or insect attack and people are no better off than they were before. The native varieties that have been successful for millennia have survived for very good reason."

The HYV's are also made more susceptible to pests by the recommended growing practices. Close planting, luxuriant foliage, and multiple cropping are all conducive to the buildup of insect pests. According to the NAS