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ATS-6 Final Engineering Performance Report

Volume IV - Television Experiments

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ATS-6 Final Engineering Performance Report

Volume IV - Television Experiments

Robert O. Wales, *Editor*
Goddard Space Flight Center
Greenbelt, Maryland

National Aeronautics and Space Administration

Scientific and Technical Information Branch

An Engineering Evaluation

in

Six Volumes

Volume I: Program and System Summaries; Mechanical and Thermal Details
- Part A: Program Summary
- Part B: Mechanical Subsystems
- Part C: Thermal Control and Contamination Monitor

Volume II: Orbit and Attitude Controls
- Part A: Attitude Control
- Part B: Pointing Experiments
- Part C: Spacecraft Propulsion
- Part D: Propulsion Experiment

Volume III: Telecommunications and Power
- Part A: Communications Subsystem
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- Part C: Telemetry and Command Subsystem
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Volume IV: Television Experiments
- Part A: The Department of Health, Education and Welfare Sponsored Experiments
- Part B: Satellite Instructional Television Experiment (India)
- Part C: Independent Television Experiments

Volume V: Propagation Experiments
- Part A: Experiments at 1550 MHz to 1650 MHz
- Part B: Experiments at 4 GHz to 6 GHz
- Part C: Experiments Above 10 GHz

Volume VI: Scientific Experiments

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FOREWORD

ATS-6 has been referred to as Arthur C. Clarke's "Star," because Mr. Clarke originated the idea for synchronous communications satellites in an article that he wrote in 1945. In 1975, Mr. Clarke was actively engaged in monitoring the Indian Satellite Instructional Television Experiment on ATS-6 and giving feedback to the Indian Space Research Organization. We, therefore, felt that it would be appropriate for him to contribute the foreword for this report.

An excerpt from his response to our request and selected paragraphs from his contribution, "Schoolmaster Satellite," follow.

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FROM THE DESK OF THE CHANCELLOR
UNIVERSITY OF MORATUWA, SRI LANKA

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Arthur C. Clarke
B.Sc., F.R.A.S., F.B.I.S.
Fellow of King's College, London.

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කේබල්: අන්ඩර්සී කොළඹ
Tel: 94255
Cable: Undersea Colombo

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කොළඹ 7.
"Leslie's House"
25, Barnes Place,
Colombo 7.

24th September 1980

The extracts that follow are from an essay that was written in 1971, almost five years before the SITE program became fully operational, and originally appeared in the *Daily Telegraph Colour Magazine* for 17 December 1971. It was later read into the *Congressional Record* (27 January 1972) by Representative William Anderson, first commander of the nuclear submarine *Nautilus*, and now forms Chapter 12 of *The View From Serendip* (Random House, 1977; Ballantine, 1978).

To me, it brings back vivid recollections of my meetings with Dr. Sarabhai, the chief instigator of the program. I would like to dedicate it to his memory – and to that of another good friend, also closely associated with the project – Dr. Wernher von Braun.

Arthur C. Clarke
Vikram Sarabhai Professor, Physical Research Laboratory, Ahmedabad
India

Chancellor
University of Moratuwa
Sri Lanka

"For thousands of years, men have sought their future in the starry sky. Now this old superstition has at last come true, for our destinies do indeed depend upon celestial bodies—those that we have created ourselves . . .

"In 1974 there will be a new Star of India; though it will not be visible to the naked eye, its influence will be greater than that of any zodiacal signs. It will be the satellite ATS-F (Applications Technology Satellite F), the latest in a very successful series launched by America's National Aeronautics and Space Administration. For one year, under an agreement signed on September 18, 1969, ATS-F will be loaned to the Indian Government by the United States, and will be "parked" 22,000 miles above the Equator, immediately to the south of the sub-continent. At this altitude it will complete one orbit every 24 hours and will therefore remain poised over the same spot on the turning Earth; in effect, therefore, India will have a TV tower 22,000 miles high, from which programmes can be received with almost equal strength over the entire country . . .

"ATS-F, now being built by the Fairchild-Hiller Corporation, represents the next step in the evolution of communications satellites. Its signals will be powerful enough to be picked up, not merely by multi-million dollar Earth stations, but by simple receivers, costing two or three hundred dollars, which all but the poorest communities can afford. This level of cost would open up the entire developing world to every type of electronic communication—not only TV; the emerging societies of Africa, Asia and South America could thus by-pass much of today's ground-based technology, and leap straight in to the space age. Many of them have already done something similar in the field of transportation, going from ox-cart to aeroplane with only a passing nod to roads and railways.

"It can be difficult for those from nations which have taken a century and a half to slog from semaphore to satellite to appreciate that a few hundred pounds in orbit can now replace the continent-wide networks of microwave towers, coaxial cables and ground transmitters that have been constructed during the last generation. And it is perhaps even more difficult, to those who think of television exclusively in terms of old Hollywood movies, giveaway contests and soap commercials to see any sense in spreading these boons to places which do not yet enjoy them. Almost any other use of the money, it might be argued, would be more beneficial . . .

"Those who actually live in the East, and know its problems, are in the best position to appreciate what cheap and high-quality communications could do to improve standards of living and reduce social inequalities. Illiteracy, ignorance and superstitution are not merely the results of poverty—they are part of its cause, forming a self-perpetuating system which has lasted for centuries, and which cannot be changed without fundamental advances in education. India is now beginning a Satellite Instructional Television Experiment (SITE) as a bold attempt to harness the technology of space for this task; if it succeeds, the implications for all developing nations will be enormous.

"Near Ahmedabad is the big 50-foot diameter parabolic dish of the Experimental Satellite Communication Ground Station through which the programmes will be beamed up to the hovering satellite. Also in this area is AMUL, the largest dairy co-operative in the world, to which more than a quarter of a million farmers belong. After we had finished filming at the big dish, our camera team drove out to the AMUL headquarters, and we accompanied the Chief Veterinary Officer on his rounds.

"At our first stop, we ran into a moving little drama that we could never have contrived deliberately, and which summed up half the problems of India in a single episode. A buffalo calf was dying, watched over by a tearful old lady who now saw most of her worldly wealth about to disappear. If she had called the vet a few days before—there was a telephone in the village for this very purpose—he could easily have saved the calf. But she had tried charms and magic first; they are not always ineffective, but antibiotics are rather more reliable . . .

"I will not quickly forget the haggard, tear-streaked face of that old lady in Gujerat; yet her example could be multiplied a million times. The loss of real wealth throughout India because of ignorance or superstition must be staggering. If it saved only a few calves per year, or increased productivity only a few per cent, the TV set in the village square would quickly pay for itself. The very capable men who run AMUL realise this; they are so impressed by the possibilities of TV education that they plan to build their own station to broadcast to their quarter of a million farmers. They have the money, and they cannot wait for the satellite—though it will reach an audience two thousand times larger, for over 500 million people will lie within range of ATS-F . . .

"And those who are unimpressed by mere dollars should also consider the human aspect—as demonstrated by the great East Pakistan cyclone of 1971. That was tracked by the weather satellites—but the warning network that might have saved several hundred thousand lives did not exist. Such tragedies will be impossible in a world of efficient space communications.

"Yet it is the quality, not the quantity, of life that really matters. Men need information, news, mental stimulus, entertainment. For the first time in 5,000 years, a technology now exists which can halt and perhaps even reserve the flow from the country to the city. The social implications of this are profound; already, the Canadian Government has discovered that it has to launch a satellite so that it can develop the Arctic. Men accustomed to the amenities of civilisation simply will not live in places where they cannot phone their families, or watch their favourite TV show. The communications satellite can put an end to cultural deprivation caused by geography. It is strange to think that, in the long run, the cure for Calcutta (not to mention London, New York, Tokyo), may lie 22,000 miles out in space . . .

"The SITE project will run for 1 year, and will broadcast to about 5,000 TV sets in carefully selected areas. This figure may not seem impressive when one considers the size of India, but it requires only one receiver to a village to start a social, economic and educational revolution. If the experiment is as great a success as Dr. Sarabhai and his colleagues hope (and deserves), then the next step would be for India to have a full-time communications satellite of her own. This is, in any case, essential for the country's internal radio, telegraph, telephone and telex services . . .

"Kipling, who wrote a story about "wireless" and a poem to the deep-sea cables, would have been delighted by the electronic dawn that is about to break upon the sub-continent. Gandhi, on the other hand, would probably have been less enthusiastic; for much of the India that he knew will not survive the changes that are now coming.

"One of the most magical moments of Satyajit Ray's exquisite Pather Panchali is when the little boy Apu hears for the first time the Aeolean music of the telegraph wires on the windy plain. Soon those singing wires will have gone forever; but a new generation of Apus will be watching, wide-eyed, when the science of a later age draws down pictures from the sky—and opens up for all the children of India a window on the world."

A. C. Clarke

ACKNOWLEDGMENTS

Many scientists, engineers, and technicians, too numerous to mention by name, have contributed to these volumes. Engineers at Fairchild Space and Electronics Company and Westinghouse Defense and Electronic Systems Center composed the chapters from material supplied by subsystems designers of the various systems and experiments, and have worked closely with the editors to complete this report. They have the editor's gratitude.

In particular, thanks go to Mr. Ralph Hall at Fairchild Space and Electronics Company and Mr. James Meenen of Westinghouse Defense and Electronic Systems Center for their patient cooperation, thorough review, and constructive comments and suggestions.

INTRODUCTION

ATS-6 was the final satellite in a series of six of the Applications Technology Satellite Program of the National Aeronautics and Space Administration. It was designed and built by Fairchild Space and Electronics Company, Germantown, Maryland, under NASA Contract NAS5-21100 from NASA Goddard Space Flight Center.

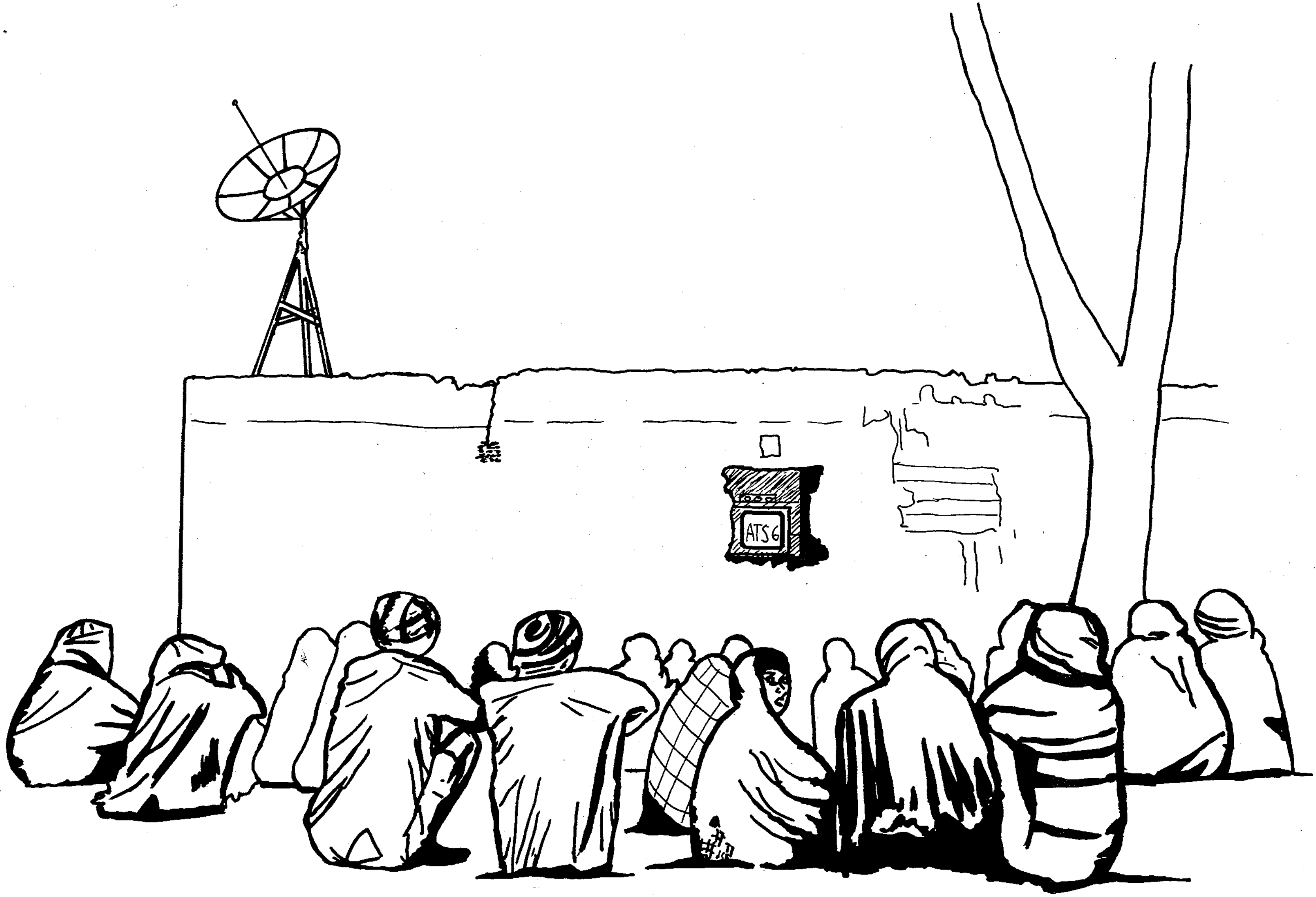
At the time of its launch, it was the largest and most powerful communications satellite to go into orbit.

The mission of ATS-6 was to demonstrate and evaluate the application of new technologies for future satellite systems. This it accomplished by demonstrating the first direct-broadcast television from geosynchronous orbit; by demonstrating many new communications technologies; by relaying data from, and tracking, low-orbiting satellites; by relaying communications and positions of ships and aircraft; and by supporting a variety of other experiments involving communications, meteorology, particle and radiation measurements, and spacecraft technology.

The purpose of this report is to document the lessons learned from the 5-year ATS-6 mission that might be applicable to spacecraft programs of the future. To satisfy this purpose, the six volumes of this report provide an engineering evaluation of the design, operation, and performance of the system and subsystems of ATS-6 and the effect of their design parameters on the various scientific and technological experiments conducted.

The overall evaluation covers the following:

- A summary of the ATS-6 mission objectives, operations, and results
- A summary description of the spacecraft system and subsystem requirements, the designs evolved to meet these requirements, and special analyses and ground testing performed to validate these designs and to confirm the flight integrity of the spacecraft
- A comparative evaluation of the 5-year performance and operations in orbit relative to those specified and demonstrated during ground tests prior to launch
- A summary of anomalies that occurred in the hardware, probable causes, and recommendations for future spacecraft systems
- A summary evaluation of the various technological and scientific experiments conducted
- A summary of conclusions and recommendations at the spacecraft system and subsystems levels that address considerations that might be relevant to future spacecraft programs or similar experiments.



". . . but a new generation of APUS will be watching, wideeyed when the science of a later age draws down pictures from the sky—and opens up for all . . . a window on the world."
A. C. Clarke

Part A

Department of Health, Education, and Welfare Sponsored Experiments

CHAPTER 1

HEALTH, EDUCATION, TELECOMMUNICATIONS EXPERIMENT

INTRODUCTION

The National Aeronautics and Space Administration (NASA) and the Department of Health, Education and Welfare (HEW), in a joint effort in 1971, planned various tests in health and educational programs to be transmitted to recipients through communication satellites. The Health, Education, Telecommunications (HET) experiment was formed from this effort and used the Applications Technology Satellite-6 (ATS-6) for communications. ATS-1 and ATS-3 were used for voice communications in the very high (vhf) band. In performing this experiment, NASA operated the spacecraft, provided technical consultation to ensure compatibility between the spacecraft, the NASA Communications Network, the Rosman Ground Station near Brevard, North Carolina and the Mojave Ground Station near Barstow, California. All of the other transmitting and receiving ground facilities were the responsibility of HEW. The HET Project Policy Committee managed the experiments and was chaired by the HEW Director of the Office of Telecommunications Policy and Planning. Members of the committee represented the National Institute of Education, the Veterans Administration, the National Institute of Health, and the National Library of Medicine.

OBJECTIVES

The HET experiment consisted of six experiments in three geographical regions comprising the Appalachian Mountains, the East and West Rocky Mountains, and Alaska. The purposes of the HET experiment included the following:

1. To televise programs to 121 low-cost, widely dispersed terminals in the United States through ATS-6

2. To provide television transmit capabilities at seven of those 121 terminals through ATS-6

3. To provide two-way voice/data communications at 17 of those 121 terminals relayed through ATS-1

4. To provide two-way voice/data communications at 32 of those 121 terminals through ATS-3

5. To provide two-way voice/data communications at two of those 121 terminals through ATS-1 and ATS-3

PARTICIPANTS IN EXPERIMENT

The HET network consisted of six independently managed groups of experimenters as follows:

1. Veterans Administration
2. Indian Health Service (Alaska)
3. Alaska Education Experiment
4. Washington, Alaska, Montana, Idaho (WAMI) medical education
5. Appalachian Regional Commission (ARC)
6. Federation of Rocky Mountain States (FRMS)

Experiments performed by the participants covered an area of 23 states and consisted of 121 terminals. During the course of the HET experiment, an evaluation was made of the effectiveness of management coordination used by the experimenters.

THE EXPERIMENTS AND THEIR OBJECTIVES

The objectives of each of the six experiments comprising the HET experiment were as follows:

Veterans Administration Health Education Experiment–The objective of this experiment was to test satellite communications for video seminars on continuing education, Grand Rounds programs, outpatient clinics, joint consultation clinics, computer assisted instructions for continuing education, and slow-scan technical experiments. Evaluation of these tests covered management, technical, cultural, and programming facets in the clinical and educational areas.

Indian Health Service Experiment (Alaska)–The purpose of this experiment was to test programs for providing better health care in remote areas. Video communications provided consultative assistance to physicians and education in the use of biomedical equipment.

Alaskan Education Experiment–The objective of this experiment was to provide information that would aid in planning a satellite telecommunications system to Alaska, primarily for educational purposes.

Washington, Alaska, Montana, Idaho Experiment (WAMI)–The objective of this experiment was to determine the cost effectiveness that satellite communications contribute to:

- increasing medical school enrollment
- containing the cost of medical education

- providing meaningful educational experience in nonmetropolitan communities
- increasing the flow of knowledge between practitioners and the university
- broadening educational opportunities
- studying medicine under physician instructors.

Appalachian Education Satellite Project (AESP)—The purpose of this experiment was to provide a variety of technology-based course work through ATS-6 to instructors at 15 terminals throughout the Appalachian region.

Rocky Mountain States Education Experiment—The purpose of this experiment was to demonstrate a communications satellite-based media distribution system for isolated and rural population areas and to evaluate the acceptance by the user and the cost of various delivery modes using a variety of program materials.

HET SYSTEM DESCRIPTION

Functional Description

The HET Experiment was operated and controlled by the ATS Operations Control Center (ATSOCC) located at the Goddard Space Flight Center (GSFC), Greenbelt, Maryland, and the HET Network Coordination Center (NCC) located in Denver, Colorado, both of which were common to the HET network. All operations with the spacecraft, such as spacecraft pointing and configuration, telemetry monitoring, scheduling, and experiment coordination, were controlled by ATSOCC. Real-time voice communications between ATSOCC, NCC, and the ATS Rosman Ground Station in North Carolina, were maintained by NASA dedicated lines.

The NCC coordinated all HET network programs with ATSOCC, since it was the sole interface with NASA for the six experiments. A computer controlled map in NCC provided a real-time display of the status of the entire HET network. NCC controlled all of the HET network transmissions using vhf frequencies through ATS-1 and ATS-3 by means of digital command signals. HET programs, that originated from NCC, were routed by a microwave relay link to the Denver Uplink Terminal (DUT) and from there to the HET network. Both NCC and DUT were equipped with a conference and monitoring system that contained SCAMA* voice and teletype facilities. Test equipment was also provided in both areas to continuously monitor the quality and signal level of the network programs. A block diagram of the overall HET network is presented in Figure 1-1.

Each HET experiment had a unique conceptual structure and employed a variety of programs, audience, and equipment combinations. Among the health and educational services offered were medical training, medical diagnosis, community health services teacher training programs, career education for junior high school students, and community educational programs. Included in the

*Switching, conference and monitoring arrangement (GSFC)

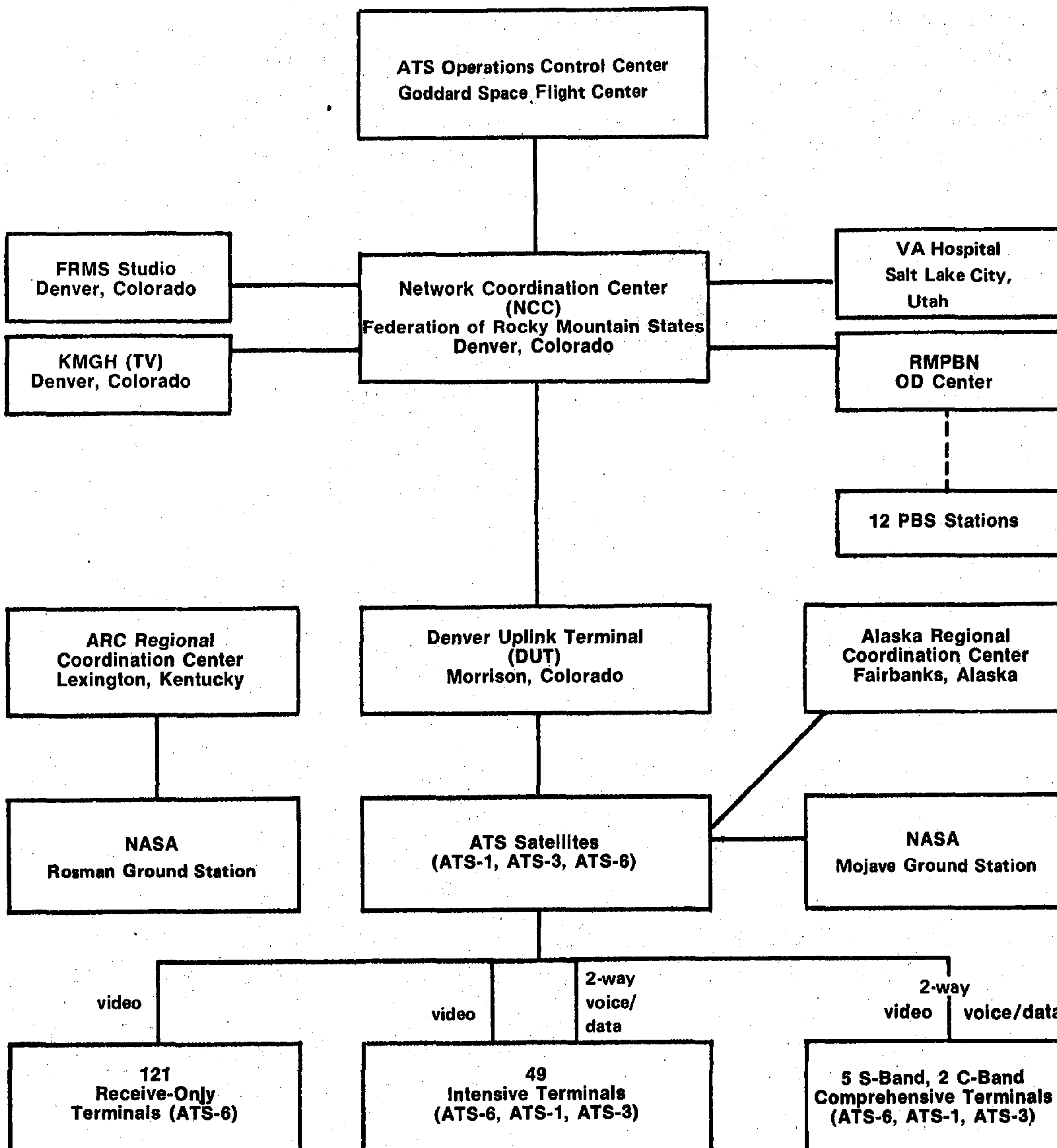


Figure 1-1. Health, Education, Telecommunications Experiment Network

complex network for provision of these services were two-way television, two-way audio, computer-assisted instruction, slow-scan television, and teletype. Although the six experiments differed, they all shared a common network and required basic equipment that was compatible with satellite communications.

A pictorial illustration of a typical communications experiment via the satellites in the HET network, Alaska in this case, is presented in Figure 1-2. This figure presents a consultation program in Alaska between a village, such as Galena or Yukon, and Tanana with Anchorage and Fairbanks participating. The village transmitted video, audio, and biomedical data to all of the three consultants through ATS-6. The consultants talked back in a party-line system by ATS-1.

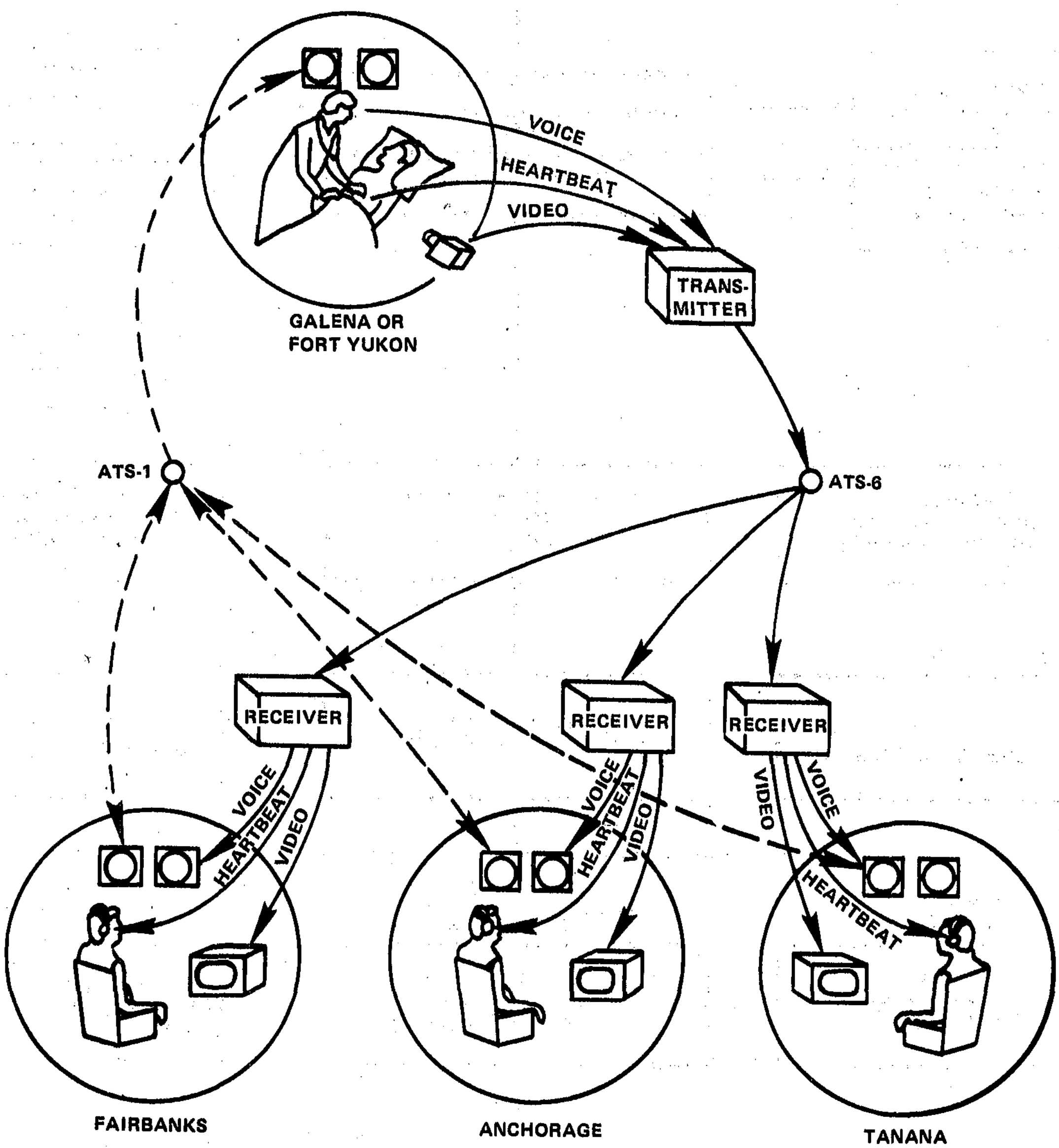


Figure 1-2. Consultation Links in Video and Audio Between Three Consultants and a Village

The Veterans Administration deployed 10 video receive-only terminals at hospitals located in remote regions of the Appalachia. Programming originated in a television studio of station KMGH in Denver, was routed to the NCC by landlines, transmitted by microwave to the DUT, then transmitted to the Earth-coverage horn of ATS-6 and retransmitted to the 10 hospitals. Interaction between the remote sites and the studio was accomplished by telephone.

The University of Washington, Seattle, conducted the WAMI Experiment whose main facility in Seattle could transmit and receive C-band signals via the 9.14-meter reflector of ATS-6. A clinic in Omak, Washington, had a similar transmit and receive capability. The third terminal in the WAMI Experiment was located at the University of Alaska in Fairbanks. This terminal operated at S-band with half-duplex video transmitted between Seattle and Omak; however, the link between Fairbanks and Seattle was provided with full-duplex video.

The intra-Alaska experiments were conducted by two networks. The first was the Indian Health Service (IHS) that used a half-duplex video between one of three S-band comprehensive terminals located in small clinics in the bush area and a similar terminal in Fairbanks. In an Anchorage hospital, an intensive terminal received simplex video. The second network consisted of 15 intensive terminals in remote villages and S-band comprehensive terminals in Fairbanks and Juneau. A Fairbanks to Seattle link transmitted full-duplex video. The VHF terminals in Alaska used ATS-1 during the IHS program.

The Appalachian Education Satellite Project (AESP) was an educational experiment under the direction of the Appalachian Regional Commission. The main facility, the Resource Coordination Center was located at the University of Kentucky, Lexington. This was a video receive-only terminal with vhf transceive capability. The video that originated here was transmitted by commercial facilities to the Rosman Ground Station for transmission via ATS-6 to 15 Earth stations deployed throughout the Appalachian region. The 15 terminals were grouped in clusters of three, all capable of receiving video, but only one in the cluster was able to transceive telephony at vhf using ATS-3. The two other terminals in the cluster were connected to the third by telephone lines. This allowed the interaction between the remote sites and the University of Kentucky.

The eight states of the Federation of the Rocky Mountain States required two pointings of the satellite to cover the region; however, the network functioned in the same manner in each area (footprint) covered by the pointing. Educational material generated in the Federation studio, adjacent to the NCC, was transmitted by microwave to the DUT and then transmitted via ATS-6 to 56 junior high schools and the 12 Public Broadcasting Service (PBS) stations in the region. The PBS stations retransmitted the programs throughout their area of coverage. Twenty-four of the junior high schools were equipped with vhf telephone transceivers. All other sites interacted by telephone.

Satellite Configuration

The Applications Technology Satellite-6 was used in performing the communications experiments for the HET network. A diagram showing the configuration of ATS-6 is illustrated in Figure 1-3. The satellite provided an oriented stable platform at synchronous altitude and was equipped with a spot-beam antenna and two global-beam antennas. The spot-beam antenna, which radiated energy

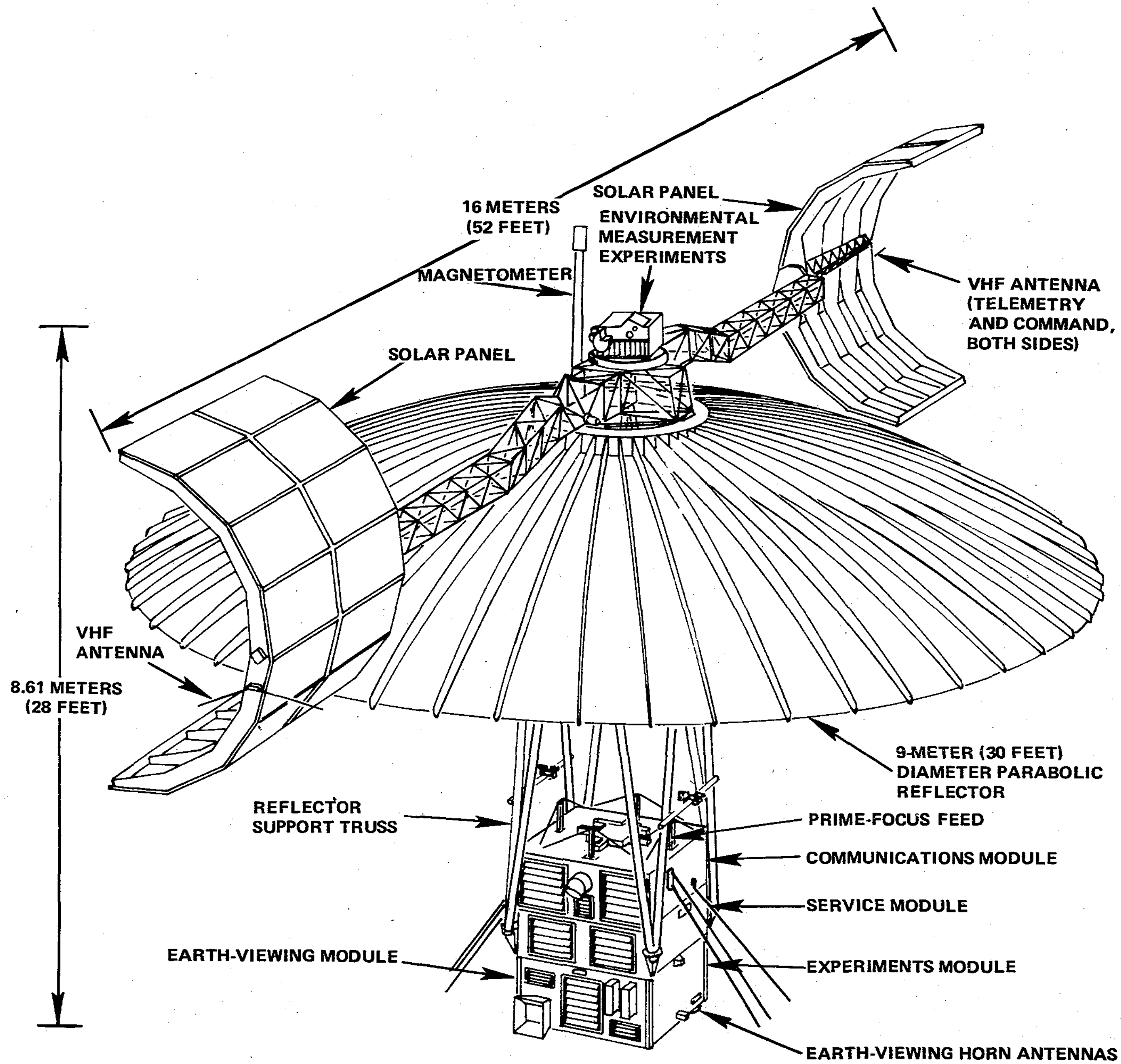


Figure 1-3. Configuration of ATS-6.

to, and received energy from, the 9.14-meter parabolic reflector, was a prime-focus feed antenna located on top of the Earth-viewing module. The prime-focus feed complex had a cross array of switchable broadband S-band feed elements. Two of these feed elements, the first and second offset elements in the south arm of the crossed array, were used for the HET experiments. Through spacecraft boresight reorientation, these feeds provided a satisfactory field-of-view (FOV) to illuminate the ground terminals. With the satellite pointed to one position, the feeds produced a northern beam and a southern beam resembling a footprint. A typical example of the footprints provided by the north and south S-band beams from the spacecraft over the Veterans Administration network are presented in Figure 1-4. The global-beam antennas, which transmitted and received signals directly to and from the Earth, were two Earth-viewing horn antennas, both of which were located on the bottom surface of the Earth-viewing module.

The spacecraft's communication subsystem provided the basic interface between ATS-6 and the ground terminals for the HET experiments. This subsystem was capable of generating multiple frequencies, diverse beam paths, and high power levels, all of which were needed for the various communications experiments.

With the 9.14-meter parabolic antenna and 15 watts of radio frequency (rf) power from the transponder at 2.6 gigahertz (GHz), the effective isotropic radiated power (e.i.r.p.) was 49.7 decibels (reference level of 1 watt) (dBW) at the beam edge. These characteristics enabled a reception at the terminals of high quality color video signals accompanied by four audio channels with modest system sensitivities. The range of figure of merit (G/T) provided a TASO 1* or better picture quality.

Special frequency translation capabilities of the transponder with hard limiting in the intermediate frequency (i.f.) amplifier permitted any combination of received and transmitted signals in the C-band and S-band frequencies. Frequency translation with automatic gain control (AGC) was available on any of the downlinks. Therefore, ATS-6 could receive video transmissions at 6 GHz or 2.25 GHz, and also simultaneously transmit video signals at 4 GHz and two S-band frequencies at 2.5 GHz and 2.69 GHz. One transmitter for each HET frequency channel provided operational redundancy for the HET experiments. This flexibility also enabled the Network Coordination Center in Denver to monitor all transmissions and to coordinate the unique distribution needs of each experimenter. A block diagram of the ATS-6 transponder in the prime mode for the HET experiments is shown in Figure 1-5.

The ATS-6 link parameters in the C-band and S-band frequencies were as follows:

ATS-6 Downlink C-Band Parameters

Frequency	3947.5 MHz
Satellite E.I.R.P. (ECH)	25.7 dBW
Path Loss at 4 GHz	196.5 dB
Satellite Pointing Error Loss	0.3 dB

*TASO 1 is a standard set by the Television Allocation Study Organization to describe a picture of high quality with imperceptible noise.

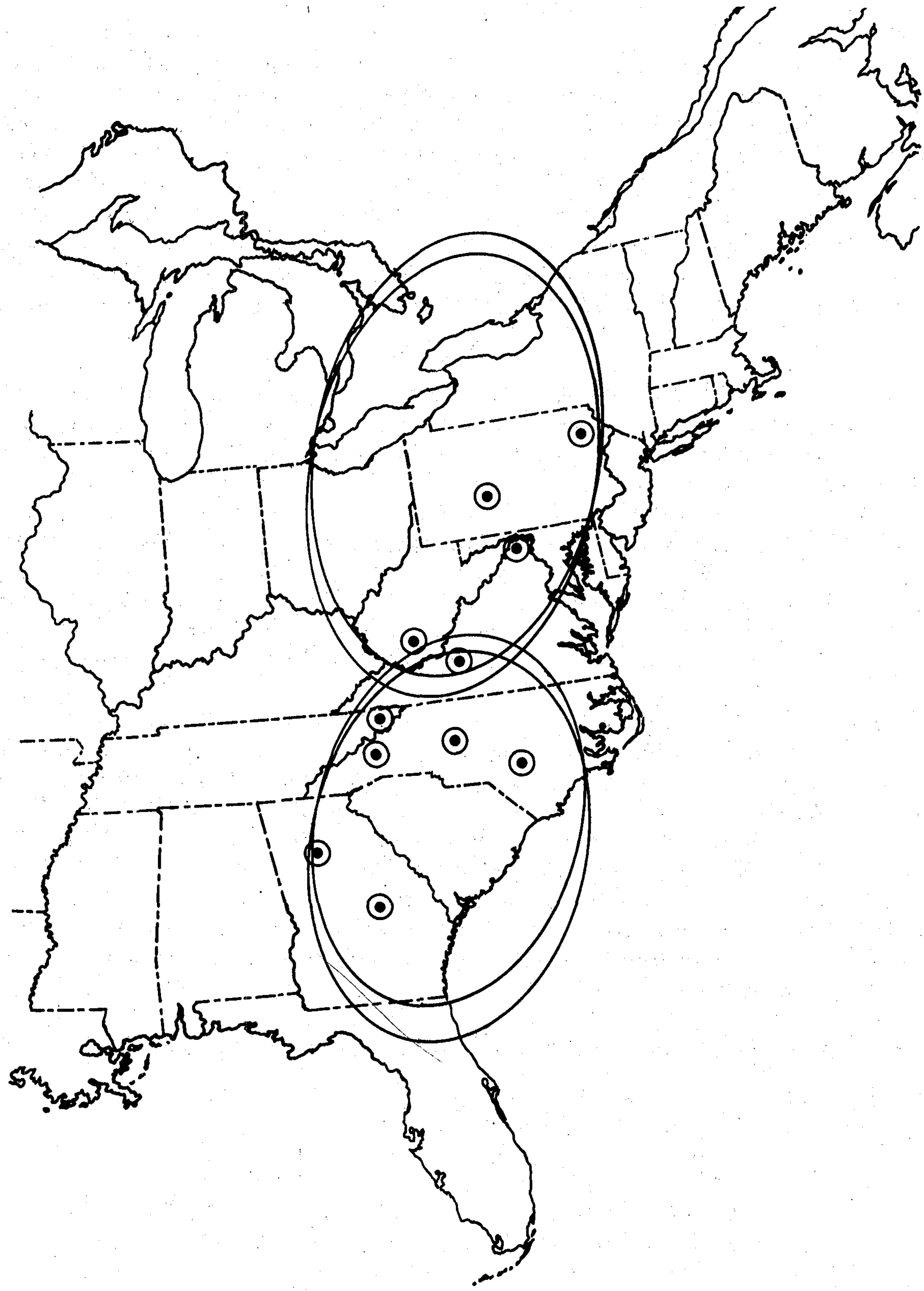


Figure 1-4. Footprints of North and South S-band Beam from ATS-6 Over VA Network

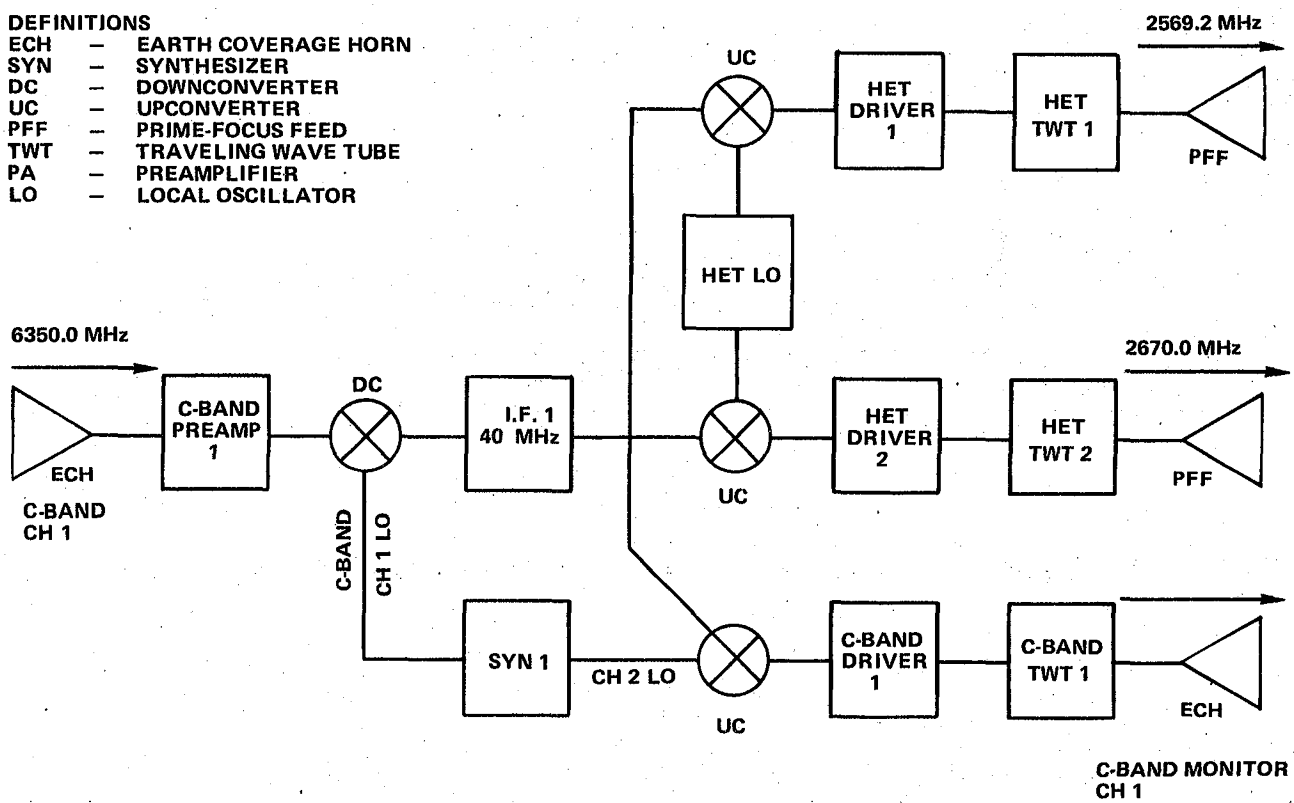


Figure 1-5. Transponder Block Diagram in Primary Mode for the HET Experiment

ATS-6 Uplink C-Band Parameters

Frequency	5947.5 MHz
Satellite G/T (ECH)	-14.0 dB/K
System Noise Bandwidth	24.7 MHz
Satellite Pointing Error Loss	0.4 dB
Path Loss at 6 GHz	200.1 dB

ATS-6 Downlink S-Band Parameters

Frequency	2556.7 MHz
Satellite E.I.R.P. (PFF)	52.7 dBW
Path Loss at 2.66 GHz	192.6 dB
Satellite Pointing Error Loss	0.5 dB

ATS-6 Uplink S-Band Parameters

Frequency	2250.0 MHz
Satellite G/T (PFF)	10.4 dB/K
System Noise Bandwidth	24.7 MHz
Satellite Pointing Error Loss	0.5 dB
Path Loss at 2.25 GHz	191.0 dB

ATS-1 and ATS-3 were used primarily for voice communications in the vhf band during the HET experiments. Both ATS-1 and ATS-3 were spin-stabilized, synchronous-altitude satellites. The ATS-1 transponder was the same as that employed in ATS-3 with the exception that ATS-1 had a compression or nonlinear characteristic in the final stages of the transmitter power amplifier. When two high-level signals were applied to the input of this transponder, the output level of the weaker signal would be further suppressed to an output level below that of the stronger signal. For the ATS-3 transponder, the two input signals of different power levels would appear in the output at the same power ratio as that at the input.

The vhf communications transponder for both satellites received uplink signals at a frequency of 149.22 megahertz (MHz) and transmitted the received signal at a downlink frequency of 135.6 MHz. Eight transmitters were provided for the full-power mode and were applied to an eight-element phased array antenna. There were also eight receivers provided with their associated antennas.

Under the full-power mode, ATS-1 provided a power output of 48 dBm and ATS-3 provided 47.6 dBm. A basic block diagram of the transponder used in both ATS-1 and ATS-3 is presented in Figure 1-6.

The link parameters for ATS-1 and ATS-3 in the vhf communications mode are presented in Table 1-1.

Ground Terminals

The ground terminal system consisted of a terrestrial network that was compatible with the satellites and comprised the following facilities:

1. A total of 121 low-cost terminals, in the Rocky Mountains, Appalachia, Alaska, and the Pacific Northwest, received television video.
2. Five low-cost terminals in Alaska transmitted television video at 2.25 GHz.
3. Forty-nine low-cost terminals, in the Rocky Mountains, Appalachia, Alaska and the Pacific Northwest, with two-way voice/data capability at vhf.
4. One uplink facility at Morrison, Colorado, interfaced with the satellites at 4 and 6 GHz and 135.6 and 149.2 MHz.
5. A microwave relay operated at 12 GHz and interconnected the Network Coordination Center with the Denver Uplink Terminal.
6. A terrestrial coordination and managing facility at Denver, Colorado, the Network Coordination Center.
7. Television video at 6 GHz was transmitted by two low-cost, C-band terminals, in Seattle, Washington, and Omak, Washington.

A complete list of all of the terminals that comprised the HET network is presented in Table 1-2.

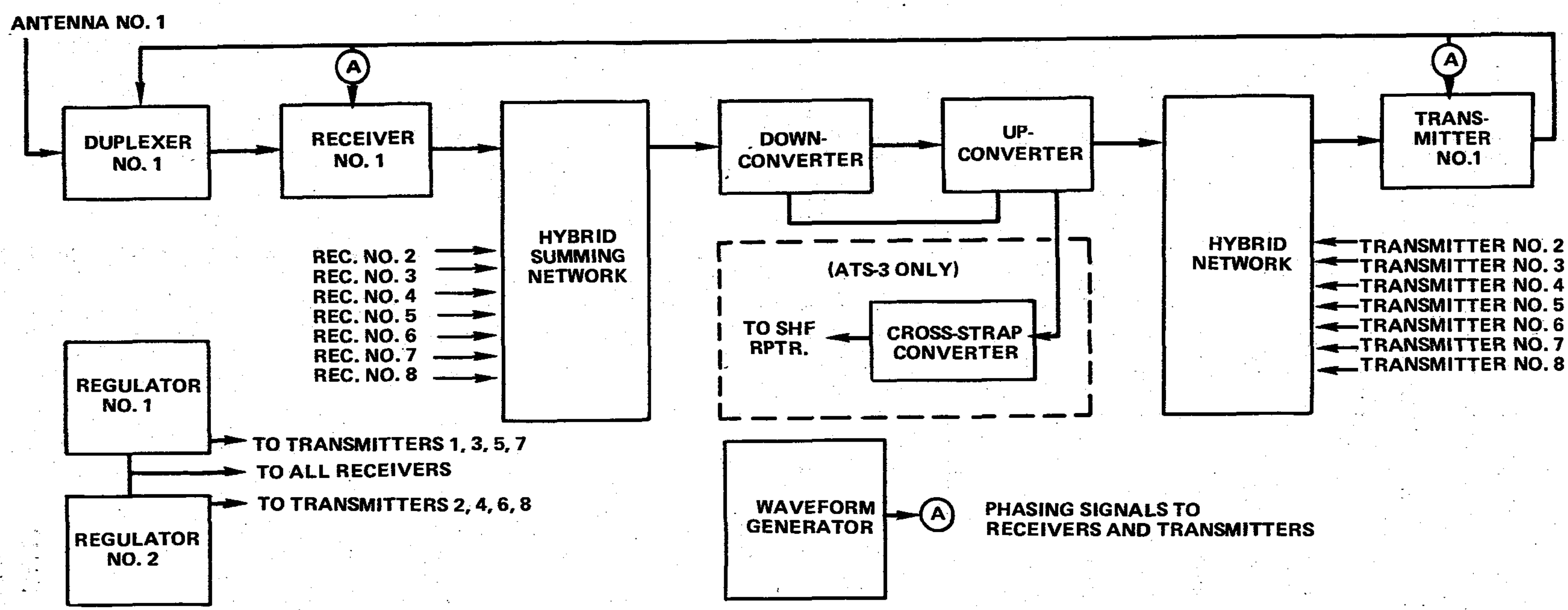


Figure 1-6. ATS-1 and ATS-3 VHF Communications Transponder

Table 1-1
ATS-1 and ATS-3 VHF Link Parameters

	ATS-1	ATS-3	Units
Location	149°, ±1°	70°, +1°	W. long.
Orbit inclination	7.34°	5.74°	–
E.i.r.p. (September 1970)	48.0	47.6	dBm
Receiver noise figure	4.0	4.0	dB
Receiver bandwidth	100.0	100.0	kHz
Transmitter frequency	135.6, ±0.05	135.6, ±0.05	MHz
Receiver frequency	149.22, ±0.05	149.22, ±0.05	MHz
Translation error	±50	+800, ±100	Hz

Table 1-2
Terminals in HET Network

	2.5-GHz ROT	GE Components VHF (Modified) and Digital Coordinator)
ARIZONA		
Hayden	X	X
McNary	X	X
Tuba City	X	X
Fredonia	X	–
Gila Bend	X	–
Seligman	X	–
St. Johns	X	–
COLORADO		
Meeker	X	X
Monte Vista	X	X
Montrose	X	X
Antonito	X	–
Collbran	X	–
Craig	X	–
Naturita	X	–
Morrison (DUT)	X	X
Denver (NCC)	X	X

Table 1-2
Terminals in HET Network (continued)

	2.5-GHz ROT	GE Components VHF (Modified) and Digital Coordinator)
IDAHO		
Challis	X	X
Lapwai	X	X
McCall	X	X
Osburne	X	–
Salmon	X	–
St. Maries	X	–
Vallivue	X	–
Fairfield	X	–
MONTANA		
Busby	X	X
Colstrip	X	X
Ft. Benton	X	X
Roundup	X	–
Three Forks	X	–
W. Yellowstone	X	–
Whitehall	X	–
NEVADA		
Carlin (changed mid-semester to Ruth)	X	X
McDermitt	X	X
Owyhee	X	X
Battle Mountain	X	–
Elko	X	–
Ely	X	–
Winnemucca	X	–
University of Nevada	X	–
NEW MEXICO		
Cuba	X	X
Dulce	X	X
Penasco	X	X
Mora	X	–
Questa	X	–
Springer	X	–
Wagon Mound	X	–

Table 1-2
Terminals in HET Network (continued)

	2.5-GHz ROT	GE Components VHF (Modified) and Digital Coordinator)
UTAH		
Blanding	X	X
Enterprise	X	X
Heber	X	X
Hyrum	X	–
Kanab	X	–
Morgan	X	–
Panquitch	X	–
WYOMING		
Pinedale	X	X
Riverton	X	X
Saratoga	X	X
Arapahoe	X	–
Dubois	X	–
Lovell	X	–
Sundance	X	–
TOTAL	59	26

PUBLIC BROADCAST STATIONS

		2.5-GHz ROT
KAET	Tempe, Arizona	X
KAID	Boise, Idaho	X
KBGL	Pocatello, Idaho	X
KBYU	Provo, Utah	X
KRMA	Denver, Colorado	X
KTSC	Pueblo, Colorado	X
KUAT	Tucson, Arizona	X
KUID	Moscow, Idaho	X
KNME	Albuquerque, New Mexico	X
KENW	Portales, New Mexico	X
KUED	Salt Lake City, Utah	X
KLVX	Las Vegas, Nevada	X
	Total	12

Table 1-2
Terminals in HET Network (continued)

APPALACHIAN EDUCATIONAL SATELLITE PROJECT

	2.5-GHz ROT	VHF (Modified GE Components and Digital Coordinator)
Lexington, Kentucky	X	X (RCC)
Huntsville, Alabama	X	X
Guntersville, Alabama	X	–
Rainsville, Alabama	X	–
LaFollette, Tennessee	X	X
Coalfield, Tennessee	X	–
Johnson City, Tennessee	X	–
Norton, Virginia	X	X
Boone, North Carolina	X	–
Stickleyville, Virginia	X	–
Cumberland, Maryland	X	X
Keyser, West Virginia	X	–
McHenry, Maryland	X	–
Fredonia, New York	X	X
Erie, Pennsylvania	X	–
Olean, New York	X	–
TOTAL	16	6

VETERANS ADMINISTRATION EXPERIMENT

	2.5-GHz ROT
Dublin, Georgia	X
Fayetteville, North Carolina	X
Oteen, North Carolina	X
Salisbury, North Carolina	X
Altoona, Pennsylvania	X
Wilkes-Barre, Pennsylvania	X
Johnson City, Tennessee	X
Salem, Virginia	X
Beckley, West Virginia	X
Clarksburg, West Virginia	X
TOTAL	10

Table 1-2
Terminals in HET Network (continued)

	ROT	VHF**	VHF***	S-TX	C-TX	C-RX
ALED:						
Allakaket	X	–	X	–	–	–
Anchorage	X	–	X	–	–	–
Angoon	X	X	–	–	–	–
Aniak	X	X	–	–	–	–
Craig	X	X	–	–	–	–
Fairbanks (AOC)	X	X	–	X	–	–
Galena	X	–	X	X	–	–
McGrath	X	X	–	–	–	–
Minto	X	X	–	–	–	–
Nenana	X	X	–	–	–	–
Nikolai	X	X	–	–	–	–
Petersburg	X	X	–	–	–	–
Chuathbaluk	X	X	–	–	–	–
Sleetmute	X	X	–	–	–	–
Valdez	X	X	–	–	–	–
Yakatat	X	X	–	–	–	–
Tanana	X	–	X	X	–	–
Juneau	X	X	–	X	–	–
IHS:						
Anchorage	*	–	*	–	–	–
Fairbanks (NHC)	X	–	X	–	–	–
Fort Yukon	X	–	X	X	–	–
Galena	*	–	*	*	–	–
Tanana	*	–	*	*	–	–
Tucson	–	X	–	–	–	–
WAMI:						
Fairbanks (AOC)	*	*	–	–	–	–
Omak, Washington	X	X	–	–	X	X
Seattle, Washington	X	X	–	–	X	X
TOTAL SYSTEMS	22	17	6	5	2	2

*Equipment counted in ALED
**Modified GE Components and Digital Coordinator
***Motorola Components without Digital Coordinator

WASHINGTON, D.C.

	2.5-GHz ROT
National Institute of Education	X
Department of Health, Education and Welfare	X
TOTAL	2

Table 1-2
Terminals in HET Network (continued)

TOTAL NUMBER OF HET EQUIPMENT SYSTEMS	
2.5-GHz Receive-Only Systems	121
VHF (Modified GE Components and Digital Coordinator)	49
VHF (Motorola Components without Digital Coordinator)	6
S-Band TX/RX	5
C-Band TX/RX	2

Uplink Facilities

Federal restrictions prevented uplink communications to a satellite on S-band in all of the states except Alaska because of possible rf interference with existing terrestrial communications systems. Therefore, C-band frequencies were used for both uplink and downlink transmission and S-band in only the downlink transmission. In Alaska, S-band was used for both uplink and downlink transmission since rf interference was not a problem.

Most C-band terminal equipment was "off the shelf" units that were specially configured to serve the Washington, Alaska, Montana, and Idaho project. The two systems were almost identical, with the exception of the receive side. Seattle and Omak, Washington terminals employed a 3.05-meter parabolic reflector equipped with a dual-mode feed for reception of left-hand circularly polarized waves and for transmission of right-hand circularly polarized waves. Video reception was at 2.6 GHz and video transmission was at 5947.5 MHz. Video transmission from Seattle was in color, while from Omak the video was in black and white.

A video processor/modulator, of the same basic unit that was used in the S-band transmitter in Alaska, provided a modulated signal output at 2247.5 MHz and at a level of 18 dBm. This signal was then upconverted to 5947.5 MHz and amplified to a level of 30 dBm for transmission through 150 feet of coax cable to the antenna. At the antenna, a traveling wave tube amplifier (TWTA) brought the level to 20 watts (43 dBm) and into the feed for an e.i.r.p. of about 55 dBw. Figure 1-7 shows a block diagram of the C-band transmitter-receiver terminal at Seattle and Omak, Washington.

The HET experiment required a terminal having the capability of originating a single video channel with four associated program channels to each of seven regions served. To access ATS-6 from the seven regions, the global-beam antenna on the spacecraft was used. This Earth-coverage horn had a beam that intersected one-third of the Earth's surface.

To provide communications with the ATS-6 global beam, the Denver Uplink Terminal at Morrison, Colorado, was used to transmit uplink at a frequency of 6 GHz and downlink at 4 GHz. Facilities for the terminal consisted of an 11-meter antenna with a prime-focus feed, a 3-kilowatt (kW) (34.8 dBW) transmitter and had the capability of providing an e.i.r.p. of 84 dBW and a G/T of

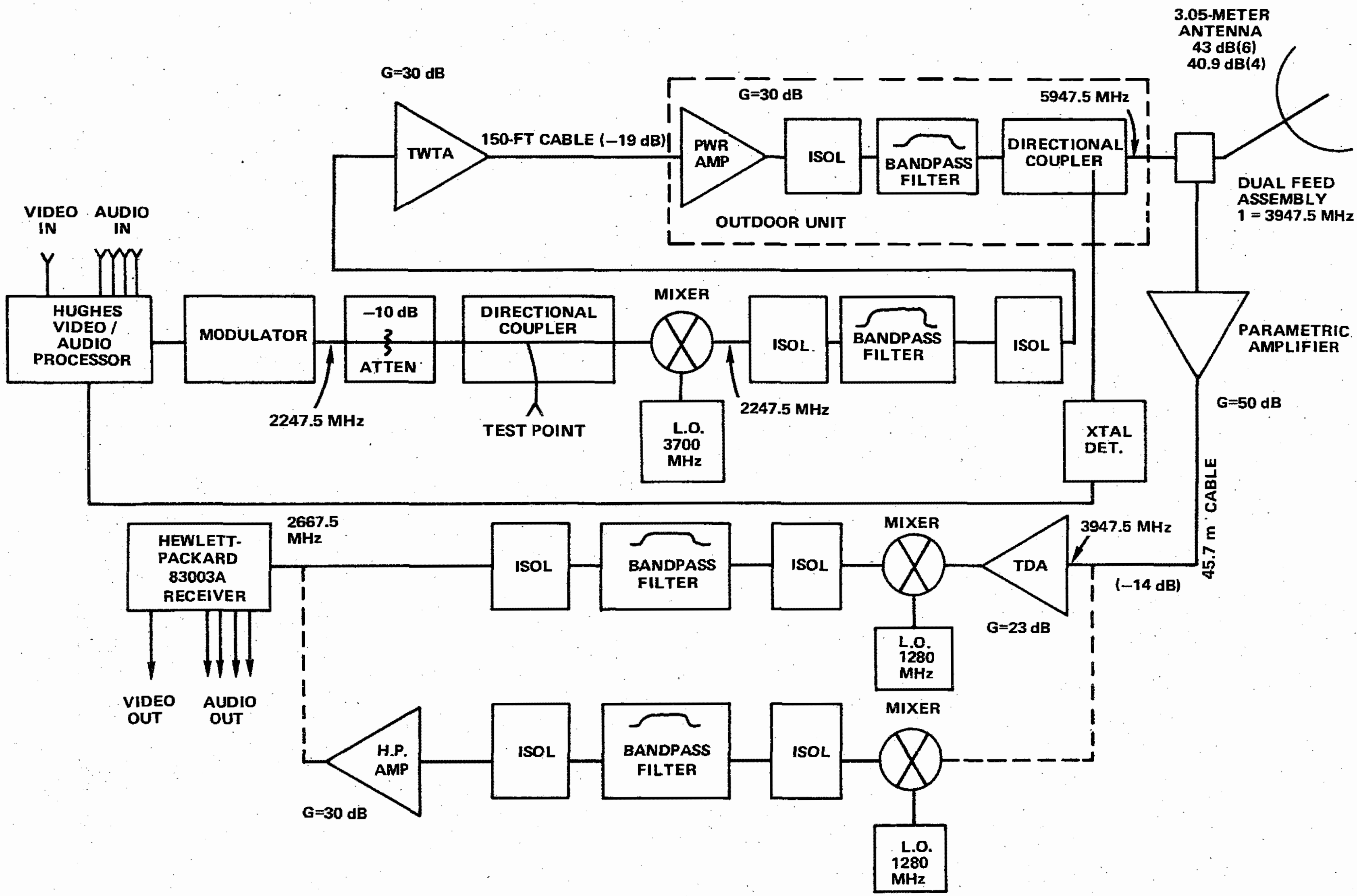


Figure 1-7. C-Band Transponder/Receiver Subsystem at Seattle and Omak

29 dB/K. The receiving system employed an uncooled parametric amplifier having a noise temperature of 90 kelvin (K). Figure 1-8 shows a block diagram of the transmitter/receiver configuration for the DUT (Morrison) terminal.

A microwave relay link transmitted information from the DUT terminal to the Network Coordination Center at a frequency of 12.5 GHz and from the NCC to the DUT terminal at 12.240 GHz. Transmission in both directions used channels having a 30-MHz bandwidth.

The S-band uplink terminals in Alaska only, consisted of a 3-meter prime-focus feed antenna having a right-hand circular polarization and a transmitter that operated at a frequency of 2247.5 MHz. An e.i.r.p. of 46.5 dBW was provided by the system. A composite baseband was transmitted and consisted of a television video and four audio channels on separate subcarriers. Video from live television programs was in black and white, but videotape programs were in color. A block diagram of the system is shown in Figure 1-9 and primary characteristics of the S-band transmitter are as follows:

Operating frequency	2247.5 MHz
Modulation type	wideband FM
Antenna polarization	right-hand circular
Power amplifier output	28 watts
Antenna diameter	3 meters
Signals	
video (one channel)	1 V peak-to-peak, 30 Hz to 4.2 MHz
audio (four channels)	-21 dBW, 30 Hz to 10 kHz
Primary power	115 V, 10%, 60 Hz single phase, 800 W maximum, or 27 Vdc, ±3 V; 34 A maximum
Preemphasis video	CCIR recommendation 405 for 525 line television FCC standard 75 μs

There were five Alaskan terminals that had the uplink transmission capability and were located in Fairbanks, Galena, Tanana, Juneau and Ft. Yukon. An illustration of the WAMI communication links in the HET network indicating the up- and downlinks in C-band, S-band, and vhf is presented in Figure 1-10.

Forty-nine of the remote sites were equipped with vhf transmitter-receiver systems, thus permitting live voice interaction between the various experiment coordination centers and sites, and among the sites themselves using either ATS-1 or ATS-3. This capability of live interaction was used extensively throughout all of the experiments.

In addition, the Appalachian Regional Commission experiment made extensive use of the teletype capability, and the Federation of Rocky Mountain States experimented with a limited digital-response system for collecting data in real time from students.

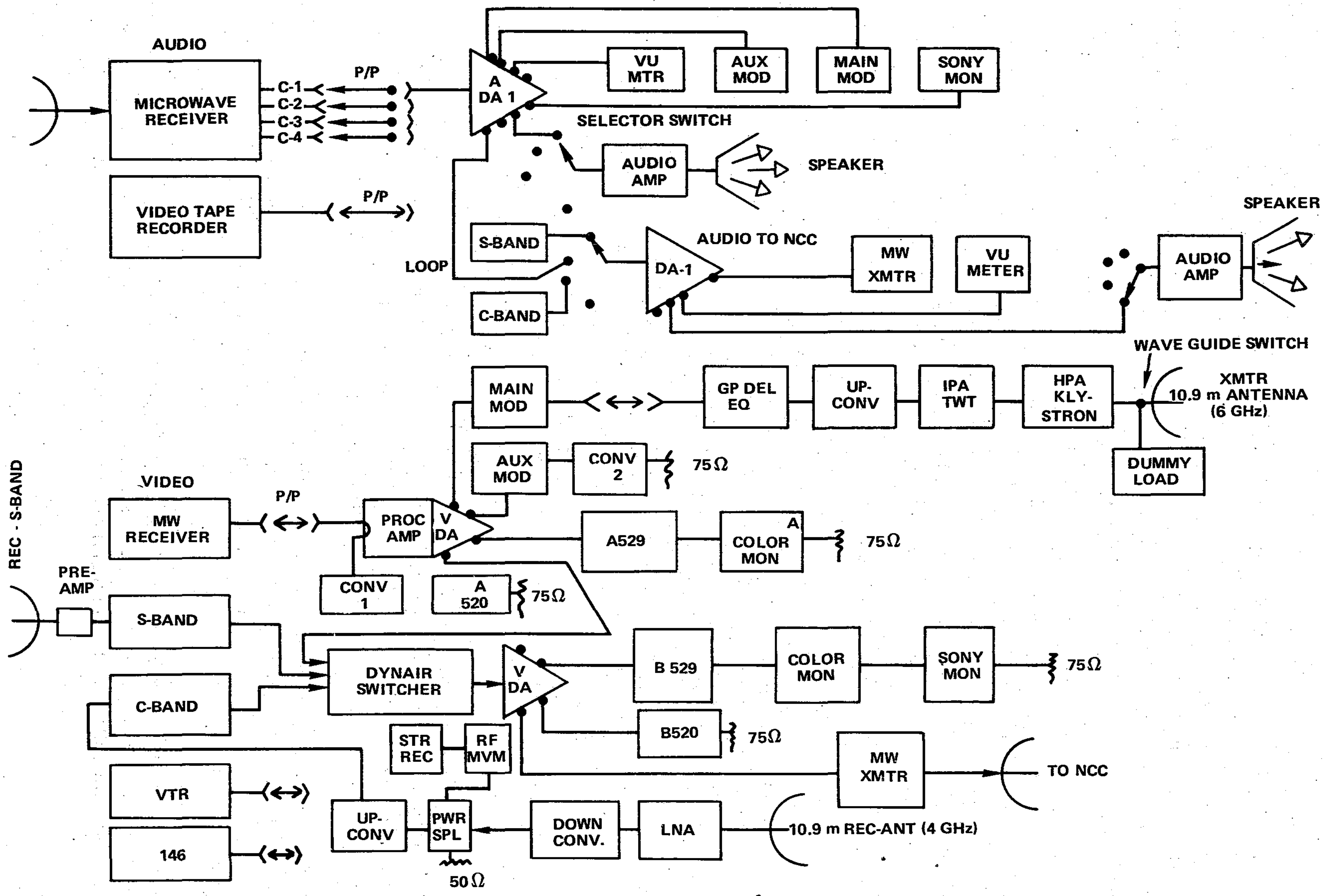


Figure 1-8. Transmit/Receive Configuration for DUT Terminal

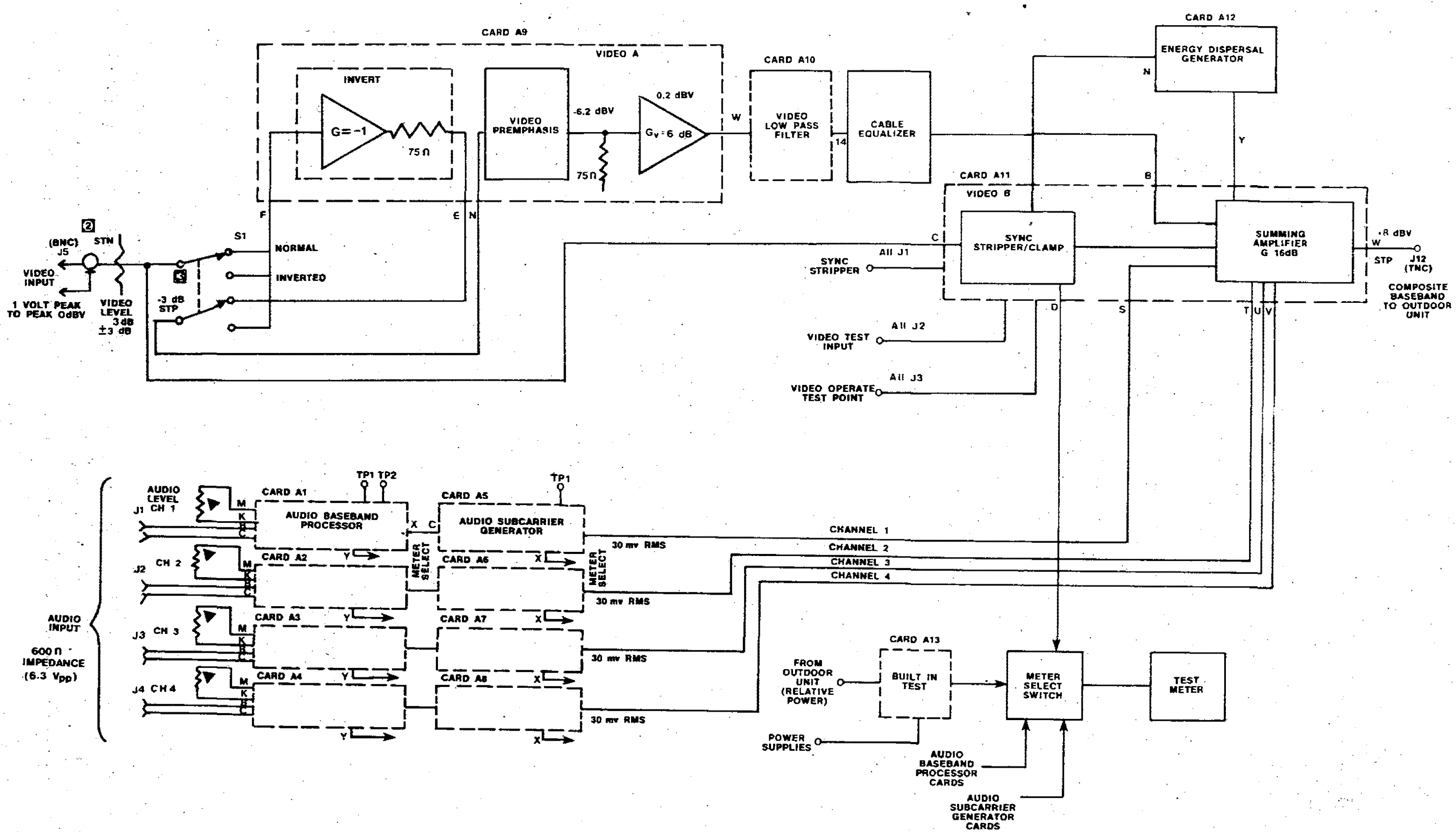


Figure 1-9. Block Diagram of S-Band Transmitter

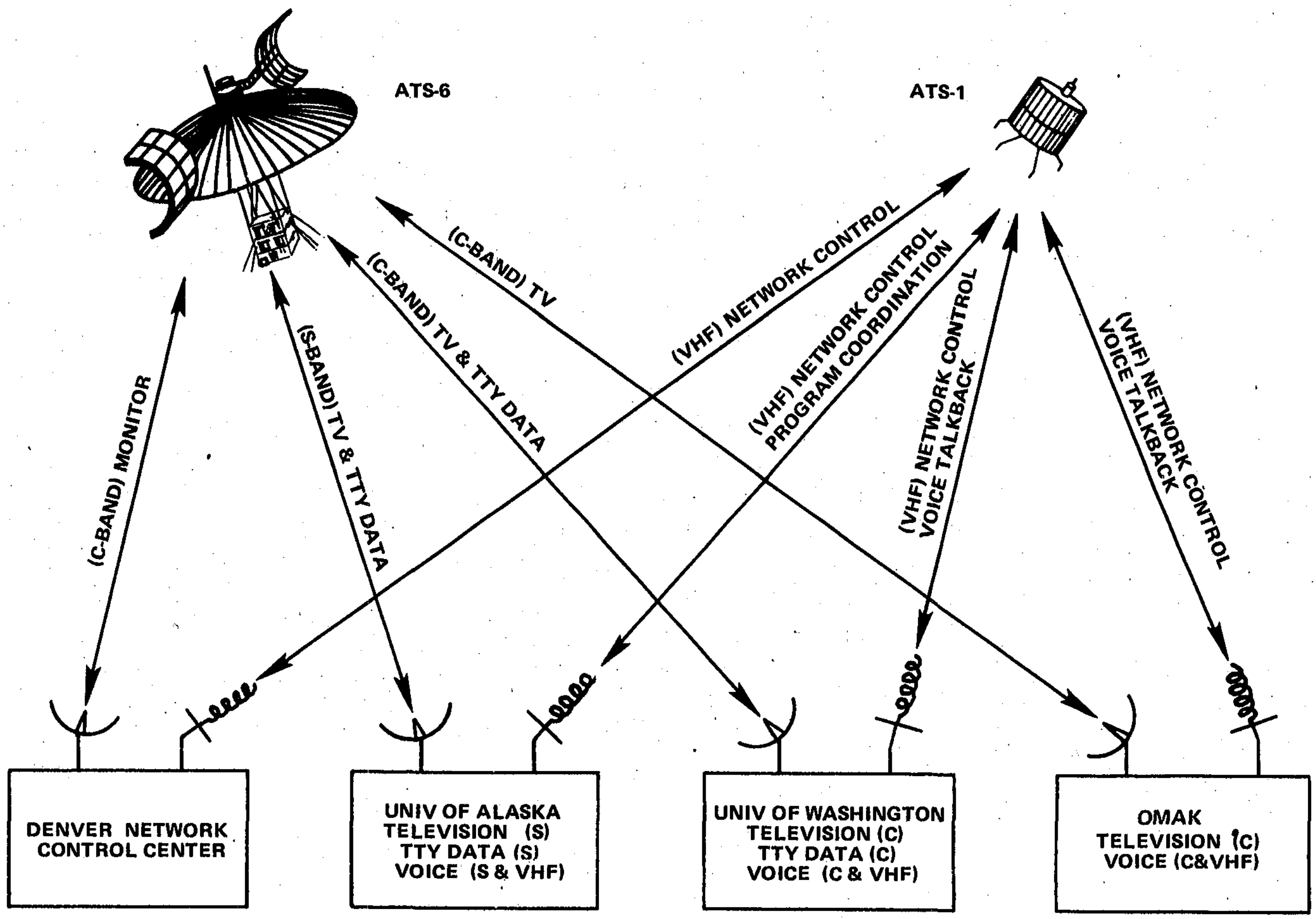


Figure 1-10. WAMI HET Experiment Network

A vhf terminal consisted of a 90-watt transmitter-receiver, a helical antenna that was used for simultaneous transmission and reception, a duplexer, a low-noise preamplifier, and a digital coordinator. The transmitter-receiver and the digital coördinator were housed in a cabinet with a desk top.

To conform with the requirements placed on the HET experiment by the Interdepartment Radio Advisory Committee (IRAC), the vhf terminal had to operate in a half-duplex mode. In this mode, there had to be an open receive channel at the remote site even as the sites were transmitting. Only in this manner was it possible to terminate transmissions from a remote site by a command from NASA at ATSOCC, or from Denver in case of an emergency or unauthorized transmissions.

Each station had a unique address number that was digitally coded. This address was transmitted in a five-word preamble every time the site transmitter was keyed on, thus providing positive identification for all terminals at the Network Coordination Center. Transmissions to remote sites from the NCC were also preceded by the same type of digital preamble. This permitted selective control of the terminal functions at any particular site. The NCC in Denver received the phase-shift-keyed preambles via phase-locked receivers at the Morrison Earth station (DUT).

With the use of a broadband helical antenna, simultaneous transmission and reception was provided. This antenna consisted of a three-piece, counterweighted boom mounted on a pivot to facilitate adjustment in both the azimuth and elevation angles. A theoretical gain of 15 dB over isotropic radiator (dBi) at a frequency of 135 MHz was provided by the antenna.

The diplexer and preamplifier were off-the-shelf units and were directly mounted on the fixed antenna structure in an enclosure.

A crystal-controlled transmitter was employed that provided either phase modulated (PM) or FM signals at two rf frequencies consisting of 149.1950 MHz and 149.2450 MHz.

A superheterodyne FM receiver, using double conversion, was employed and had the capability of receiving two rf frequencies at 135.5750 MHz and 135.6250 MHz. The receiver used a crystal oscillator for frequency control and had a stability of ±5 parts per million. A block diagram of the vhf transmitter-receiver configuration is shown in Figure 1-11.

The digital coordinator was a dedicated digital controller and communications accessory that performed the control functions for the vhf equipment by sending and receiving digitally-coded commands to and from the sites to Denver. To simplify its use, the coordinator was designed to perform as a complete control device for the equipment and also to serve as the control panel for the vhf transmitter-receiver.

The digital coordinator had three main functional circuits: (1) receive and decode logic, (2) encode and transmit logic, and (3) command-control logic. There were four modes of operation: CALL, VOICE, DATA, and AUTOMATIC DATA. In the CALL mode, the remote operator would indicate on the spacecraft order wire (channel 2), by digital transmission only, a desire to establish contact with the NCC. In the VOICE mode, normal two-way communications took place on the spacecraft channel 4 in the lower 48 states and on channel 3 in Alaska. In the DATA mode, teletype data was transmitted from a site to any other site that was similarly equipped. In the AUTOMATIC DATA mode, the NCC operator would collect data from peripheral (digital) devices directly without remote operator assistance. In addition, the NCC could transmit up to 20 separate commands to perform tasks such as: (1) the automatic shutoff of equipment in emergency situations or during unauthorized transmissions, and (2) the activation of other peripheral equipment. This feature, though not used operationally, enabled videotape recorders at unattended sites to record early morning transmissions for later playback.

The use of the digital coordinator was strictly experimental; however, the previously-described capabilities were built into all of the vhf remote equipment and were available for use at any time during the HET experiments.

S-Band Receive-Only Terminals

To minimize cost and simplify the procurement of equipment, a single design was employed for all color television S-band receive-only terminals (ROT). One exception was Roundup, Montana, where a 2-meter experimental antenna was used because its location was very near the satellite beam

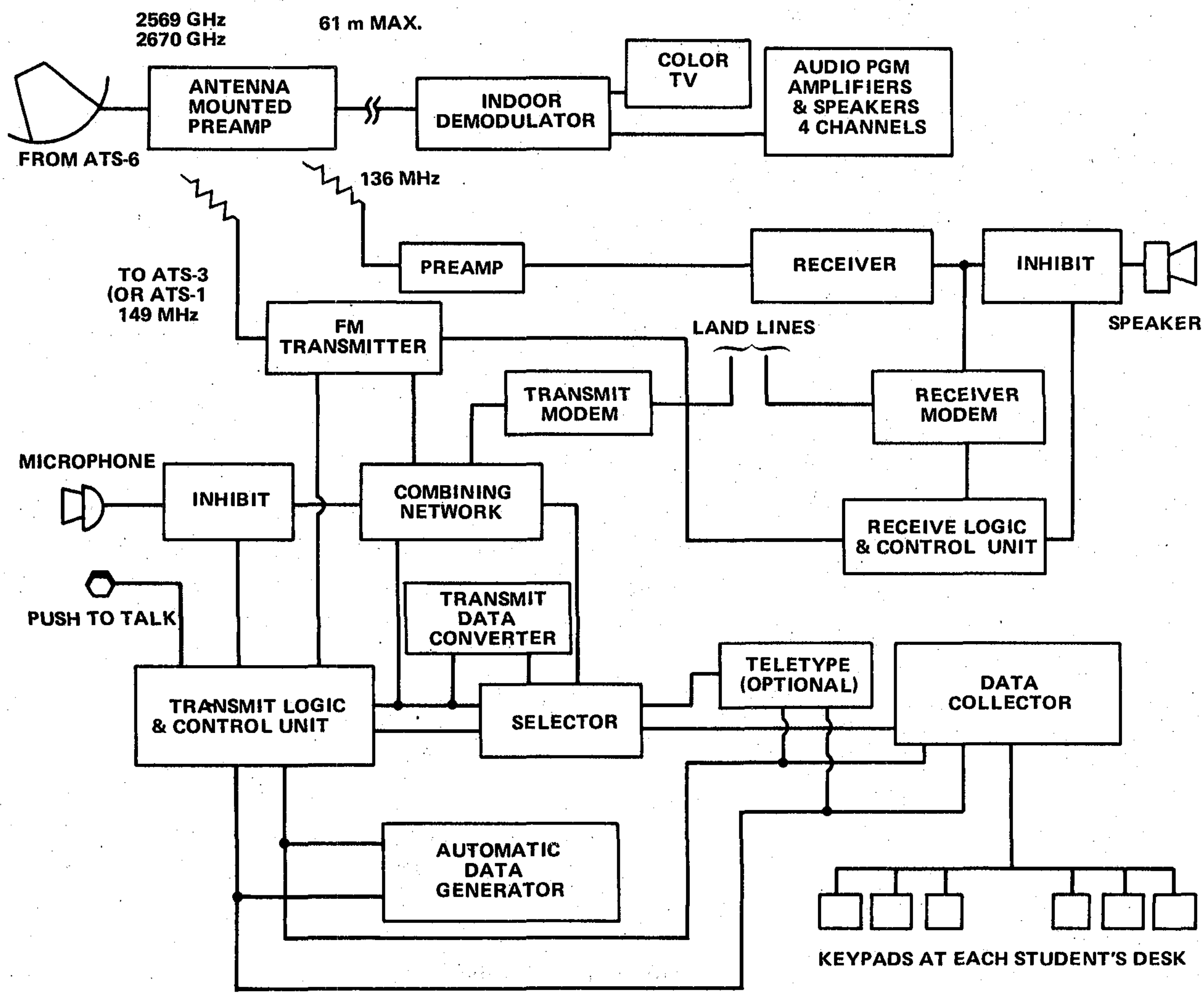


Figure 1-11. Block Diagram of VHF Terminal Configuration

center. The ROT terminals consisted of a 3.05-meter parabolic reflector; an antenna-mounted, low-noise transistor preamplifier; and an indoor demodulator unit. A composite spectrum of the audio subcarriers and the video signals were transmitted by wideband FM on either of two rf channels whose carriers were centered at 2566.7 MHz and 2667.5 MHz.

To assure satisfactory operation at the stations near the beam edge, a 3.05-meter parabolic reflector and a low-noise preamplifier front end were necessary to receive the required rated output signal that had a 49 dB peak-to-peak video to weighted rms noise ratio.

The antenna had a prime-focus feed with a right-hand circular polarized helix that would accept a downlink signal that was left-hand circular polarized. A measured gain of 35 dB at a frequency of 2500 MHz was provided by this antenna with an efficiency of 53 percent. The antenna mount had an adjustment range of ±20 degrees in azimuth and an elevation range from 0 degree to 70 degrees. Inclination of the spacecraft orbit was ±2 degrees with respect to the equator at the beginning of the launch. With a 3-dB antenna beamwidth of only 2.7 degrees, a daily repointing of the antenna was required. Because of the relative position of the ground receiving terminals with respect to the satellite, the only adjustment necessary was in elevation. To expedite the elevation adjustment, 89 of the terminals employed a motorized remote control system. Minor adjustments were occasionally necessary in azimuth to account for the precession of the spacecraft orbit.

The low-noise preamplifier was a sealed unit with an rf gain of 55 dB, a noise figure of less than 4dB and was permanently mounted to the antenna. The remainder of the total receiver gain of 130 dB was in the indoor unit.

The S-band receiver accepted a wideband fm signal at either of two frequencies centered at 2569.2 MHz or 2670.0 MHz and provided a National Television Standards Committee (NTSC) standard video output signal at a baseband suitable for driving television monitors. The receiver also provided four audio channels, transmitted as subcarriers in the video channel from 4.65 MHz to 5.36 MHz.

Early in the development of the receiver, a decision was made not to remodulate the video signal onto a standard television channel because a high quality modulator covering all vhf (2 to 13) television channel would cost considerably more than that of a standard model. The receiver differed from ordinary microwave video receivers in two important respects: a fast automatic gain control loop was used instead of a limiter, and it demodulated the signal at the received rf frequency rather than at an intermediate frequency. The fast AGC loop used a PIN-diode attenuator network that provided up to 40 dB of amplitude-modulation (AM) suppression over a 40-MHz bandwidth. The only disadvantage with this type of AM suppression system was that the dynamic threshold was sensitive to the peak-to-peak deviation of the video signal; however, the threshold was under 11 dB for the signal format that was employed.

The video signal was demodulated directly at rf using a transmission line discriminator of a balanced and compensated design. The discriminiator bandwidth covered the entire frequency allocation from 2500 MHz to 2690 MHz. A desired channel was selected by a 23.5-MHz bandpass filter that was centered at the selected frequency channel. Since the programming of the transmissions operated on fixed channel assignments throughout the duration of the experiment, there was never a need to change the filters. With the receiver being a tuned-radio-frequency type, all the gain was at the 2500 MHz frequency. A block diagram of the S-band receive-only terminal is presented in Figure 1-12.

As mentioned previously, the four audio channels at the 2.5-GHz receive-only terminals were transmitted as subcarriers above the video spectrum. The four-channel audio distribution system was an extension of the video transmission. A variation of its use was the addition of prerecorded signals on tapes for polling applications. To use this capability, distribution cables, encoders/decoders, individual response pads, and headphones were connnected to the receiver.

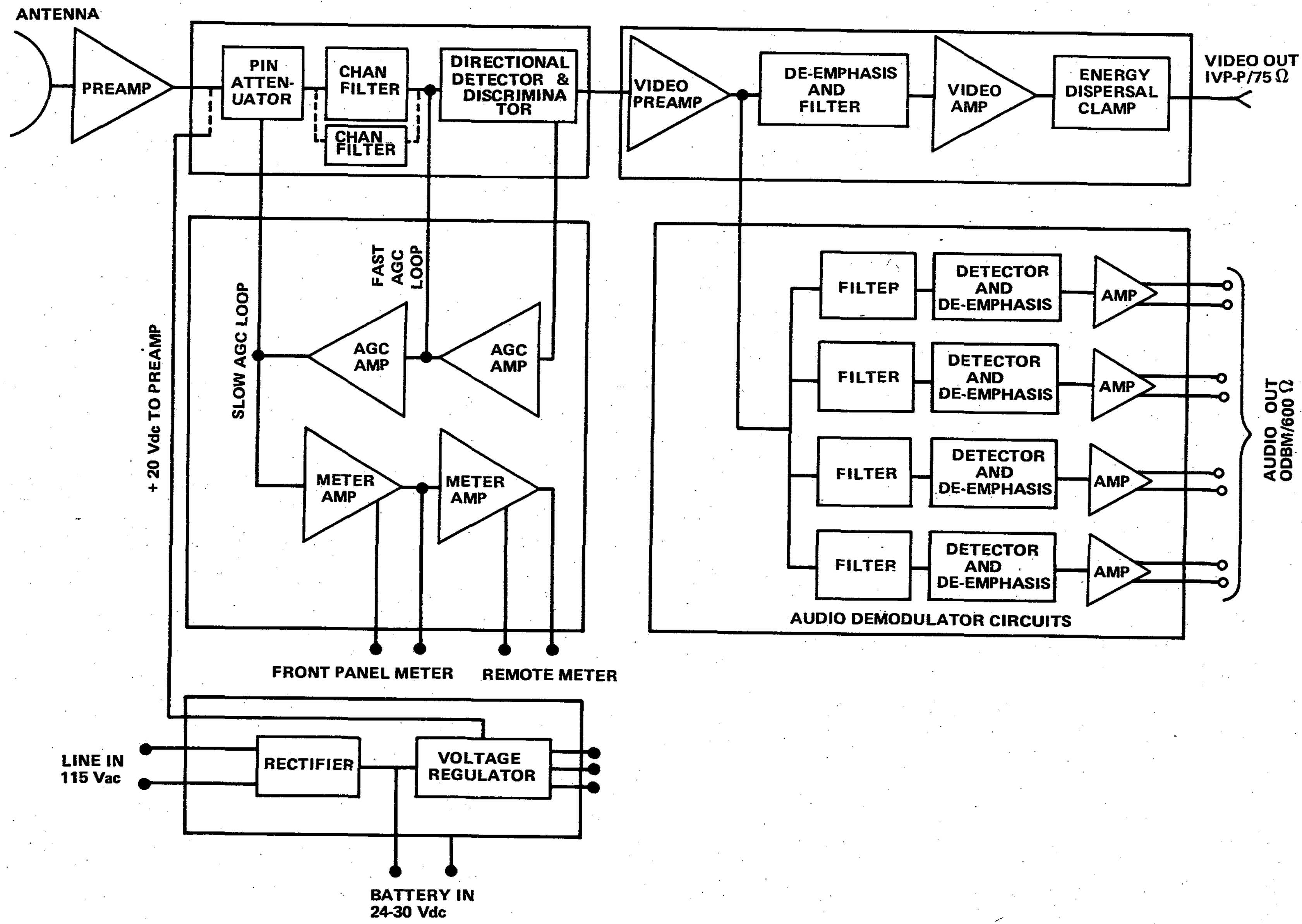


Figure 1-12. Block Diagram of S-Band Receive-Only Terminal

LINK CONFIGURATIONS AND PERFORMANCE

Introduction

The HET network covered 23 states in the Rocky Mountain and Appalachian regions, in Alaska and the Pacific Northwest. A functional representation of the various links that made up the HET experiment is shown in Figure 1-1. As shown, there were 121 video receive-only terminals that operated at S-band. Forty-nine of the terminals were capable of receiving the transmitted voice and data at vhf using ATS-1 or ATS-3 as relays. Five of the low-cost terminals could transmit and receive at S-band. Two of the terminals could transmit at C-band (6 GHz); also one uplink facility, located at Morrison, Colorado, could interface with the satellites at 4 and 6 GHz, and 135.6 and 149.2 MHz. An example of the large number of links involved in the overall experiment is shown in Figure 1-10 for the WAMI portion of the experiment. Because of the multiplicity of links in the overall experiment, it is reasonable to present a description of the various links according to frequency rather than locations.

S-Band Links

S-band transmitters were limited to operating in Alaska because interference on the uplink frequency would result if they were operated within the continental United States. The system parameters for the 2250-MHz S-band uplink are shown in the following list.

Earth station e.i.r.p. (peak)	4.74 dBW
Path loss at 2.25 GHz	191.0 dB
Pointing error losses:	
Spacecraft	0.5 dB
Ground receiver	0.5 dB
Miscellaneous losses	0.6 dB
System noise bandwidth = 24.7 MHz	73.9 dB-Hz
Satellite G/T (PFF)	10.4 dB/K on axis
Uplink CNR	19.9 dB
Antenna diameter	3.1 meters
Gain (55%)	⩾34 dB
Transmitter power to feed	50 watts, nominal

The S-band downlink could be used with either an S-band uplink or a C-band uplink. As previously stated, the former was employed in the Alaskan sector and the latter in the continental United States.

The following lists the system parameters for the 5947.5-MHz uplink:

Earth station e.i.r.p. (peak)	84.0 dBw
Path loss at 6 GHz	200.1 dB
Pointing error losses:	
Satellite	0.4 dB
Morrison	0.5 dB

Miscellaneous losses	0.3 dB
System noise bandwidth = 24.7 MHz	73.9 dB-Hz
Satellite G/T (ECH)	-14.0 dB/K
Uplink CNR	23.4 dB
Antenna diameter	11 meters
Gain (55%)	53.1 dB
Transmitter power	3 kW
Waveguide loss	1.0 dB
Operating margin	2.9 dB

The S-band (2500-MHz) downlink parameters and the overall link carrier-to-noise ratio (CNR), measured and calculated, are presented in Table 1-3. A measured overall CNR of 16.4 dB was obtained. This resulted in a measured post-detection signal-to-noise ratio (SNR) of 50.4 dB. Excellent television fidelity was obtained for SNR values of this magnitude. The required SNR values were determined for five TASO (Television Allocation Study Organization) grades of subjective viewing fidelity.

Table 1-3
Communications Systems Parameters

Element	Calculated	Measured/Used
Satellite e.i.r.p. (FOV)* (dBW)	47.9	49
Path loss at 2.5 GHz (dB)	192.6	192.6
Pointing error losses (dB):		
Spacecraft	0.5	0.5
Ground receiver	1.0	0.5
Miscellaneous losses (dB)	0.5	0.5
System noise (Bandwidth = 25 MHz) (dB · Hz)	74	74
System G/T (dB/K)	7.1	8.0
Downlink CNR** (dB)	15.0	17.5
Uplink CNR (dB) – 6 GHz	23.0	23.4
Resultant received CNR (dB)	14.4	16.4
Deviation index	2.38	1.96
FM improvement (dB)	17.0	16.4
Preemphasis improvement (dB)	2.4	2.4
Noise-weighting factor (CCIR) (dB)	10.2	10.2
Peak-to-peak video conversion factor (dB)	6.0	6.0
Peak-to-peak video signal-to-rms noise ratio (dB)	50.0	51.4
Less implementation loss (dB)	–	1
Net signal-to-noise ratio (dB)	–	50.4

*FOV–Field of view for PFF/reflector
**CNR–Carrier-to-noise ratio

For an S-band uplink, the overall link CNR for the total S-band system is 15.5 dB (uplink CNR is 19.9 dB and downlink CNR is 17.5 dB). The resulting SNR for the overall S-band link is 44.5 dB. This magnitude also ensured a good quality television picture.

C-Band Links

To accommodate the Washington, Alaska, Montana and Idaho regions, C-band Earth stations were built for use in the State of Washington. The various C-band uplinks and downlinks are shown in Figure 1-10. The corresponding downlink (3947.5 MHz) parameters are shown in the following listing:

Satellite e.i.r.p. (ECH)	25.7 dBW
Path loss at 4 GHz	196.5 dB
Pointing error losses:	
Spacecraft	0.3 dB
Ground receiver	0.3 dB
Miscellaneous losses	0.6 dB
System noise bandwidth = 24.7 MHz	73.9 dB-Hz
System G/T	28.5 dB/K
Downlink CNR	11.2 dB
Uplink CNR (6-GHz)	23.4 dB
Resultant received CNR	10.9 dB
Deviation index	1.96
FM improvement, dB	15.3 dB
Preemphasis improvement	2.4 dB
Noise-weighting factor (CCIR)	10.2 dB
Peak-to-peak video conversion factor	6.0 dB
Peak-to-peak video to weighted rms noise ratio	44.8 dB
Less implementation loss	1.0 dB
Net SNR	43.8 dB

For an uplink CNR of 23.4 dB, the resulting downlink CNR was 11.2 dB and an overall link CNR of 10.9 dB was obtained. The post-detection SNR was 43.8 dB. This SNR value still produced an excellent TASO grade picture quality.

Very High Frequency Links

Introduction

The vhf links were instrumented by employing both ATS-1 and ATS-3. Seventeen of the 121 terminals were instrumented to provide two-way voice/data communications via ATS-1. Thirty-two of the terminals were instrumented to provide the same capability via ATS-3. Two of the terminals were instrumented to provide the capability via ATS-1 and ATS-3. The overall spacecraft system parameters are listed in Table 1-4.

Table 1-4
VHF Communications System Parameters—ATS-1 and ATS-3

	ATS-1	ATS-3	Units
Location	149°, ±1°	70°, +1°	W. long.
Orbit inclination	7.34°	5.74°	–
E.i.r.p. (September 1970)	48.0	47.6	dBm
Receiver noise figure	4.0	4.0	dB
Receiver bandwidth	100.0	100.0	kHz
Transmitter frequency	135.6 ±0.05	135.6 ±0.05	MHz
Receiver frequency	149.22 ±0.05	149.22 ±0.05	MHz
Translation error	±50	+800, ±100	Hz

The significant system parameters for the vhf ground stations were:

Transmitter: 300-watt General Electric unit

Receivers: Two specially modified GE receivers for phase-lock modulation; one GE receiver for voice reception

Communication with NCC was by dedicated phone lines with encode/decode modems for data transmissions

Modulation: FM

Frequencies:

Channel 2 transmit: 149.195 MHz
Channel 2 receive: 135.575 MHz
Channel 4 transmit: 149.245 MHz
Channel 4 receive: 135.625 MHz

Antennas: Two single 9-turn helicals and 1 phased array of three 9-turn helicals mounted on a motorized azimuth/elevation table

VHF Link Configurations

The overall link characteristics for the vhf system are shown in Table 1-5. The calculations show that the system was downlink limited by a factor of 8.4 dB. The overall link ratio of carrier power to spectral noise density (C/N_o) was 56 dB. This produced an overall CNR of 14 dB in a 16-kHz bandwidth.

Assuming a 300-watt ground transmitter, the resulting test-tone signal-to-noise ratio (test tone-to-noise [TT/N]) was 25 dB, and the error rate for the digital transmission was smaller than 10^{-6}. For the typical links listed in Table 1-5, the TT/N should be about 20 dB. The error value should still be less than 10^{-6}.

Table 1-5
ATS-1 and ATS-3 Remote Site Transmit/Receive Terminal Parameters

Rf power at transmitter	100 W (typical)	
Rf power at antenna	80 W (typical)	
Antenna gain (linear)	10 dBi	
E.i.r.p.	29 dBW	
Uplink carrier/noise ratio	65 dB-Hz	
Satellite downlink power (full power mode)	17 dBW	
Path loss at 135.6 MHz	167.5 dB	
Preamplifier noise temperature	300 K	
Sky and manmade noise	200 to 1200 K	
Downlink C/kT (worst case)	56.6 dB-Hz	
Total C/kT	56.0 dB-Hz	
Antenna	9-turn helical	
Operation	Half-duplex*	
Operation and control (indoor unit)	By digital coordinator**	
Transceiver	Modified GE unit	
	Voice	Digital
Predetection noise bandwidth	16 kHz	3 kHz***
Post-detection bandwidth	300 to 3400 Hz	–
Type of modulation (receive)	Analog FM	FSK, both channels
Type of modulation (transmit)	Analog FM	Channel 2: PSK Channel 4: FSK
Test-tone signal/noise ratio	25 dB****	–
Data bit rate	–	1200 bps
Energy noise density (per bit)	–	29 dB
Expected error rate	–	$<10^{-6}$
Frequency	149.195 MHz 135.575 MHz 149.245 MHz 135.625 MHz	Channel 2 transmit Channel 2 receive Channel 4 transmit Channel 4 receive

*The half duplex used a diplexer and a low-noise preamplifier at the antenna.
**The digital coordinator transmitted and received a 5-word preamble for identification and control operations; it also served as the front panel for the vhf equipment.
***Noise bandwidth equals: $\pi/2 \times 3$ bandwidth.
****The 25 dB figure is based on the 300-watt transmitter used by the Morrison uplink.

SYSTEM EFFECTIVENESS

Introduction

Because of the large number of participants in the overall HET experiment, a detailed listing of the results from each station would be impractical. Therefore, a statistical approach using a defined concept called the "system-effectiveness factor" will be presented as an overall measure of the ability of the system to meet the required objectives. Also a discussion of the support structure for the HET experiment will be presented. This involves equipment operation, equipment maintenance, and network coordination. The third part of the section will involve a discussion of the availability of the peripheral equipment employed at the sites.

System-Effectiveness Factor

A quantitative estimate of how well the system met or exceeded its objectives can be obtained from a defined system effectiveness (Reference 7) probability function P_{SE}. System effectiveness (SE) was measured as a product of two probabilities–availability (A) and design adequacy (DA)–as shown in the following equation:

$$P_{SE} = P_A \times P_{DA}$$

Availability, which is a measure of system reliability, is the probability that the system operated satisfactorily during scheduled operating times. Availability excludes assessment of the quality of performance and uses as criteria a go/no-go dichotomy for uptime and downtime. If the systems operated in such a manner that programs were not watched, then the station was not operational and downtime was recorded.

Design adequacy is the probability that the system successfully accomplished its mission, given that the system was operating within design limits. Thus, design adequacy is not a function of time, but measures the performance level of operation and is computed from signal quality information.

Availability (P_A) is computed from this equation

$$P_A = \frac{\text{(total operating time)}}{\text{(total operating time)} + \text{(total downtime during demand time)}}$$

Design adequacy (DA) is computed as the following ratio:

$$P_{DA} = \frac{\text{number of instances (OMR reports) accomplishing mission}}{\text{total number of observed operational instances (OMR reports)}}$$

Objective aggregates of signal quality information were obtained by a combination of signal strength measurements and a subjective picture quality rating scale adapted from the Television Allocation Study Organization (TASO).

Although the range of acceptable signal strengths is well established, many factors impact on signal quality that are not manifested in levels of signal strength, such as the effects of seasonal variations on propagation and the effects of interference between space and terrestrial services in the 2500- to 2690-MHz band. Further, the combination of data from signal strength readings and subjective picture assessments provides information not only on quality of performance, but also on idividual effects of the degrading factors.

For the HET experiments, two-dimensional, signal-quality range scales were employed by remote equipment operators for both audio and video assessments. However, for the Washington, Alaska, Montana, and Idaho program; the Indian Health Service (Alaska) experiment; and the Alaskan Educational experiment development only one-dimensional scales were used.

The mission that had to be met at receive-only terminals was a TASO 1, a weighted, peak-to-peak, video-to-rms noise of 49 dB and an associated audio SNR of 44 dB. TASO 1 corresponds to a Hewlett-Packard (HP) receiver meter signal strength reading of 11 dB or better. At vhf sites, a minimum test-tone SNR of 20 dB was required. All information on remote sites was recorded daily on optical mark read (OMR) cards.

S-Band System Receive-Only Terminals

Design Adequacy—Calibrated signal strength data were obtained at 10 HET S-band receive-only sites in the Rocky Mountains. The data were contained in a series of tables and graphs written over a 3-month period from July to September 1975. Average HP signal strength readings from these same 10 sites were obtained from OMR cards during the November 7, 1974 to May 14, 1975 period. Also, the Network Coordination Center compiled NASA telemetry data regarding the signal levels in ATS-6 from transmissions originated by Rosman, Seattle, Omak, University of Washington, and Morrison.

The results pertaining to the calibrated sites were quite accurate (+1.5 dB). The same cannot be said for the estimates concerning median sites in Alaska, Appalachia, and the Rocky Mountains.

Nine of the 10 calibrated sites (the exception being Panguitch, Utah) were far from beam center. Nonetheless, calculated carrier-to-noise ratios ranged from 13.4 dB to 19.4 dB, and calculated signal-to-noise ratios ranged from 46.3 dB to 52.3 dB. The median SNR of 56 sites in the Rocky Mountains was estimated to be 51.1 dB; the median SNR for Alaskan and Appalachian sites was estimated to be 48.1 dB and 45.6 dB, respectively.

It was not clear why average Appalachian Regional Commission (ARC) sites received significantly less signal than did average Rocky Mountain sites. Possibly the geometry of the coverage pattern from ATS-6 placed a higher percentage of ARC sites at the periphery of the footprint. Also, ARC operators did not have motorized elevation adjustment mechanisms, and because the manual adjustment was inconvenient to use, they made fewer adjustments than did operators who used motorized mechanisms. The lower signal levels received in the Alaskan region are explained by the following factors: The larger path loss from ATS-6 to Alaska; the low e.i.r.p. of the transmitters used for Alaskan broadcasts (in Seattle, Omak, and the University of Washington); and the extremely low elevation angles of the receivers in Alaska.

A listing of the system parameters measured for various sites is shown in Table 1-6. The resulting CNR and SNR values were more than adequate for excellent television reception.

Table 1-6
SNR's and CNR's (11/7/74 to 5/15/75)

Site	HP SS	C_{in} (dBm)	Noise Figure	Sys. Noise Temp.*	CNR_{down}	CNR_T (dB)	SNR (dB)
Hayden, AZ	13.11	-82.86	4.20 dB	548°K	14.43 dB	13.4	46.3
Gila Bend, AZ	17.02	-75.98	4.34 dB	573°K	21.11 dB	18.6	51.5
St. Johns, AZ	16.90	-76.20	4.27 dB	560°K	21.00 dB	18.5	51.4
W. Yellowstone, MT	18.45	-77.03	4.07 dB	525°K	20.44 dB	18.1	51.0
Whitehall, MT	16.78	-77.72	4.20 dB	548°K	19.57 dB	17.5	50.4
Heber City, UT	15.70	-82.43	4.38 dB	580°K	14.61 dB	13.5	46.4
Panquitch, UT	19.02	-74.96	4.00 dB	513°K	22.62 dB	19.4	52.3
Pinedale, WY	16.11	-77.78	4.20 dB	548°K	19.51 dB	17.5	50.4
Saratoga, WY	17.87	-77.13	4.20 dB	548°K	20.16 dB	17.9	50.8
Sundance, WY	18.45	-76.55	4.05 dB	522°K	20.95 dB	18.4	51.3
Median Rockies (56 sites)	17.20	-76.72**	4.20 dB	548°K	20.57 dB	18.2	51.1
Median ARC***	14.76	-81.12**	4.20 dB**	548°K	16.17 dB	15.2	48.1
Median Alaska****	14.40	-81.73**	4.20 dB**	548°K	15.56 dB	12.7	45.6

*The receiver noise temperature is calculated from the expression $T_n = (F - 1)(290)$. It is assumed that the net contribution from sky noise and insertion loss is 75 K. The system noise temperature, then, is related to the receiver noise figure in this manner: $T_{sys} = (F - 1)(290°) + 75$ K, where F is the antilog of the receiver noise figure in decibels.

**Estimated.

***The ARC typically received its programming from Rosman, which provided a higher e.i.r.p. than did Morrison. The average uplink CNR between November 1, 1974 and May 14, 1975 is estimated from telemetry data to be 26.82 dB. Noise contribution from the microwave link between Lexington, Kentucky, and Rosman, North Carolina, is assumed to be negligible. Note that the estimated median received signal strength in the ARC (-81.12 dBm) is 4.4 dB lower than the estimated median received signal strength in the Rocky Mountains.

****Alaska typically received its programming from Seattle, Omak, or College. The average uplink CNR from January 7, 1975 to May 14, 1975 is estimated to be 17.18 dB. Noise contribution from the signal sources (cameras or VTR's), microwave link, and nonlinearities in the electronics of the transmitting station is assumed to be negligible.

The SNR of the S-band receiver was measured at Morrison, Colorado, which was on the periphery of the southeast footprint and resulted in a value of 49.7 dB. Link parameters for the Morrison terminal were as follows:

E.i.r.p. (ATS-6 peak)	=	82.7 dBm
Path loss (2569 MHz)	=	192.74 dB
Antenna gain (54 percent efficiency)	=	35.62 dB
Off-axis loss	=	4.5 dB
Receiver noise figure	=	4.2 dB
CNR downlink	=	18.3 dB
CNR uplink	=	23.5 dB
Total CNR	=	16.6 dB
SNR	=	49.7 dB

An SNR of approximately 43 dB or better was required to provide a TASO 1 picture, and corresponded to a total CNR of approximately 10.5 dB or better. For an uplink CNR of 23.5 dB, a total CNR of 10.5 dB corresponded to a downlink CNR of 11.4 dB and an HP meter reading of 11. Cumulative histograms from a total of 8,105 optical mark read reports indicated that an HP meter reading of 11 or better was received 95.2 percent of the time in the period extending from July 29, 1974 to March 16, 1975, as shown in Figure 1-13.

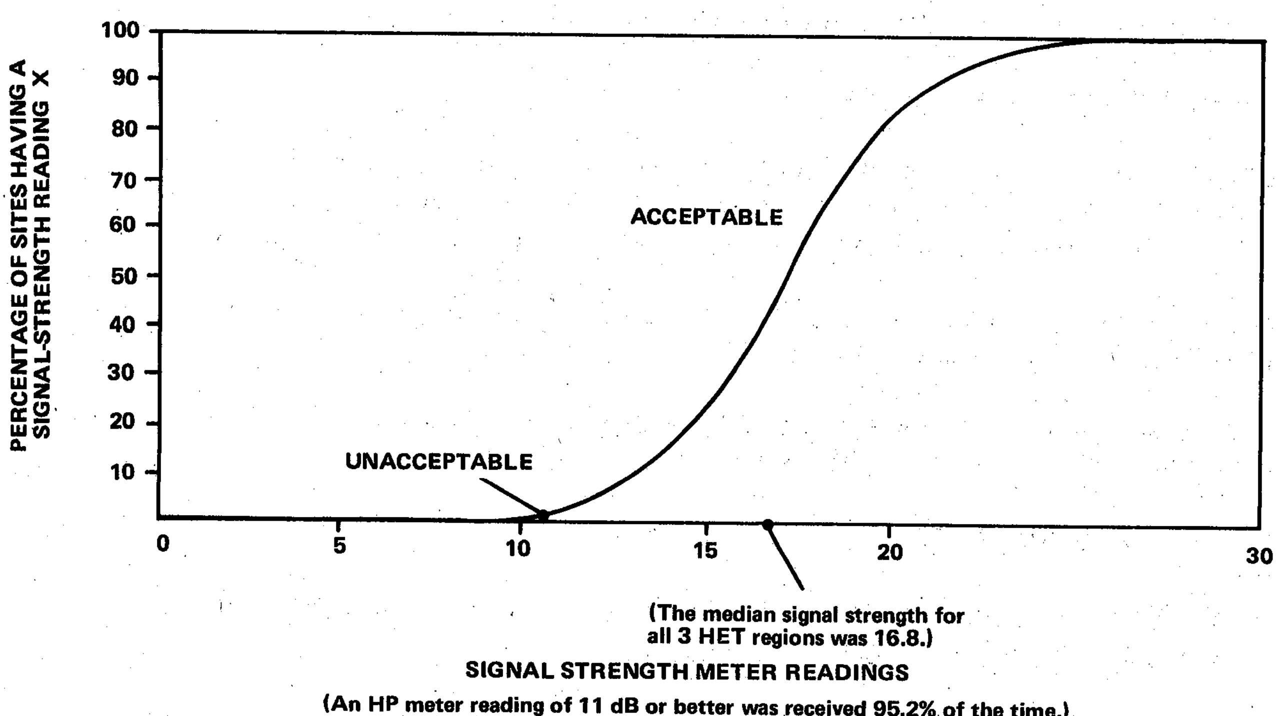


Figure 1-13. HET Cumulative Histogram of HP Signal Strength Meter Readings from July 29, 1974 to May 16, 1975 in all Three Regions

Of the 167 OMR reports indicating an HP meter reading of less than 11, a total of 104 rated the picture and sound quality excellent (TASO 1). In only 63 instances was the quality rated less than excellent; therefore, design adequacy that measured the capability of the S-band satellite system to provide TASO 1 quality was computed and a value of 99.223 percent was obtained.

The cumulative OMR reports showed that weather had no impact on signal strength. Two factors contributed to this lack of impact: (1) In the Alaskan region, parabolas were positioned at right angles to the Earth so that snow and rain would slide off the antenna; and (2) site operators cleaned snow and ice off the antennas. Snow and ice accumulations at the Denver uplink station in Colorado, indicated that, if both were allowed to accumulate on the antenna, there would be a degradation of signal strength and quality.

Availability—The 2.5-GHz receive-only terminals were observed for a total of 19,512 operating hours. For each day that a site was logged as "down," i.e., transmissions were not received because the site equipment had failed, 90 minutes of downtime was recorded. The 90-minute figure was the average operating time for each HET site per operating day. Note, however, that this was a conservative estimate, based on the assumption that, in each case, the equipment was inoperative when the system was first turned on.

There were 73 down days during the observed period which resulted in an availability of 99.442 percent for the 2.5-GHz receive-only terminals. A corresponding system effectiveness of 98.669 percent was achieved for the 2.5-GHz receive-only terminals.

S-Band Transmit/Receive Terminals

Design Adequacy—Superior picture quality, TASO 1 and TASO 2 (excellent and fine), was reported for the five S-band uplink terminals in Alaska. The system consistently delivered a TASO 1 picture; however, the extreme cold in that region made fine alignment of the antenna difficult.

Availability—Only one failure occurred when an S-band transmitter could not be turned on, caused by extremely low temperature (-57°C).

The S-band uplink terminals were observed for a total of 1,032.5 operating hours which provided an availability of 99.855 percent for the system.

C-Band Transmit/Receive Terminals

Design Adequacy—For the 4-GHz receive downlink, the typical signal level from ATS-6 was -82 dBm, with picture quality of TASO 1 and TASO 2.

Availability—The availability of the C-band transmit/receive terminals was excellent. Although cable attenuation and insufficient receive gain prior to mixing caused initial difficulties; these problems were quickly corrected.

The system at Omak, Washington, was observed for a total of 198 hours and 20 minutes. During that time, there was only one failure causing downtime when the transmitter temperature control system malfunctioned. Therefore, availability was computed and resulted in a value of 99.249 percent.

The HET experiments required a satellite Earth station capable of originating a single video channel with four associated program channels to each of the regions served. As a result the Denver uplink terminal was developed.

The uplink was operational for a total of 1,117 hours from June 1974 to April 1975. Total outages, including Network Coordination Center outages, power failures, and operator errors, amounted to 118 minutes. Therefore, availability for the Denver uplink terminals, including the NCC, achieved a value of 99.824 percent.

VHF Transmit/Receive Terminals

Design Adequacy—Signal quality at the vhf terminals consisted of two categories: voice signals and digital signals. With the exception of the Appalachian Educational Satellite Project, the system was used almost exclusively in the voice mode.

The digital capabilities of the vhf terminals were used only for brief testing periods. Several factors relating to scheduling, delivery, design, and testing prevented use of the digital data transmission system for the original network preprogram polling plan.

Voice quality data showed that intersite reception and NCC reception were unreliable. Fluctuations in quality were not predictable. Definite causes were not found, although considerable effort was expended seeking both causes and solutions. Extensive modifications and tests were made at the receiving antenna system at the Denver Uplink Terminal, including a test by a field team that had portable instruments for detecting radio frequency interference. Other tests seemed to indicate that signal quality was a function of antenna location, but the results of these tests were inconclusive. Signal results at both Denver, Colorado, and Tucson, Arizona, however, did indicate that rfi was more prevalent in metropolitan areas, and that transmissions were difficult to receive at the NCC location in Denver.

Although statistically significant data were not available regarding NCC reception, observers noted that in some cases up to 18 percent of attempted responses were inaudible.

There were considerable data concerning the quality of voice signals received from the NCC. The data neither reflected the sites' abilities to hear each other nor indicated the quality of reception at the NCC from remote sites. In evaluating the data, the NCC voice uplink used a 300-watt transmitter and, therefore, was less subject to interference than the 90-watt transmitter used at remote sites.

Most of the data were obtained from optical mark read cards recorded at remote sites. The data used readability and relative strength scales from 1 to 3, with quality increasing in that direction.

Design adequacy for the terminals was measured on the basis of the quality of the signal received at the remote sites. A readability of "3" and a signal strength of "2" or better was set as the standard for superior signal quality. For all three regions during the observed operating period, the design adequacy achieved was 95.671 percent.

Availability—The vhf two-way transmit/receive terminals were observed for a total of 8508 hours and 49 minutes which was the same for the receive-only terminals. Ninety minutes of downtime occurred for each day logged as "down." There were 93 down days during the observed period; therefore, for the vhf two-way transmit/receive terminals, availability was determined to be 98.387 percent.

The overall system effectiveness for vhf terminals was 94.128 percent.

To meet commercial communication standards, system effectiveness must exceed 99.9 percent. Whether system performance at 94 percent is sufficient for a particular service must, however, be determined on the basis of the individual needs.

Four-Channel Audio Distribution System

The four-channel audio distribution system used in the Appalachian Educational Satellite Project (AESP) was the least successful subsystem in the network, because its effectiveness was never demonstrated. Late delivery and the consequent lack of test and checkout time made it impossible to correct design and quality control flaws until operations were underway. Operators experienced severe crosstalk from other channels. The crosstalk, in turn, resulted in poor voice quality with a great deal of static and weak signal strength. The crosstalk problem was resolved by removing the individual ground on the classroom distribution amplifier and replacing it with a common ground. By the time the problem was corrected, however, the site operators were negatively biased by the problems already encountered; therefore, little additional data was collected.

The four-channel capability was employed not only for the audio mode, but also for digital polling purposes. As with the audio mode, problems were encountered in design and quality control. Because the four-channel data collection system was deficient, an alternative configuration for future applications was recommended such as elimination of response pads and use of a typewriter device with a mechanical, rather than an electronic, data-collection system. However, data polling and recording on cassette tape can be extremely reliable. An improved electronic version rather than a substitute mechanical configuration would be a more suitable alternative, considering the inherent benefits of this technology.

Support Structure

The quality of operator performance at the terminals, prior to conducting the HET experiments, was surveyed for three primary factors consisting of type of work, interest, training and capabilities in technology particularly in communications equipment. This survey, identified as the "Site Operator Profile," was administered to 82 of the 121 terminal operators. Prior to performing the experiments the major interests indicated by the terminal operators were in photography, machine repair, and audio systems. Only a small number of operators showed any interest in radio or other types of communications equipment and most of them were unfamiliar with the new mode of communications used by HET.

A training program for the operators was established prior to the performance of the HET experiments and was followed by a written examination. The test covered three basic areas consisting of network operational procedures, use of equipment, and hardware data gathering requirements. All of the training program focused on the proficiency of operator performance.

The prime operational goal in the maintenance of the HET ground network was to provide a capability of performing repair work within a 24-hour period. Time required for repair service depended upon the operators in providing efficient network coordination and reports containing accurate and reliable technical data. Three maintenance personnel were employed at the HET network for the 22 terminals in the Alaskan and WAMI experiment; three people were employed for the 26 terminals in the Appalachian experiment; and four people for the 71 terminals in the Rocky Mountains.

The total Satellite Technology Demonstration (STD) broadcast and engineering staff in Denver, Colorado, consisted of 16 members, including the maintenance team. These people had the additional responsibilities of assisting NASA in planning and implementing the terrestrial network, and installing, maintaining, and operating the Network Coordination Center and the Denver Uplink Terminal. In addition to staff employees, each experimenter employed consultants and used subcontractors.

An evaluation of the HET network coordination was performed primarily in management coordination in the technical areas and administrative procedures. In the ATSOCC/Rosman/Mojave interface, the NASA communications network (NASCOM) was an efficient system for network coordination and consisted of both voice and teletype circuits. An audio and video patch panel in the Network Coordination Center provided flexible signal routing and diagnosis that contributed significantly to the efficiency of the network coordination function.

Link reliability in the vhf range (135 MHz to 149 MHz) was relatively poor. In addition to propagation-related fades, interference was experienced from non-U.S. operators in various western hemisphere locations. The 300-watt transmitter at the Denver Uplink Terminal was able to override most interference and to reach the remote sites; however, the 90-watt transmitters at the remote terminals were subject to interference. Thus, the incoming messages from the remote terminals to the NCC were occasionally unintelligible, and the vhf interaction loop, a device permitting the terminals to hear the questions asked by rebroadcasting them over ATS-6, was unreliable. However, as a management coordination tool for relay of preprogram and post-program data, the vhf was effective.

A mapboard in the NCC displayed all of the HET remote terminals by location and type of equipment. Real-time status of terminals displayed on the mapboard was not available for all of the HET experiments. The dedicated phone line between the NCC and the Veterans Administration program origination center at KMGH-TV in Denver, Colorado, proved to be a necessary communications link.

Network failures were generally of short duration. Available backup equipment usually provided adequate network redundancy.

Peripheral Equipment

An unanticipated problem–and the greatest single source of failure reports from the sites–was defective peripheral equipment, such as television monitors and videotape recorders.[1] The repair of peripheral equipment was not the responsibility of HET maintenance personnel, but of the supplier; neither was the HET maintenance crew expected to provide an assessment of these commercially available products.

A special phone survey was organized in the Rocky Mountain region to gather data on both positive and negative video tape recorder performance. The following are the results of the survey:

- Video tape recorders were located at 42 STD sites.
- Thirty-one STD sites had some video tape recorder equipment malfunctions.
- Nineteen sites had a video tape recorder failure problem for at least one week.
- Thirteen sites had a video tape recorder failure problem for three to eight weeks.

In general, many of the users were clearly pleased with the video tape recorders; therefore, they should be considered a step forward in audio/video technology. However, the number of failure reports and the amount of time involved in repairing the video tape recorders make it necessary to conclude that this item had a poor reliability factor when used to provide services to isolated population areas.

The problem with television monitors used throughout the HET network were also disconcerting. In fact, the problems with the monitors were more severe than those of the video recorders in terms of delivery and service. The main problem was that the monitors were inoperative when they were delivered to the sites. At least 20 of the sites reported this problem. Servicing of the monitors became a very serious problem especially in rural areas. Long delays were experienced in requests for service and delivery at the sites.

SUMMARY AND CONCLUSIONS

General

The Health, Education, Telecommunications Experiment involved six different experiments conducted under the auspices of the Department of Health, Education and Welfare (HEW) with technical assistance from NASA. The six experiments were conducted in three geographical regions.

[1]See reference 8 in the bibliography at the end of this volume.

They were: (1) Alaskan Education Experiment, (2) Alaskan Health Services Experiment, (3) Washington, Alaska, Montana, Idaho (WAMI) Experiment, (4) Rocky Mountain States Education Experiment, (5) Veterans Administration Health Education Experiment, and (6) Appalachian Regional Commission Education Experiment.

The overall telecommunications systems to support these experiments consisted of many elements: ATS-6, ATS-1, and ATS-3; 121 receive-only terminals; 49 intensive terminals; and 7 comprehensive terminals and many existing terrestrial facilities. The HET Experiment was a multifaceted joint venture.

System Results

The HET Experiment demonstrated, in almost all aspects, that the performance of the satellite and the low-cost Earth terminals on health and education programs was very successful. These tests showed that an elaborate technical communications network, such as the HET complex, can provide a variety of programs to a large number of users. Despite extreme weather conditions the network operated efficiently with a minimum number of interruptions in services and provided a signal quality that exceeded the minimum design specifications.

The HET terrestrial network coordination system, implemented through NCC operations, performed at a high level of efficiency within 2 months of starting up. Based on the reasonable level of success experienced in delivering a high quality video and audio signal to a large number of small terminals via satellites, it can be concluded that the technical feasibility was demonstrated. Success was achieved in training nontechnical people in the use of satellite communications equipment, obtaining a reasonably high level of reliability from the equipment and maintaining good coordination among the many experimenters in a widely dispersed area. All this was done within modest budget constraints.

The features presented by the HET experiment offer encouragement to small underdeveloped nations to use satellite communications for small isolated communities that cannot afford the cost of expensive terminal equipment and highly skilled technicians.

CHAPTER 2

INDIAN HEALTH SERVICE (ALASKA)

INTRODUCTION

Satellite techniques have proven their ability to provide direct video and voice communication with minimal cost and complexity of equipment to isolated communities in the northern part of Alaska. The continued development of these direct patient-to-physician links is an important part of the potential for providing the native population of Alaska with day-to-day health care. The satellite communications concept is already a proven capability. The human interface remains a factor that still needs to be fully defined.

Past experiments have indicated that the training of community health aides by direct on-the-job experience is a promising potential. The needs for equipment and facilities have been defined and techniques improved. Many of these aspects and their optimization for effective planning will be invaluable to health care planners in the future.

The experiments for the Indian Health Service (IHS) in Alaska were performed in two phases. The first phase of experiments were conducted during the first year of operation of ATS-6 and were a part of the WAMI program of the HET experiments. For information on the WAMI program, refer to Chapter 1 of this volume.

PARTICIPANTS

The participants in the Indian Health Service (Alaska) experiments were:

- NASA Goddard Space Flight Center
- Indian Health Service, Department of Health, Education and Welfare, Washington, D.C.
- National Center of Educational Technology
- Alaska Community Centers of Huslia, Tanana, Bethel, Fort Yukon, Fairbanks, and Anchorage

Anchorage, Huslia, Bethel, and Tanana were the primary participants in the experiment. An outline of site locations, staff, and capabilities is shown in Figure 2-1. Figure 2-2 shows the general configuration of the experiment.

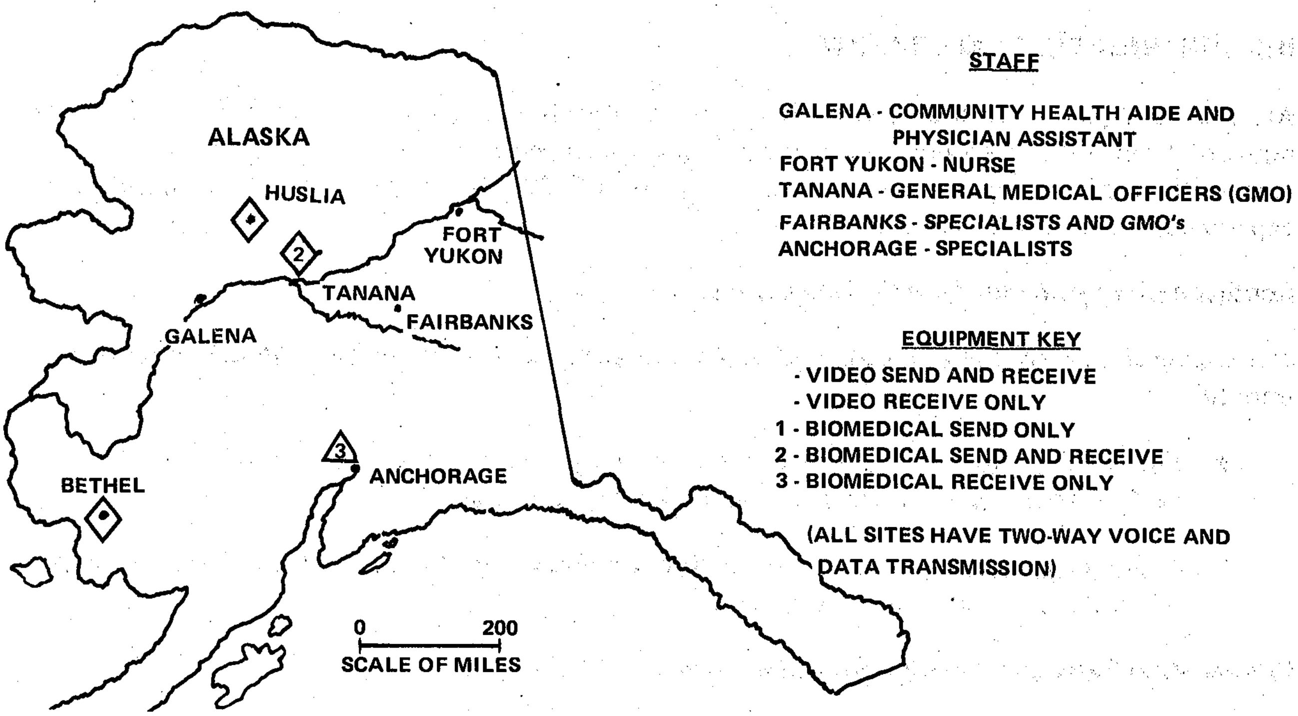


Figure 2-1. Alaska ATS-6 Health Care Experiment, Site Locations, Staff, and Capabilities

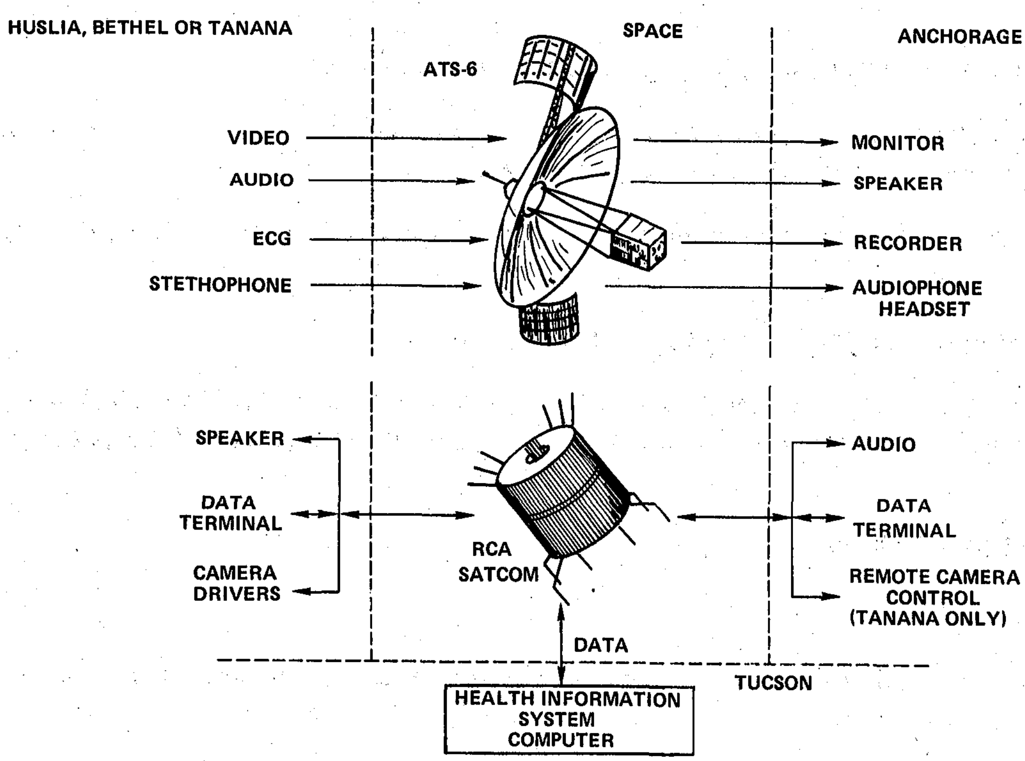


Figure 2-2. Typical Experiment Configuration

IHS CONTINUATION EXPERIMENT

After the completion of the Satellite Instructional Television Experiment over India, ATS-6 was returned from 35°E longitude and resumed the Alaskan Indian Health Service experiments for a second phase of operation between January and April 1979. The continuation of the health care experiment was especially valuable in Alaska.

Continuation Experiment Technical Objectives

The technical objectives in the continuation phase of the Indian Health Service (Alaska) experiment were to:

- Further develop the receive and transmit equipment to attain reliable daily operational performance under Alaskan conditions on a low-cost basis
- Achieve a general familiarity with satellite communication techniques for as large a number of community health aides as possible.

Continuation Experiment Sociological Objectives

With the basic operation and reliability of the satellite links under northern conditions well established, the primary objective of the continuation program was to further develop the techniques of presenting patients to physicians using these telecommunication links. The sociological objectives were to:

- Assess the performance of health aides under Alaskan conditions
- Assess the effectiveness of video and voice techniques used to present a patient for medical examination to a physician with a nurse intermediary
- Determine the optimum equipment, controls, and usage to facilitate the patient presentation
- Determine the effectiveness of patient record retrieval
- Determine whether special patient records, such as EKG's, X-rays, and cell analysis video pictures can be effectively retrieved and presented in conjunction with the patient presentation.

SYSTEM DESCRIPTION

General Configuration

The site locations in Alaska (Figure 2-1) that participated in the continuation of the Indian health experiment were as follows:

Anchorage	Latitude 61° 26′ N, longitude 149° 75′ W
Tanana	Latitude 65° 11′ N, longitude 152° 03′ W
Huslia	Latitude 66° 03′ N, longitude 156° 41′ W
Bethel	Latitude 60° 50′ N, longitude 161° 51′ W

The optimization of the spacecraft antenna pointing was achieved by biasing the spacecraft axes in roll and pitch in response to the signal strength observed by a site observer. The final pointing was latitude 60°N and longitude 156.5°W. The biasing of axes was -0.080 degree in roll and 0.00 in pitch.

The link arrangements were normally one way, where the sites in the field transmitted and Anchorage received. Figure 2-3 shows the geographical locations of the sites in Alaska. The satellite usage, and the uplink and downlink configuration with frequencies used in each mode using RCA SATCOM and ATS-6 are presented in Figure 2-4. Generally, the video transmissions showed the patients' problems to the doctor in Anchorage, which was the reason for the emphasis on outlying site transmission to the center; however, the verbal discussions were always two-way, and the health aides tried to establish direct patient participation in the patient/doctor interface.

Consultation Procedure

Approximately 15 minutes before scheduled consultation time, the village clinic contacted HET network control in Denver via the RCA SATCOM satellite to request that the Alaska ATS-6 systems be enabled. At the same time, NASA transmitted a signal to ATS-6 to reorient the satellite to point toward the Alaskan stations.

The health aide at the village clinic and the physician at Anchorage then turned on the equipment switch in their radio rooms that permitted operation of both ATS-6 and RCA SATCOM communication systems. Once the system had been activated and the controls set for the appropriate communication modes, all other operating functions were controlled from the point of use, e.g., the clinic examining room.

At the scheduled time for the consultation, the aide was in the examining room at the clinic with the patient seated or lying before the television camera. The physician was in either the radio room (usually) or examining room at the Anchorage hospital.

Both health aide and patient used lavialiere microphones around their necks that connected to the control panel mounted on the wall to carry their speech via ATS-6 or RCA SATCOM. An RCA SATCOM push-to-talk switch, attached by a long cord to the control panel/junction box, was available for use when needed.

The physician, at Anchorage hospital, was seated in front of the television monitor (the mobile cart-mounted unit) in the radio room with his microphone for voice input and with the RCA SATCOM push-to-talk switch at hand.

The health aide at the village clinic televised the patients' picture to the physician at the Anchorage hospital through ATS-6. The physician at Anchorage hospital received the televised picture and talked to the patient at the clinic through the RCA SATCOM satellite. If the physician desired, he could start the consultation with transmission from Anchorage, so that the patient could see him before the examination began.

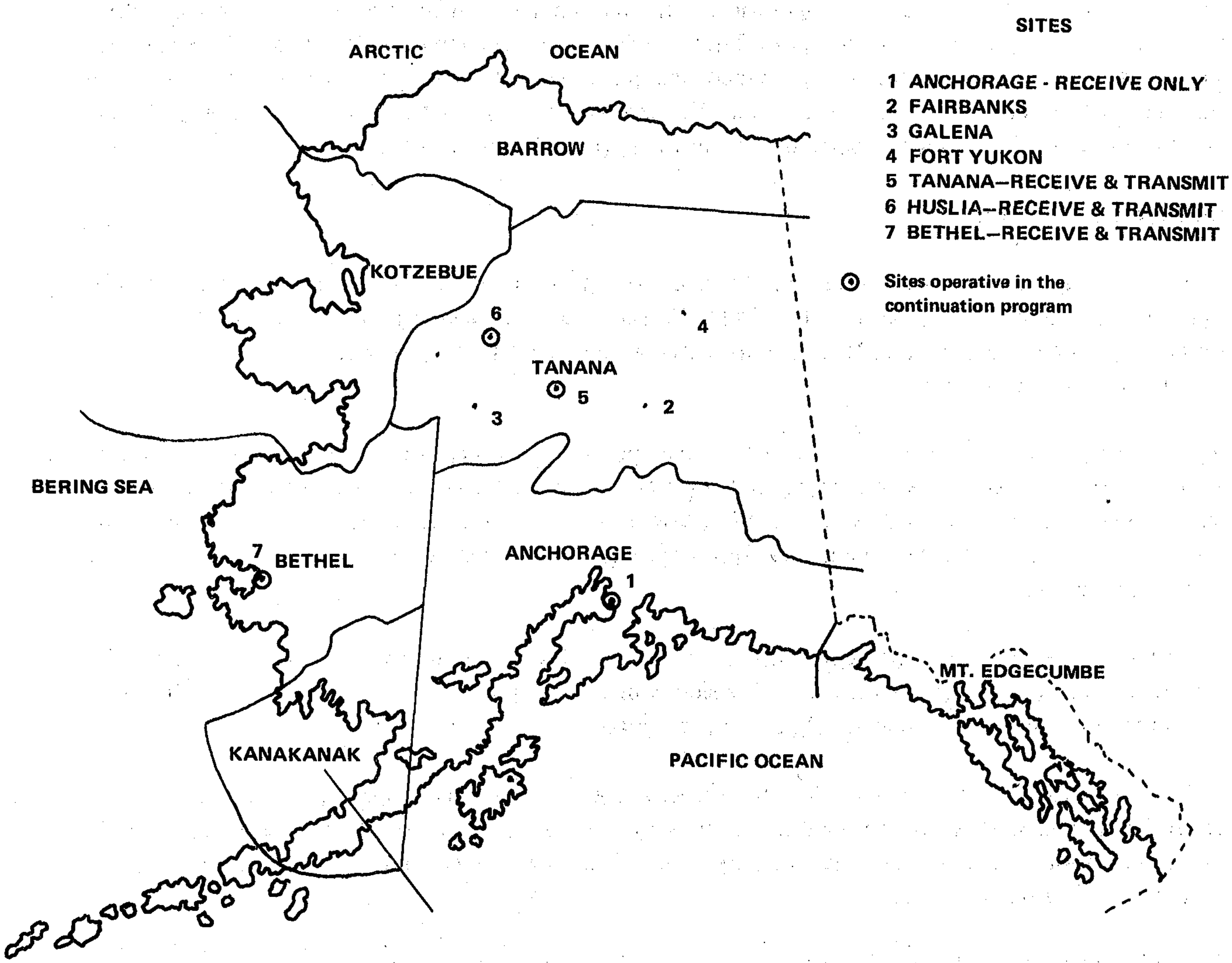


Figure 2-3. Location of ATS-6 Ground Stations

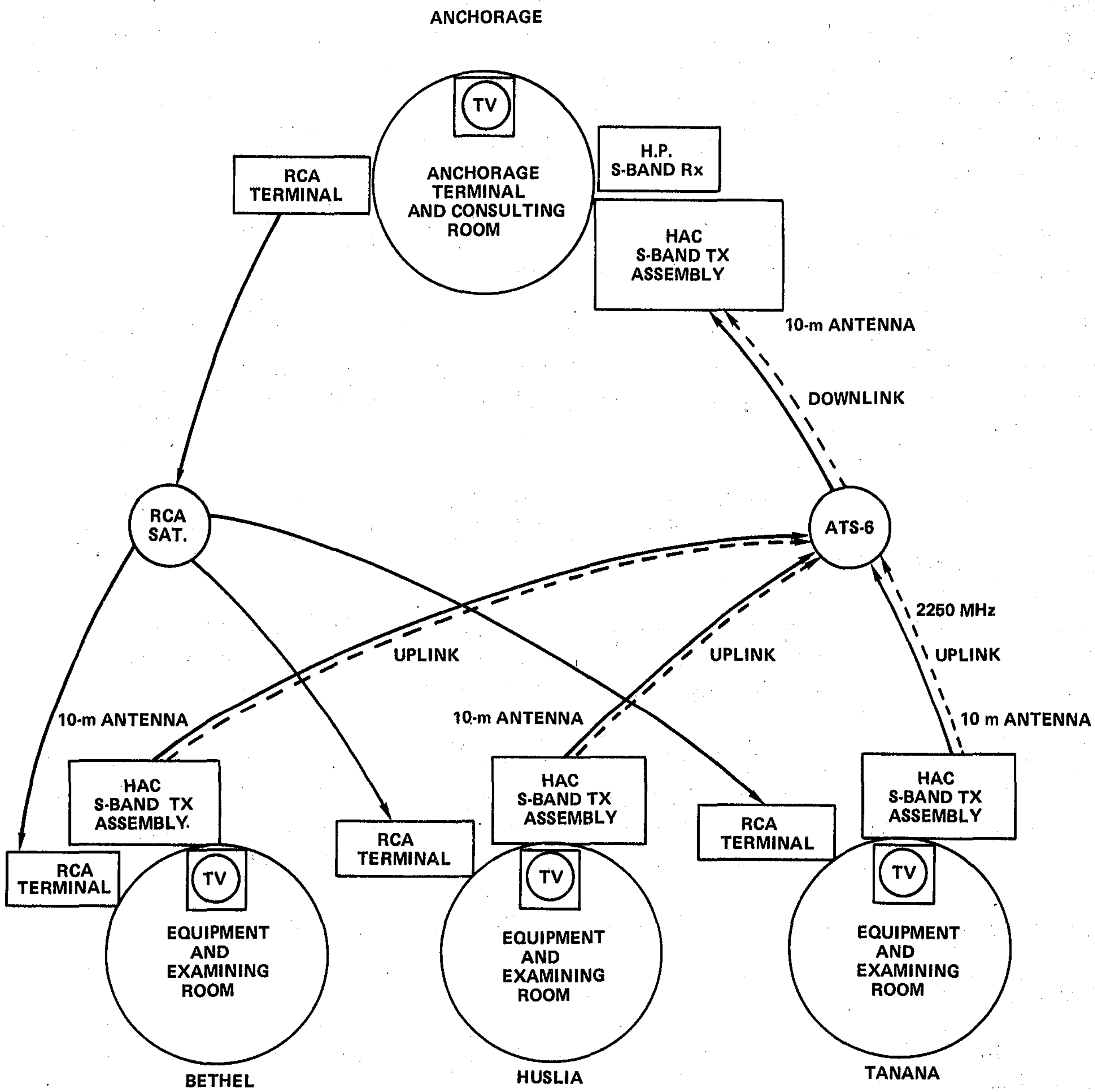


Figure 2-4. System Configuration for the Communication Links S-Band Voice and Video with Frequencies

To begin the consultation, the aide summarized the problem for the physician and the physician obtained additional information by questioning the patient or the nurse. A physical examination followed, beginning with the physician making visual observations of the patient.

The television camera at the village clinic was operated by the physician through remote controls to obtain the picture of the patient he wanted to see. He was able to make his observations quickly and efficiently without having to give verbal instructions to the aide for camera operation. The signals for remote camera operation were transmitted via RCA SATCOM. A control on the physician's RCA SATCOM push-to-talk switch allowed him to select either voice transmit, voice receive, or remote camera control. Controls on his television monitor allowed him to adjust for camera pan, tilt, zoom and focus.

The next step in the examination generally was auscultation in which the physician listened to the patient's heart, lung, and abdominal sounds by stethoscope.

The health aide connected the stethoscope to the "heart sound" amplifier on the top of the biomedical instrument cart. As he or she applied the stethoscope and listened to the sounds, the physician heard the same sounds over a headset via one of the ATS-6 audio channels. Video and voice interaction continued simultaneously.

If an electrocardiogram was needed, it, too, was transmitted to the physician via ATS-6 through another connection on the biomedical instrument cart. The aide also performed other tests and reported the results verbally.

During the course of the consultation, the physician assumed the ATS-6 transmit mode to demonstrate to the health aide how to perform a procedure. The aide then transmitted voice responses of EKG or heart sound telemetry through the RCA SATCOM satellite.

If needed, the hospital physician could "call in" the specialists at Fairbanks or Anchorage or both to examine the patient. When additional consultants were called, they received the patient's televised image, the audio, and the biomedical signals from the village clinic via ATS-6 and Anchorage. The consultants could confer in party-line fashion on the RCA SATCOM link.

After the consultation, the physician updated the patient's medical record.

Studio Configurations

The site (clinic) facilities for patient examination were very similar at all the outlying stations in native Alaskan regions.

The site arrangement for the Galena Clinic was a single room, partitioned for a waiting room, patient reception facilities, data files, television audio, and lighting equipment.

The nursing aide controlled the facility and conducted the patient examination with the assistance of the televideo and audio contact with the doctor. Equipment maintenance was, of course, external but the nurse's aide was in full control of the remote site facilities, hence the importance of individual training, familiarity with the local village, and the general operation of the technical equipment used in telemedicine of this nature.

Teleconsultation Electronic Equipment—The Radio Room

The radio room equipment for a typical studio/examining room is shown in Figure 2-5. In the continuation experiment described, the equipment was limited to that essential for an effective facility.

Diagrams of the facilities and the site configuration are shown for some of the participating locations in Figures 2-5, 2-6, and 2-7.

S-Band Uplink

The satellite links are shown in Figure 2-4 with the associated phone link (two-way) through the RCA communications satellite.

The majority of the teleconsultation was handled by transmissions from the three outlying sites, Bethel, Huslia, and Tanana, using the S-band video link. Transmissions in the reverse direction (from Anchorage) were used to send X-ray video images and other patient record material pertinent to each medical case when necessary from Health Information System at Tucson, Arizona. The video link also included the patient's voice on a simplex basis. In each case, the associated phone link through RCA SATCOM was used in a duplex mode for the patient and medical aide-to-consultant voice interface. No details of the RCA phone link through satellite are given in this report.

ATS-6 was at synchronous altitude over the 140° West longitude meridian and looked at the Earth through a spot beam.

The satellite eye view from this synchronous position was with the satellite beam directed at a point west of Anchorage. This position was optimum for all four intercommunicating points. Huslia received a slightly better signal strength than the other three sites.

A typical ground station configuration for the transmit sites that used parabolic antennas is shown in Figure 2-8. The S-band sites at Huslia, Bethel, and Tanana had similar Earth station transmitter equipment.

The major units comprising a site used for an uplink Earth station were:

1. Microphones and video cameras with studio mixing and level adjustment preamplifier/mixer to give specified audio/video levels at transmitter inputs. A video recorder unit could also be used as an alternate to live program inputs.

2. (Indoor unit), transmitter unit preamplifier with a source of primary power.

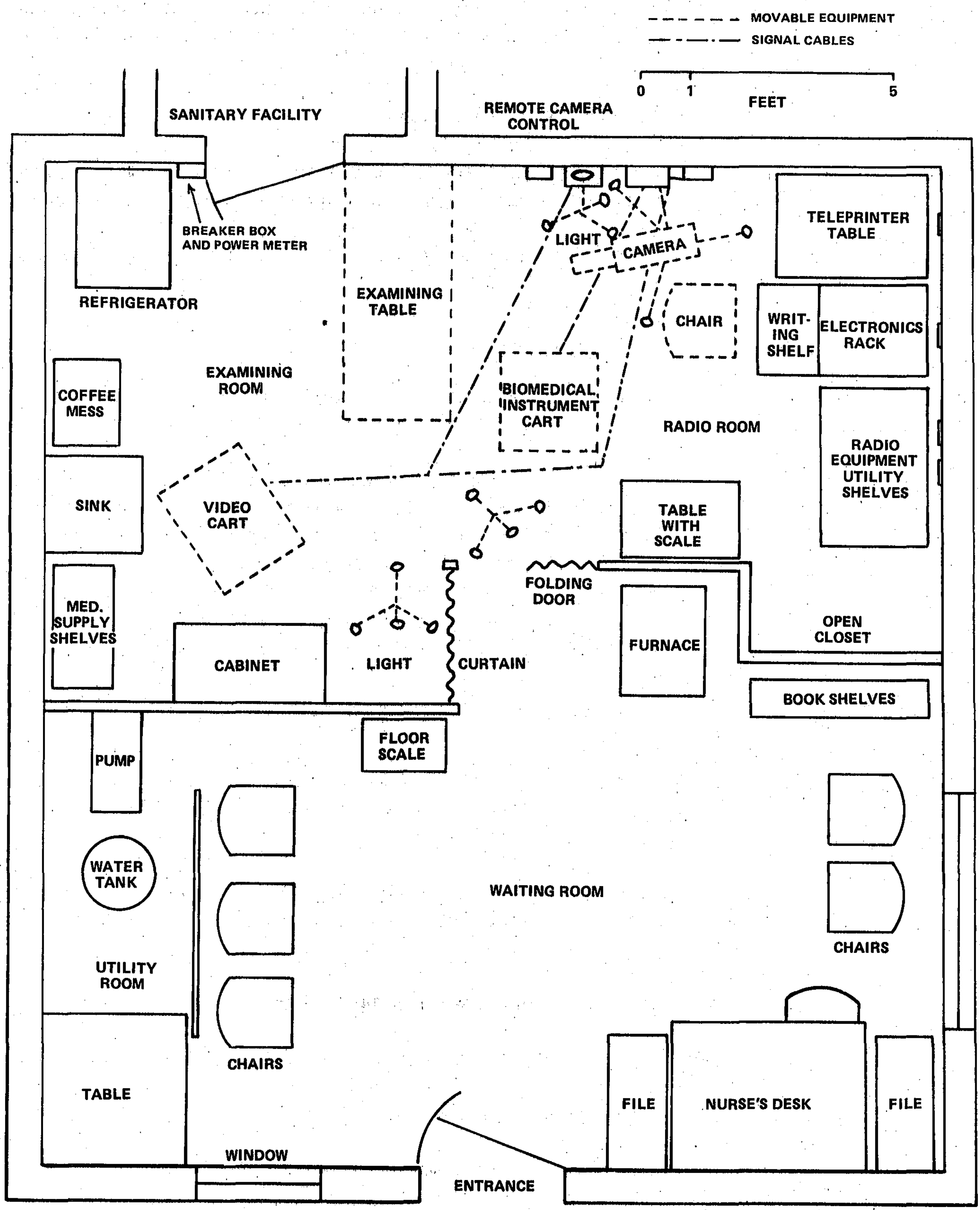


Figure 2-5. Equipment Layout in Galena Clinic Examining Room/Radio Room

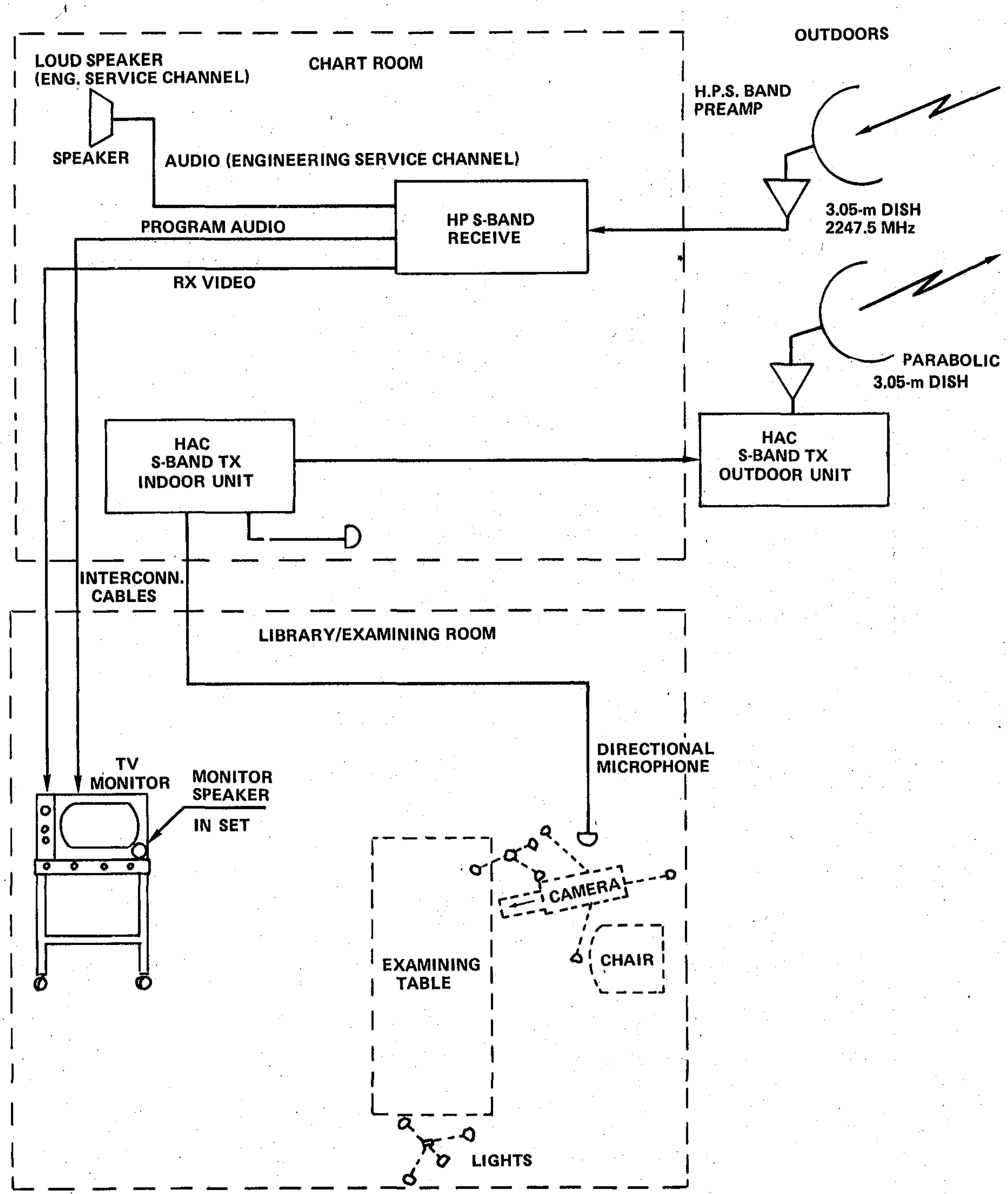


Figure 2-6. Site Equipment and Examining Rooms at Bethel

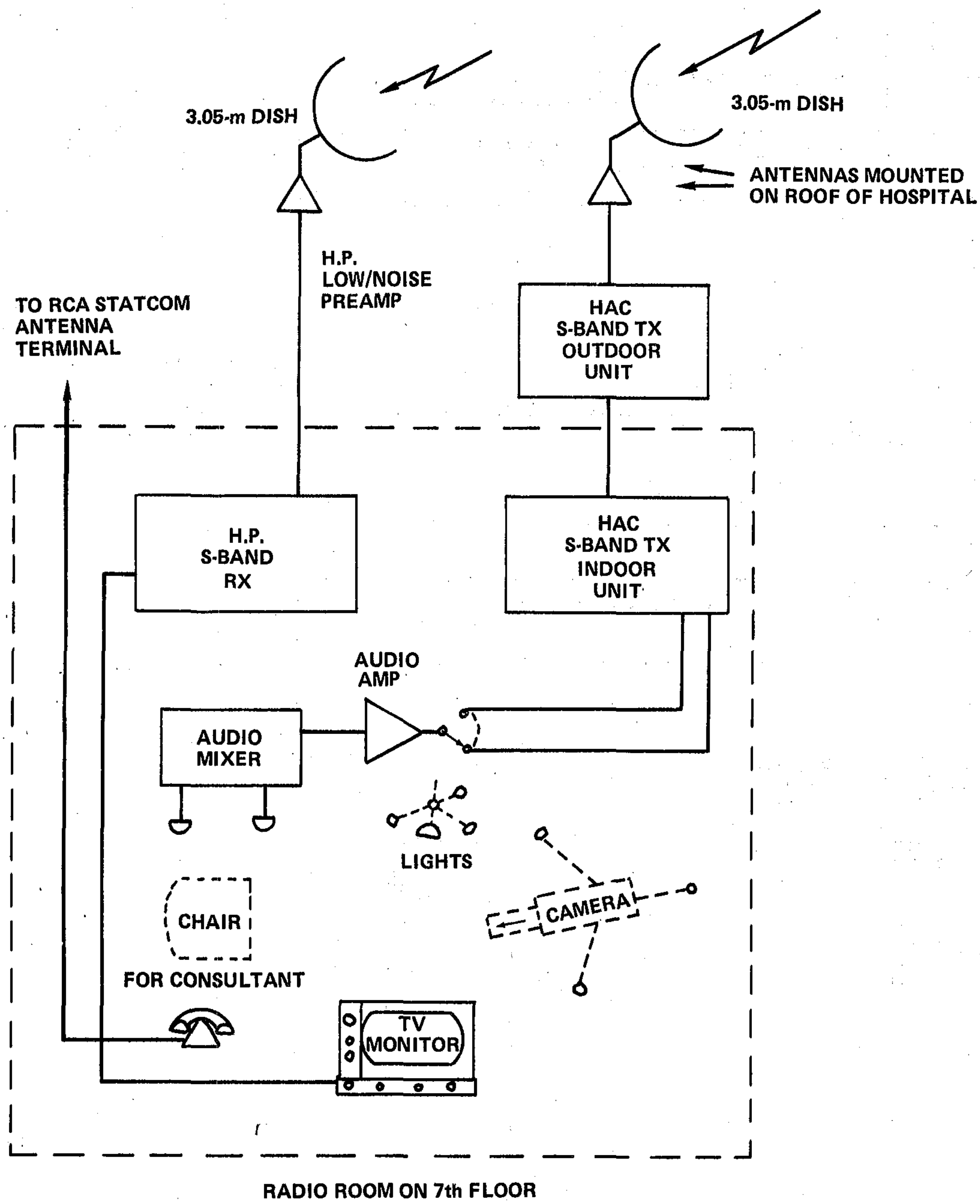


Figure 2-7. Site Equipment and Consulting Rooms at Anchorage

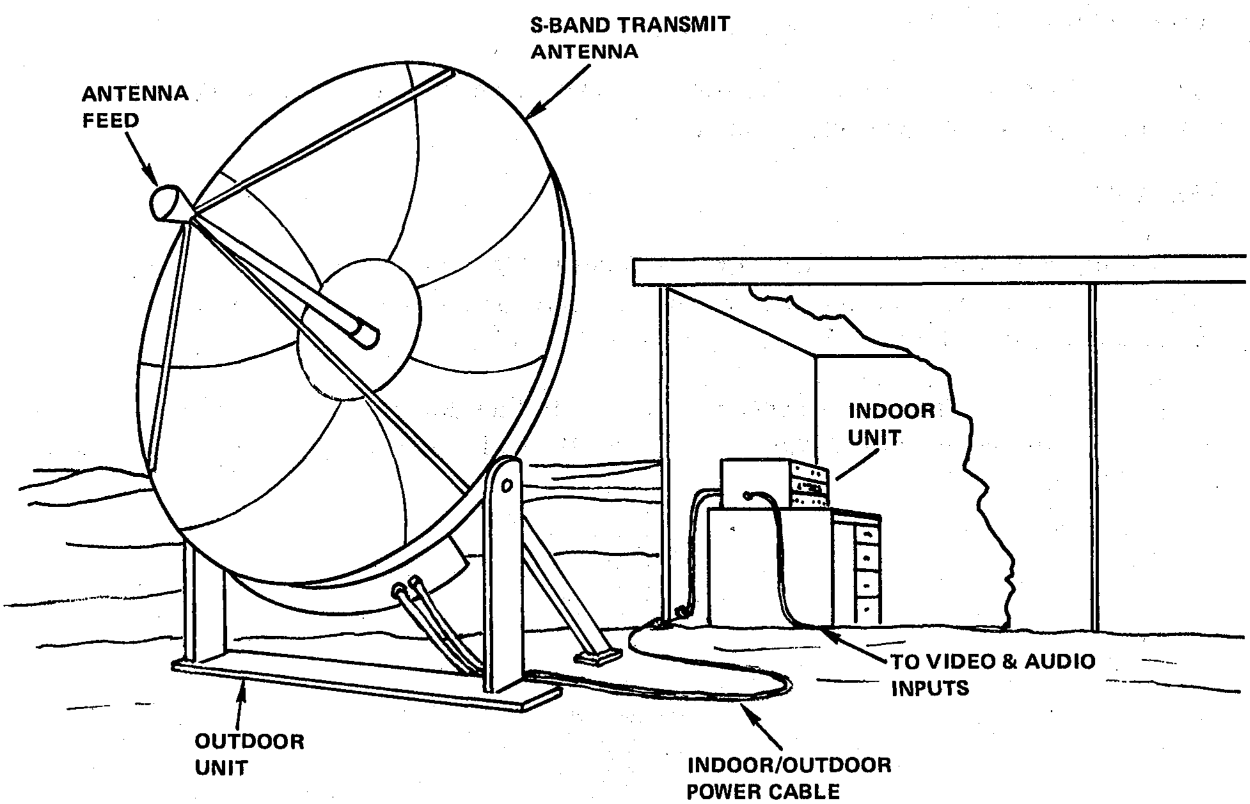


Figure 2-8. Typical System Setup for an Uplink Ground Station

3. Indoor/outdoor power cable, transmitter to modulator and power/amplifier, in outdoor unit

4. Outdoor unit, modulator and power amplifier

5. Parabolic antenna and feed unit

A composite baseband was transmitted that consisted of a television video and four audio channels on separate subcarriers. Video from live television programs was in color or black and white but video tape programs were all in color.

S-Band Downlink

A satellite output power of 20 W provided a spot beam that formed a footprint on the Earth covering the sites in Alaska.

MANAGEMENT AND CONTROL

The control and management was conducted via the NASA Rosman Ground Station in North Carolina from a monitoring network similar to the previous Alaskan Telemedicine experiment.

NASA provided the ground station sites in Alaska and supervised the day-to-day operations during the experimental period.

The block diagram in Figure 2-9 illustrates the management and control network for the continuation of the Alaskan Telemedicine Experiment.

RESULTS

The results of this experiment are given in detail by D. Foote, et al.,* that presents a specific analysis of the human factors involved and the relationship between equipment setup and the optimization of the telemedicine aides by on-the-job training.

The purpose for continuing this experiment was to further develop the techniques of telemedicine as a tool to improve the health care standards for the native Alaskan population. This purpose was successfully fulfilled.

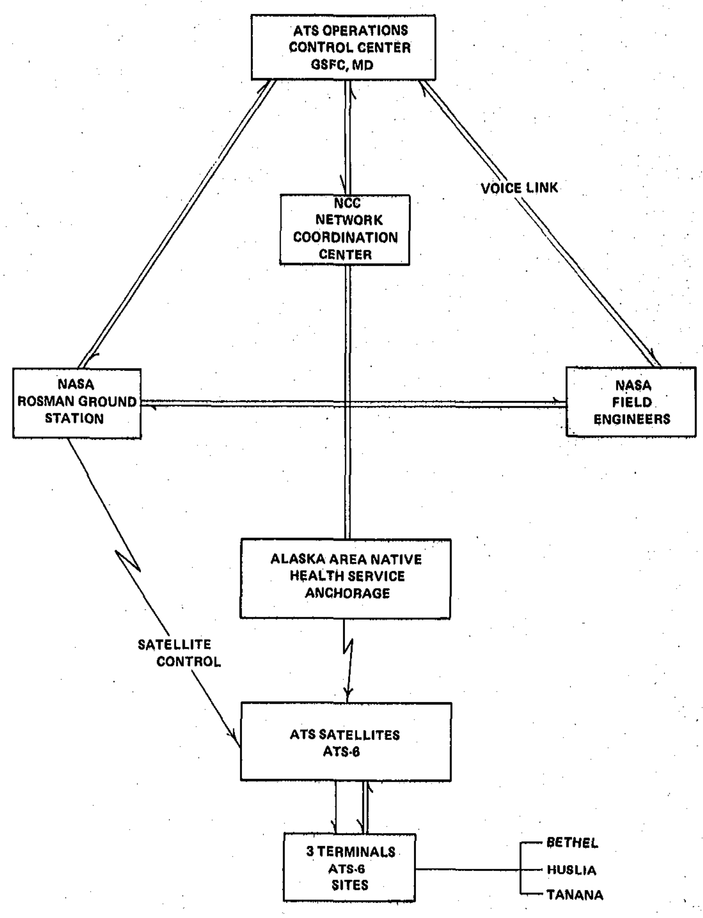


Figure 2-9. Management and Control Network for the Continuation of the Alaskan Telemedicine Experiment

*Foote, D., E. Parker, and H. Hudson, "Telemedicine in Alaska–The ATS-6 Satellite Biomedical Demonstration," Stanford University, Institute for Communications Research, Lister-Hill National Center, February 1976.

CHAPTER 3

APPALACHIAN EDUCATION SATELLITE PROJECT

INTRODUCTION

Within the area programmed for telecommunications relay, the Appalachian Education Satellite Project (AESP) was one of the six educational telecommunications experiments planned for ATS-6. To demonstrate the educational functions ATS-6 could perform, many of the learning activities in the AESP courses were designed to exploit different capabilities of ATS-6 alone or in conjunction with ATS-3, launched in 1967. The main satellite access (uplink) stations were the Rosman Ground Station, near Brevard, North Carolina; Lexington, Kentucky (AESP); Morrison, outside Denver, Colorado; and at Goddard Space Flight Center in Maryland (Figure 3-1).

BACKGROUND

Area and Population To Be Served

During the 1960's, the Federal Government and the American public became more acutely aware of the poor economic and social conditions in Appalachia. Funding and services were provided in an attempt to alleviate these ills. Still, even though economic and social conditions have improved, particularly in the urban areas, progress in the rural areas of Appalachia has continued to lag behind that of the rest of the nation.

By 1970, 44 percent of the population had graduated from high school, as compared with the national average of 52 percent, an improvement over previous periods. Thus, it is apparent that an auspicious upward economic trend had been established by 1972.

The figures reported above, although giving cause for considerable optimism, nevertheless reflect a series of needs still facing the region. Despite gains of significant proportions on a broad front, one decade later Appalachia was still faced with the following:

- An illiteracy rate among 24- to 40-year olds approximately three times as high as that of the U.S. population
- A substantial lack of career information or counseling for students in rural areas
- More demands for state or professional recertification of professional and paraprofessionals
- The geographic inaccessibility or technical inapplicability of available education services

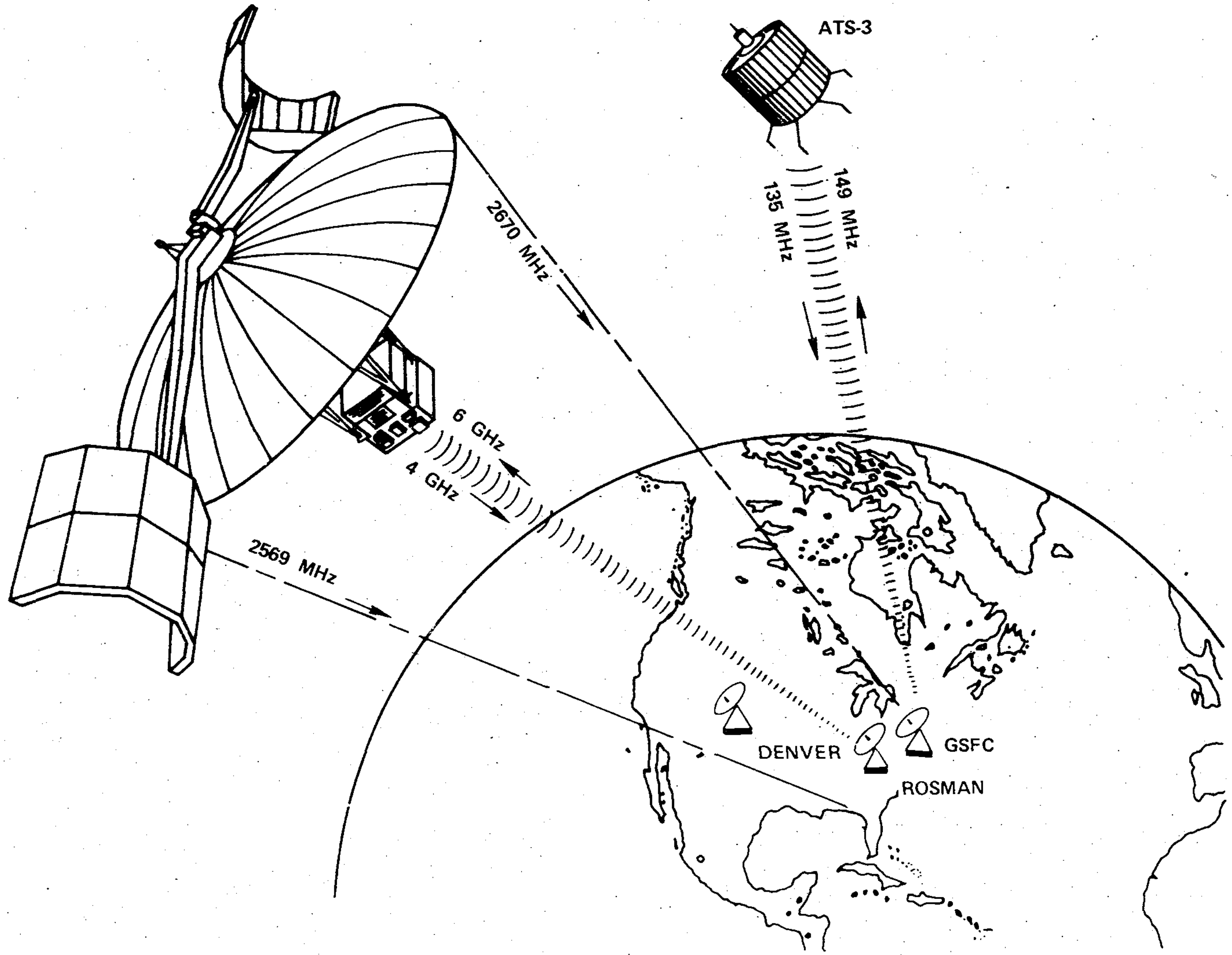


Figure 3-1. AESP Satellites and Earth Stations

- Changing career trends, with an accompanying requirement for retraining adult manpower
- The inadequacy of the manpower supply in health careers and child development work
- Declining achievement in reading at the elementary and secondary levels
- Inadequate and inappropriate educational planning aimed primarily at short term crisis solutions rather than at long range community development.

The terrain and the sparseness of the population have impeded progress in many essential areas of economic and social development. Correspondingly, these same characteristics have inhibited efforts to rectify the region's problems. Particularly in education, those demographic characteristics have made traditional adult education and in-service training costly.

The benefits and cost-effectiveness of satellite delivery in these instances was cited in a report by the former Office of Telecommunications Policy of the Executive Office of the President of the United States. The report comparing satellite broadcast delivery to other methods of delivery stated that:

> A broadcast satellite can reach any number of receiving sites simultaneously at nominal cost as far as the ground terminals are concerned. It can reach isolated regions where no current communications facilities exist. Furthermore, it delivers information at a cost which is independent of distance, being, therefore, most advantageous where distances and geographical dispersion of terminals are great. Ultimately, all benefits are reducible to economic ones because a broadcast satellite cannot do anything that could not theoretically be done by other communications systems. It can, however, do some things at less cost–often, much less cost.

History of the Appalachian Education Satellite Project

The Appalachian Education Satellite Project (AESP) was initiated in the early 1970's as a result of two concurrent events: (1) the identification by the Appalachian Regional Commission (ARC) of in-service training for educators as a significant need in Appalachia, and (2) the launching of ATS-6 by the National Aeronautics and Space Administration (NASA), providing the technology for such a venture.

During the initial phase (1973 to 1975), the experimental nature of AESP limited the scope of the program; e.g., numbers of courses, receiving sites, and participants. Fifteen receiving sites were established in 8 of the 13 Appalachian states: Alabama, Maryland, New York, North Carolina, Pennsylvania, Tennessee, Virginia, and West Virginia. (See Figure 3-2.)

During this period, graduate continuing education courses were developed, broadcast, and evaluated by the AESP. Two courses involved the development of teacher expertise in the areas of career education; the remainder provided instruction to teachers on diagnostic and prescriptive techniques for the development of skills in reading.

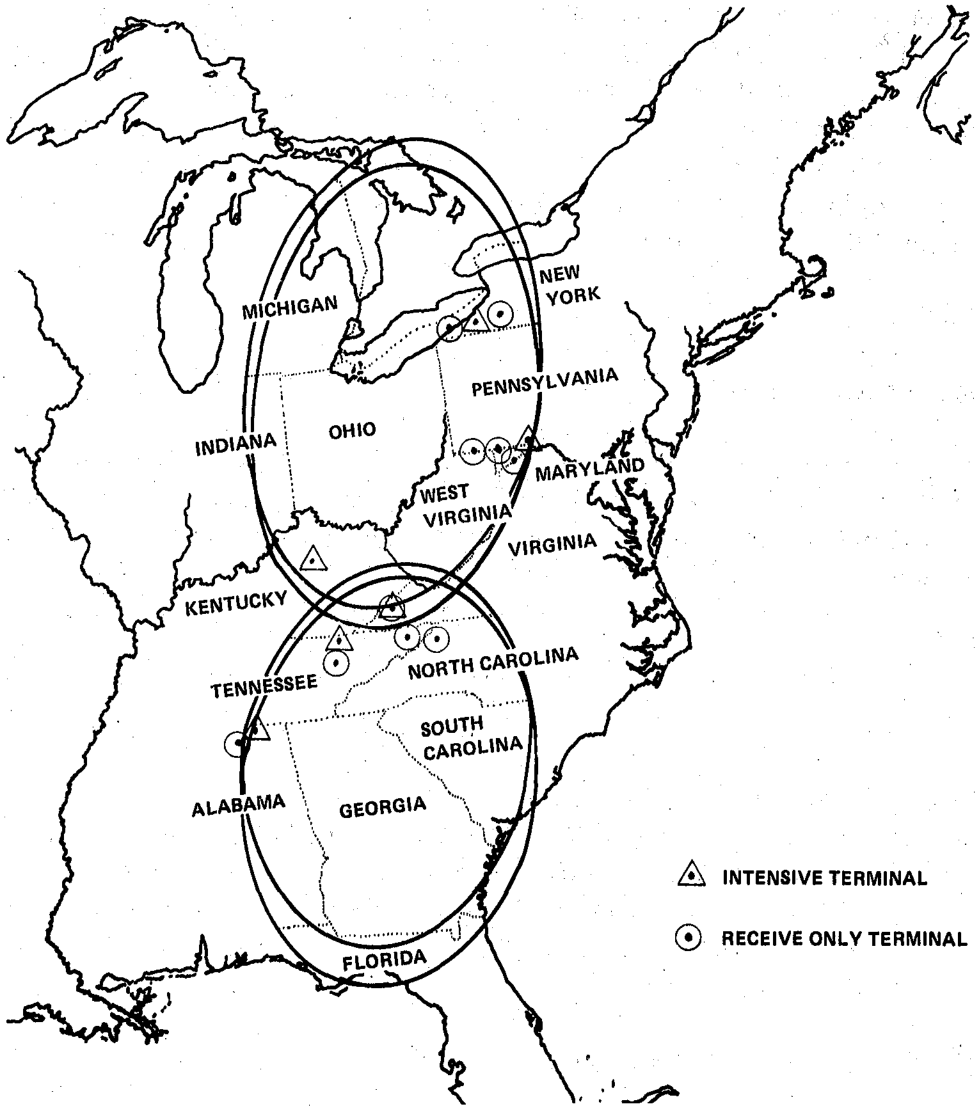


Figure 3-2. AESP Receiving Sites

For these offerings, approximately 1200 participants received graduate credit from 13 institutions of higher education. The evaluation data obtained in this phase revealed that the technology had proven acceptable and dependable, that participants had demonstrated cognitive and effective gains from participation and had responded positively to the instruction, and that the costs of delivery had been comparable to those of a traditional university level graduate course.

Also, during this time, the basic structure of administrative management was established to obtain local input, assess needs, and design, develop, and deliver courseware. The primary components of management were the AESP Central Office in the Division of Education within the ARC; the Resource Coordinating Center (RCC), located at the University of Kentucky; and the Regional Education Service Agencies (RESA), located in the eight target states.

As prime contractor and fiscal agent, ARC developed this decentralized organizational structure. As manager of the program, the AESP Central Office provided a broad range of expertise, resources, and continual contact at the local, state, and Federal levels. The Resource Coordinating Center was responsible for planning, development, production, delivery, and evaluation of the courseware. At the local level, the program was managed and implemented by groups of regional education service agencies. In addition to managing the activities at the 15 local receiving sites, the 5 main RESA's also coordinated the use of local resources.

OPERATIONS

Appalachian Education Satellite Project—1974

The Appalachian Education Satellite Project (AESP) began its initial planning in 1973 to use ATS-6 to demonstrate and test the effectiveness of ground coverage (called "footprints") and program quality of satellite educational broadcasting. Under the general overview of the Appalachian Regional Commission and the University of Kentucky, which was designated as the AESP Resource Coordinating Center, five Regional Education Service Agencies covering eight target states were established.

Organization

As indicated in Figure 3-3, the technical aspects of the AESP were under the direction of NASA and its subagents who supplied and controlled the satellites. The Federation of Rocky Mountain States (FRMS) Broadcast and Engineering (B&E) Division in Denver, Colorado, coordinated contact between NASA and the ground terminals in the Health, Education, Telecommunications (HET) Network. AESP Engineering was responsible for ordering, installing, and maintaining the ground equipment at the fifteen Appalachian sites.

Identification of Initial (1974) AESP Sites and System

At each of the clusters and ground terminals (circles and triangles) shown in Figure 3-2, one of the original AESP reception sites was established as an "intensive terminal" (IT) that could transmit and receive two-way vhf radio by ATS-3, as well as receive television programs by S-band from ATS-6.

Identification of Delivery Route—To televise programs by ATS-6, it was necessary to devise a means whereby the television signals could be delivered to the classroom sites from the RCC broadcast studio at the University of Kentucky in Lexington, Kentucky. As shown in Figure 3-4, the television signals were transmitted from the studio over telephone grade microwave links to the Rosman Ground Station in North Carolina. From Rosman, the signals were uplinked on C-band to ATS-6 for relay to parabolic antenna systems at the sites. A similar procedure was employed to provide vhf voice and teletype (data) access to the University of Kentucky Broadcast Studio from the receiving sites as shown in Figure 3-5.

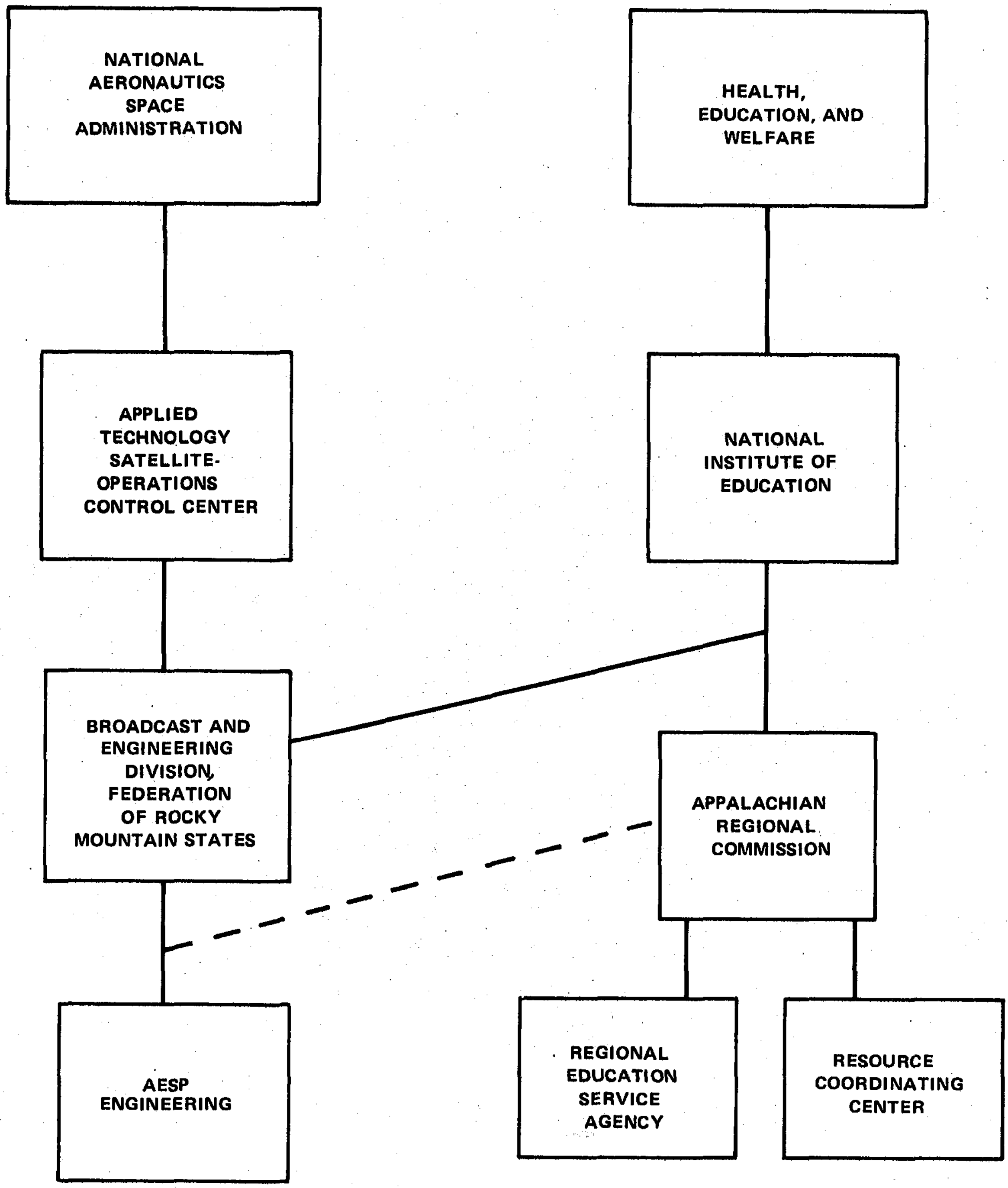


Figure 3-3. Organizational Chart for the Appalachian Education Satellite Project

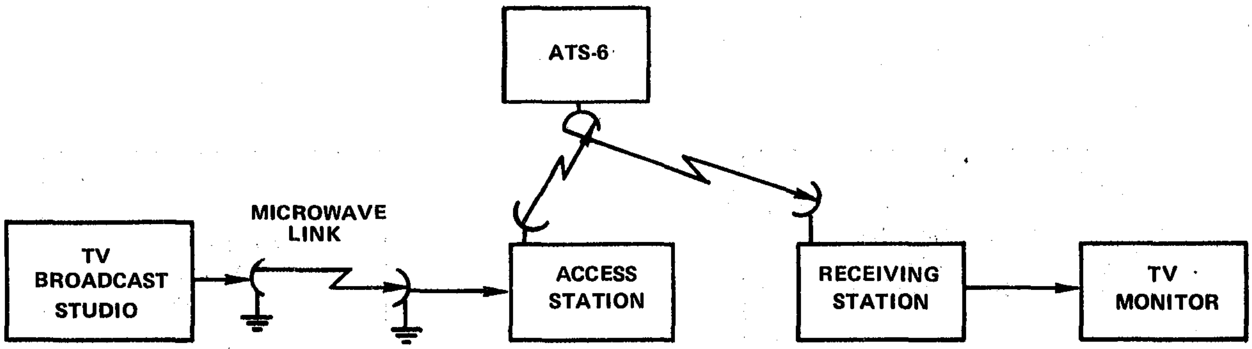


Figure 3-4. Audio-Video Link System

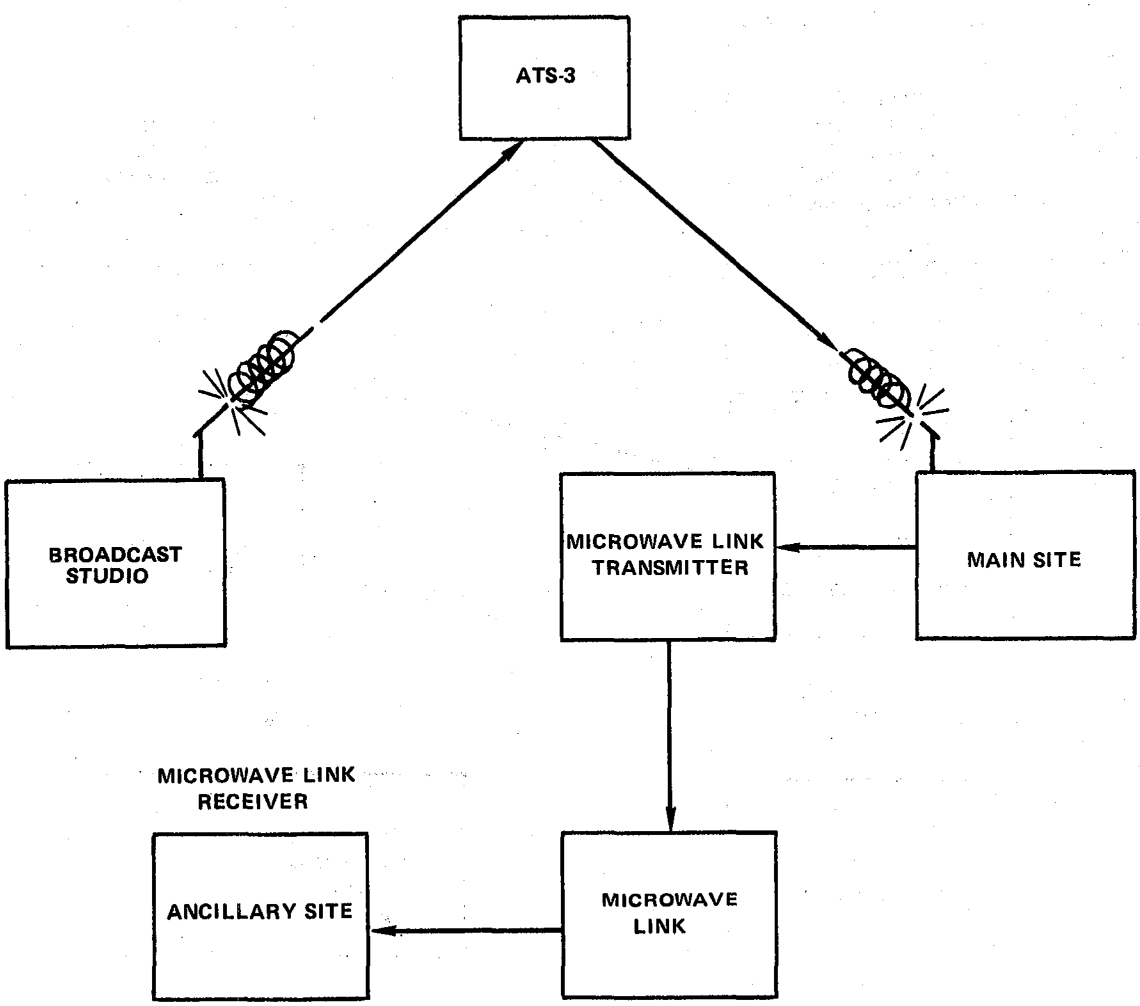


Figure 3-5. VHF-Teletype Relay System

Identification of Site Reception Equipment—At each of the 15 sites, the television reception system consisted of an outdoor, 3-meter diameter parabolic antenna positioned on an adjustable mount. The reception equipment at the intensive site in Cumberland, Maryland, consisted of a disc-shaped parabolic antenna for S-band television reception and the helical antenna for vhf voice and teletype (data) reception. Mounted on the back of the parabolic antenna was a preamplifier that was connected to the indoor receiver by a 30-meter coaxial cable. The solid state, 2.5-GHz Hewlett Packard receiver converted the signals to a video baseband.

Broadcast Content and Distribution—For the initial 1974 AESP demonstration and test, the project produced pretaped and/or live television program series for three courses. For delivery during the summer, 12 satellite-broadcast, half-hour, pretaped programs and four three-quarter-hour, live, interactive seminars were developed for both the diagnostic and prescriptive reading instruction (DPRI) course for teachers of kindergarten through third-grade and the career education course for elementary-grade teachers (CEE). For delivery during the Fall of 1974, 16 one-hour long, live, interactive seminars were developed for the career education course for secondary-grade teachers (CES).

The feedback from students in the classroom to the broadcast studio was accomplished by vhf voice and teletype signals through ATS-3 from the five intensive sites located at the Regional Education Service Agencies (RESA). The 10 receive-only terminals were linked to the RESA's by landline. Furthermore, in an effort to use the four-channel, C-band capacity of ATS-6, a program review technique was tried in which students heard questions and responded by depressing an answer button on a tone coded data responder. This later technique was not too successful, primarily because of equipment problems.

General Problems—During the first 6-month period when a total of 34 hours of televised programs was scheduled for transmission over ATS-6, 13 malfunctions in site television reception equipment were reported. Table 3-1 lists the cause and date of each malfunction at each site; the total number of times each type of malfunction occurred; and the television programs missed because of the malfunction. Sometimes a malfunction occurred and no television programs were missed, either because the malfunction did not make reception impossible or because repairs were made before the program began. Out of 720 program transmissions (48 programs times 15 sites), 18 programs (2.5 percent) were not received because site equipment malfunctioned.

1974 Accomplishments—Below is a list of AESP accomplishments during its initial phases:

- Approximately 1200 participants in Appalachia completed in-service courses or workshops provided by AESP.
- Courses were granted graduate and/or in-service credit by over 30 institutions of higher education in Appalachia participating as credit-granting institutions.
- A sophisticated satellite communication network was established that included:
  - Fifteen receiving sites in Appalachia equipped with television receivers, teletype intercommunications, libraries, and special instructional materials with trained satellite communicators at all sites
  - Two of NASA's communication satellites, ATS-6 and ATS-3

Table 3-1
Causes of Malfunctions in Ground Station's
Television Reception Equipment

Causes	Site	Date	Total Mal-functions/ Cause	TV Programs Missed
Defective Preamplifier	23	9/11 to 9/17	1	
Broken Coaxial Cable Assembly	13	7/10 to 7/11	3	DPRI 1 and 2
	13	9/7 to 9/19		CES III
	13	10/1 to 10/8		CES VI and VII
Blown Fuse in Hewlett Packard Receiver	41	7/23	1	CES VII
Blown Transistor in Hewlett Packard Receiver	53	10/15 to 10/18	1	CES VII
Broken Signal Strength Meter in Hewlett Packard Receiver	13	7/16 to 8/5	2	
	53	10/29		
Open Audio Cable Between TV and Hewlett Packard Receiver	11	10/15 to 10/22	1	CES VII
Defective BNC Connector to Video	21	11/26 to 11/27	2	CES XIII DPRI 1 and 2
	23	7/9 to 7/17		CEE 1, 2, 3, 4, 5, I
Broken Remote Meter Cable	53	7/30	1	
Short in Encoder-Decoder	13	10/8	1	CES VI
TOTALS			13	18

- A Resource Coordinating Center where 5 graduate credit courses and 20 workshops were developed that included extensive auxiliary materials and computer support activity for evaluation of information.

- In-service programs and workshops previously unavailable in many parts of Appalachia.

Appalachian Education Satellite Project—1975 to 1979

After the return of ATS-6 to provide Western Hemisphere coverage, AESP conducted the necessary planning in 1975 and 1976 to reinitiate the Appalachian satellite educational broadcast project. Besides intensifying the planned program production, the number of receiving sites was expanded from 15 to 45 to facilitate increasing the attainable audience as shown in the following listing.

ALABAMA

Gadsden
[a]Guntersville
[a]Huntsville
[a]Rainsville

GEORGIA

Gainsville
Rome

KENTUCKY

[a]Hazard Morehead
Somerset

MARYLAND

[a]Cumberland
Hagerstown
[a]McHenry

MISSISSIPPI

Scooba
Tupelo

NEW YORK

Alfred
[a]Fredonia
Olean

OHIO

Athens
Mt. Orab

PENNSYLVANIA

Altoona
Edinbora
[a]Pittsburgh
Smithport

SOUTH CAROLINA

Columbia
Greenville
Spartanburg

TENNESSEE

Chattanooga
[a]Cookeville
[a]Johnson City
[a]La Follette
McMinnville
Tazewell

VIRGINIA

Dublin
Norton
[a]Strickleyville

[a]15 Original Sites

NORTH CAROLINA	WEST VIRGINIA
Asheville	Bethany
[a]Boone	Petersburg
Marion	Romney
Morgantown	Wheeling
Sylva	[a]Keyser

[a]15 Original Sites

During the January to March 1977 period, AESP and NASA (Goddard Space Flight Center) conducted various technical/operational tests using essentially the same network configuration used during the initial 1974 to 1975 demonstration phase. Program material was originated at the University of Kentucky (Lexington) studios (UKTV) and transmitted by microwave to the NASA Rosman Ground Station for C-band uplink to ATS-6. Rebroadcasting to the various sites was again accomplished by S-band downlinks. The number of sites equipped with vhf transceiver access to ATS-3 were increased from 5 to 15 to facilitate feedback to UKTV.

Delivery Remote/Network Changes

During the January to March test period, reception levels and picture quality were less than expected or desired at many of the ground sites, particularly around the periphery of the satellite footprint on the Earth. In addition, the microwave link between Lexington and Rosman was expensive and added interface problems that reduced the quality of the program video and audio. With the loan of an S-band transmitter and antenna from Goddard Space Flight Center, the University of Kentucky could access ATS-6 directly by S-band uplink (2250 MHz). The spacecraft provided the ground site coverage by two "spot-beam" downlinks, one for the North AESP area and the other for the South AESP area. Although Federal Communications Commission (FCC) regulations prohibit the use of satellite S-band uplink transmissions within the 48-continental United States, ARC/AESP was granted special permission to use the S-band 2250 MHz frequency. The Rosman Ground Station acted as backup in case of UKTV uplink failure by accessing ATS-6 on C-band with prerecorded tape program copies of the scheduled UKTV broadcast.

This revised communications network was activated in May 1977 and remained in service until May 1978, not without some problems, however. Primarily, the problems of narrow (spot) beam spacecraft/ground antenna pointing and alignment reduced the reliability of reception at many of the sites. Additionally, the FCC (and the U.S. Army) grew increasingly reluctant to continue authorizing NASA/AESP use of the S-band uplink to ATS-6 because of interference problems. These problems were compounded by marginal performance of the S-band uplink, various equipment failures, broadcast degradation caused by winter weather, and delayed activation of some of the added ground sites.

To overcome the C-band uplink problems and improve the S-band downlink reception, planning was initiated in the summer of 1977 to shift the uplink frequency into the L-band sector of the spectrum. This action required the loan of a 4.6-meter parabolic antenna and a 1 kW L-band transmitter with upconverter and ancillary equipment from NASA, for UKTV station installation. The feasibility of this access mode had been previously examined in March 1977 using Rosman Ground Station equipment.

In May 1978, the L-band installation at the stadium of the University of Kentucky was completed and checked. The revised network configuration consisted of the following:

- UKTV: L-band uplink transmission to ATS-6 at 1649.5/1650.0 MHz with 1 kW of power. A 4.6-meter antenna mounted at the University athletic stadium with a 2.4-kilometer microwave link to the UKTV studio.

- Rosman Ground Station Backup: C-band uplink to ATS-6 at 6147.5 MHz (L-band at Rosman could be used if C-band was inoperative).

- All ARC ground stations continued to receive program signals by ATS-6 transmitted S-band signals.

- ATS-6 control was exercised by NASA Goddard Space Flight Center at Greenbelt, Maryland.

1976 to 1979 Accomplishments

The ARC/AESP/ATS-6 program continued until its termination in May 1979 when ATS-6 support was stopped because of spacecraft hardware problems. The original life-expectancy of ATS-6 was established at 2 years minimum and it provided outstanding service for over 5 years. During this second phase of AESP, more than 2,000 participants completed in-service courses and/ or workshops. The scope and contents of which were considerably expanded over the original 1974 test period. Additionally, the program delivery area was expanded from the original 15 ground sites to a total of 45.

The Appalachian Community Service Network (ACSN) was formed in September 1979 to expand the accomplishments of AESP in case of the loss of ATS-6. In addition to broadening the east coast coverage of the original system, ACSN planned future service that included Nevada and Colorado ground sites to provide cable television coverage throughout the lower 48 states. Since a government satellite would not be available, the Radio Corporation of America (RCA) satellite Satcom-1 was chosen as the spacecraft for ACSN.

Of all the communication experiments conducted by ATS-6, only the ARC/AESP experiment continued, after successful demonstration, into a self-supporting, viable operation. This action may well be considered the most important accomplishment of ATS-6 and AESP.

CHAPTER 4

THE UNIVERSITY OF WEST INDIES EXPERIMENT

INTRODUCTION

The University of West Indies Experiment (part of the Health, Education, Telecommunications [HET] Experiment) demonstrated the ability of satellites to provide telecommunications between remote points that normally would have great difficulty in establishing intercommunication. Two modes were used, as illustrated by the link interconnections of Figures 4-1 and 4-2.

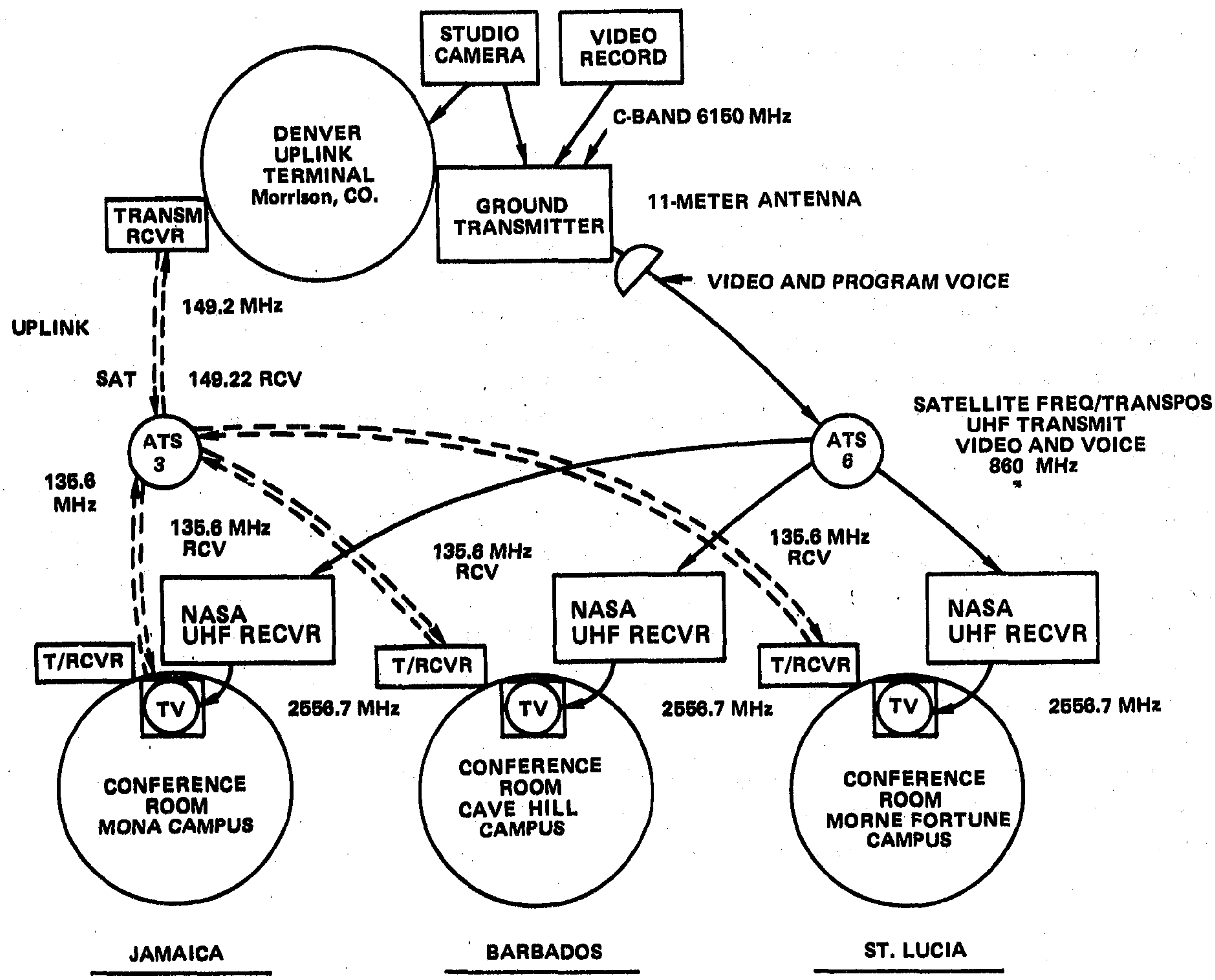


Figure 4-1. Links for an Introductory Video/Sound Transmission and Voice Conference from Denver Terminal

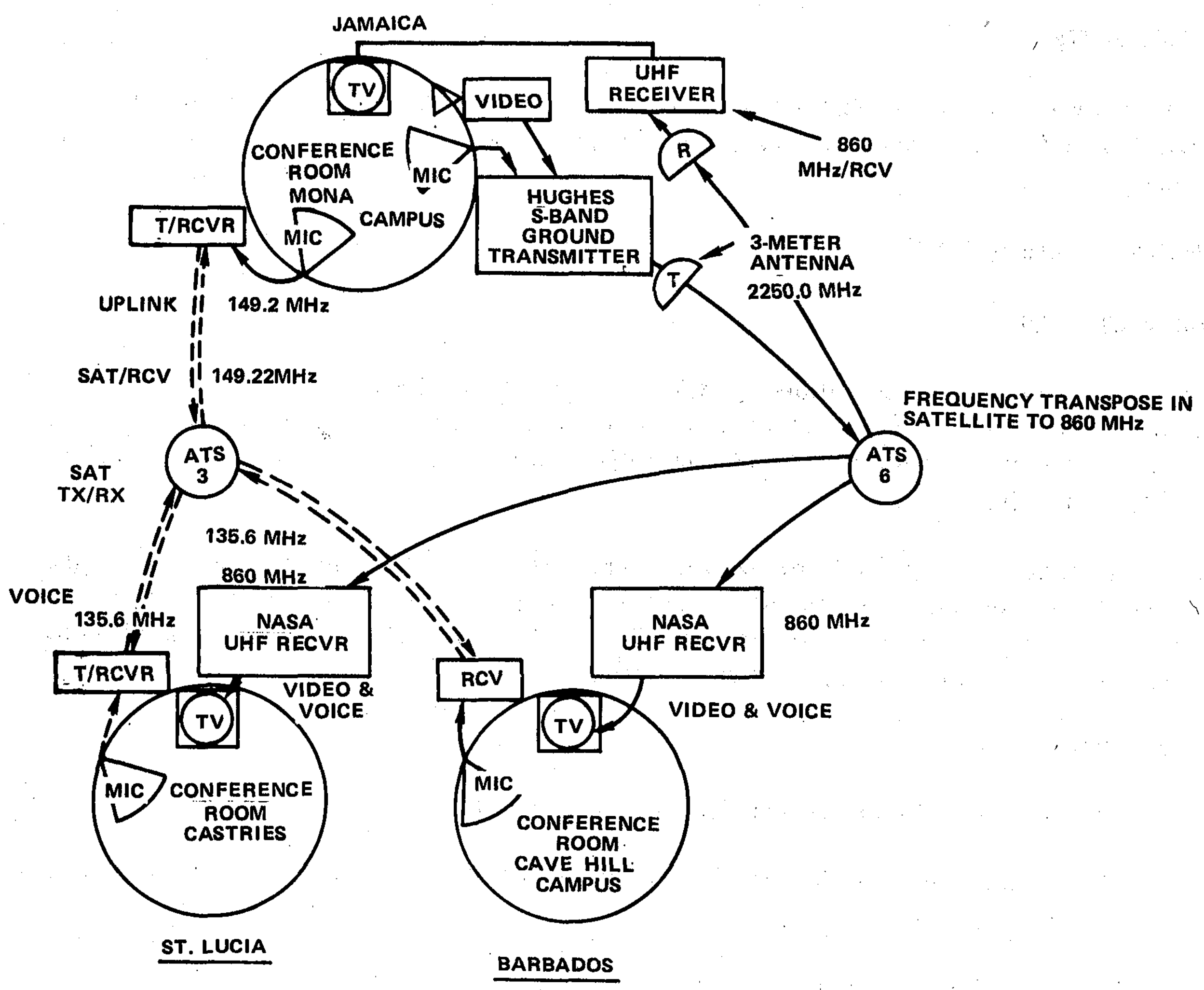


Figure 4-2. Consultation Links in Video (S-Band and UHF) and Audio (VHF) Between Jamaica Campus (Mona) and Island Receive Sites

A communication problem existed for the university that was partly economic and partly due to the physical barriers involved in the Caribbean. Communication centers on the Caribbean Islands can be 600 to 1000 miles apart over the ocean with no direct communication.

Satellite technology is, therefore, important because it allows efficient and low cost solutions to the intercommunication problems for communities that are widely dispersed and low on the socio-economic scale.

The experiment was planned by the National Aeronautics and Space Administration and the U.S. Agency for International Development and initiated various tests in health and education programs.

PARTICIPANTS

The University of West Indies had a number of sites within the Caribbean Islands consisting of Jamaica (Mona Campus), Barbados (Cave Hill Campus), and St. Lucia Island (Morne Fortune Campus).

EXPERIMENT OBJECTIVES

Technical Objectives

The technical objective of the Caribbean experiment was essentially the same as the other HET telecommunication experiments. These are stated in Chapter 1, the Health, Education, Telecommunications Experiment, with only ATS-6 and ATS-3 being involved in the links in the case of the University of West Indies.

The communication links consisted of two site interconnections, one within the United States and one within the Caribbean. These comprised the two experiments for the University of West Indies and are depicted by the two-link setup shown in Figures 4-1 and 4-2. The experiments achieved by these linkages were the only Caribbean interconnections.

Socio-Economic Objectives

The socio-economic objectives were to measure:

- The feasibility of delivering programs to the widely scattered sites of the University of West Indies campuses
- The degree of user acceptance generated by the technology
- The usefulness of video programs and lecture courses to the university as a teaching procedure
- The value of teleconferencing and consultation to the university teaching staff to coordinate teaching, research, and administration with much reduced costs.

The degree to which the objectives were achieved can be assessed from a report written by G. C. Lalor of the University of West Indies. This report describes the extent of isolation existing between the various sites of the university and the response to the satellite video and sound lectures and conferences.

SYSTEM DESCRIPTION

An introductory video/sound program from the Denver center was the initial test for the University of West Indies Experiment. The two previous illustrations (Figures 4-1 and 4-2) show the links from the Denver terminal and the link setup for Jamaica to the Island campuses that participated in the majority of the University of West Indies programs.

S-Band Uplink

The typical ground station configuration for the S-band transmit site employed a parabolic antenna and is shown in Figure 4-3. The major units used for an uplink Earth station such as that at Jamaica were as follows:

- Microphones and video cameras with studio mixing and level adjustment preamplifier/mixer. A video recorder unit could also be used as an alternate to live program inputs.
- (Indoor unit), transmitter unit preamplifier with a source of primary power.
- Indoor/outdoor power cable, transmitter to modulator and power/amplifier, in outdoor unit.
- Outdoor unit, modulator, and power amplifier.
- Parabolic antenna and feed unit.

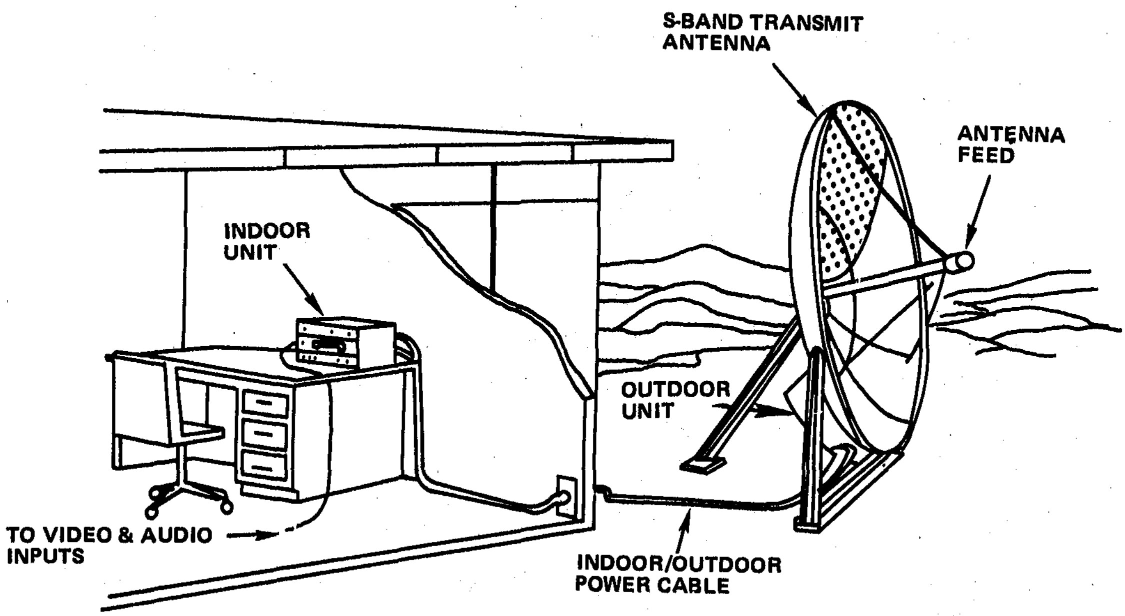


Figure 4-3. Typical S-Band Ground Station Uplink System

The operational performance characteristics of the S-band transmitter were as follows:

<u>Video Transmission</u>	
Frequency response	30 hertz (Hz) to 4.2 megahertz (MHz), ±0.5 decibel (dB)
Input impedance	75 ohms (Ω) unbalanced
Input level	1 volt (V) peak-to-peak, sync tip negative
Input connector	Mated with a UG-260/V (BNC) or equivalent
Preemphasis	CCIR Rec 405 (525 line)
Modulator linearity	+1.5 percent for ±10 MHz deviation +2.5 percent for ±15 MHz deviation
Group delay	Complied with CCIR Rec 421-2 (m)
SNR	
Continuous	>60 dB (peak-to-peak/root-mean-square (rms)) for frequencies from 1 kilohertz (kHz) to 5 MHz
Periodic	>38 dB for power supply components
<u>Audio Transmission</u>	
Frequency response	30 Hz to 10 kHz
Input impedance	600 Ω balanced
Input level	+9 decibels referred to 1 milliwatt (dBm)
Input connector	Mated with Switchcraft part number 480 or PJ-068 or equivalent with tip and ring as signal, sleeve as ground/shield (phone jack)
Preemphasis	FCC standard 75 microsecond (μsec)
Distortion	
Below 100 Hz	<2 percent total
Above 100 Hz	<1.5 percent total
Audio subcarrier frequencies	Channel 1 – 4.66 MHz Channel 2 – 4.83 MHz Channel 3 – 5.06 MHz Channel 4 – 5.36 MHz
<u>Primary Power</u>	115 V, 10 percent, 60 Hz, single phase, 800 watts (W) maximum or 27 volts direct current (Vdc), ±3 V, 34 amperes (A) maximum, switch selectable

Federal restrictions prevented uplink communications to a satellite in S-band in all states except Alaska, due to possible rf interference with existing U.S. terrestrial communication systems. To comply with this restriction, uplink frequencies to ATS-6 in Colorado were at C-band (5947.5 Mhz) and the downlink frequency to Jamaica was at uhf. This arrangement applied to the Denver transmissions only. All transmissions from Jamaica employed an S-band uplink and uhf downlink for video and voice.

A composite baseband was transmitted that consisted of a television video and four audio channels on separate subcarriers. Video from live television programs was in color or black and white, but video tape programs were all in color.

Figure 4-4 shows the studio and control room block diagram at the Mona Campus. The diagram shows the monitoring receiver at uhf and the vhf coordinating arrangements through ATS-3. The rf characteristics of the S-band ground station uplink were as follows:

Frequency	2247.5 MHz
Power amplifier output	28 watts (W)
E.i.r.p.	46.5 decibels referred to 1 watt (dBW)
Modulation	Wideband frequency modulation
Antenna polarization	Right-hand circular
Antenna diameter	3.05 meter
Antenna gain	31.2 dB
Satellite G/T (ECH)	10.4 decibel/kelvin (dB/K)
Path loss at 2.25 gigahertz (GHz)	191.0 dB

The latitudes covered in the Caribbean were lower than the previous experiments and the look angle to ATS-6 was low on the horizon when receiving the uhf downlink signals on the most easterly island site. The video signals were acceptable but did not meet the normal standards for television reception.

Some deep fading was encountered in the vhf links (ATS-3) at all sites that was only partially caused by multipath effects due to the siting of the antennas. Many of the studio problems were caused by the make-shift arrangements necessitated by the use of existing facilities. These were basically quite surmountable given adequate equipment, and are documented on page 67 of Reference 1.

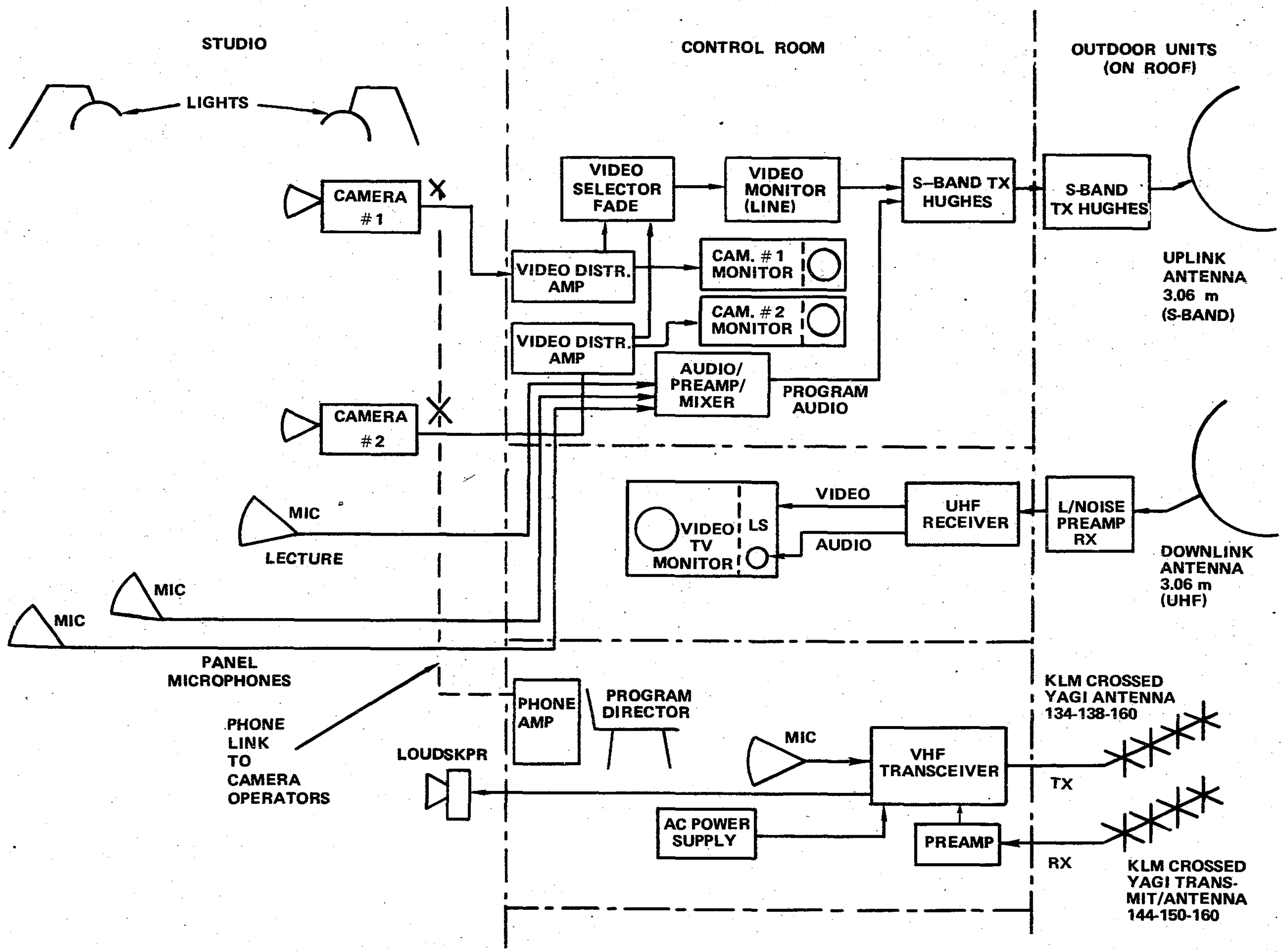


Figure 4-4. Block Diagram of Jamaica Station at Mona Campus

S-Band Transponder

The S-band transponder downlink characteristics at uhf frequencies were:

Location (1976)	140° West longitude
E.i.r.p. (PFF)	52.7 dBW
Frequency	860 MHz
Path loss (860 MHz)	183.0 dB
Pointing error loss	0.5 dB

A block diagram of the ATS-6 transponder in the prime mode for the HET experiment is shown in Figure 1-5, Chapter 1, "Health, Education, Telecommunications Experiment."

A block diagram of the uhf receiver terminal is shown in Figure 4-5.

ATS-3 Uplink and Downlink

The ATS-3 vhf transponder primary parameters were as follows:

Satellite location	70°, ±1° West longitude
Orbit inclination	5.47°
E.i.r.p. (September 1970)	47.6 dBm
Receiver noise figure	4.0 dB
Receiver bandwidth	100 kHz
Transmit frequency	135.6 MHz, ±0.05 MHz
Receiver frequency	149.22 MHz, ±0.5 MHz
Translation error	+800 Hz, ±100 Hz

The ground station vhf terminal consisted of a 15-watt transmitter/receiver feeding a power amplifier coupled to two crossed yagi antennas used for simultaneous transmission and reception. The transmit power amplifier and the transmit/receive operation was controlled by a remote control unit.

The foregoing general arrangement, except for the S-band uplink, was used at all sites. The specific arrangements for studio space, program control, and conferencing assemblies varied according to the availability of rooms and building accommodations between locations.

The specifications for the vhf transceiver terminal were as follows:

<u>Transmitter</u>	
Frequency Range	144.0 to 140.0 MHz
Modulation type	F3
Power Supply	13.8 Vdc, ±15 percent
Current drain	Transmit–Max. (15 W) average 3.2 A

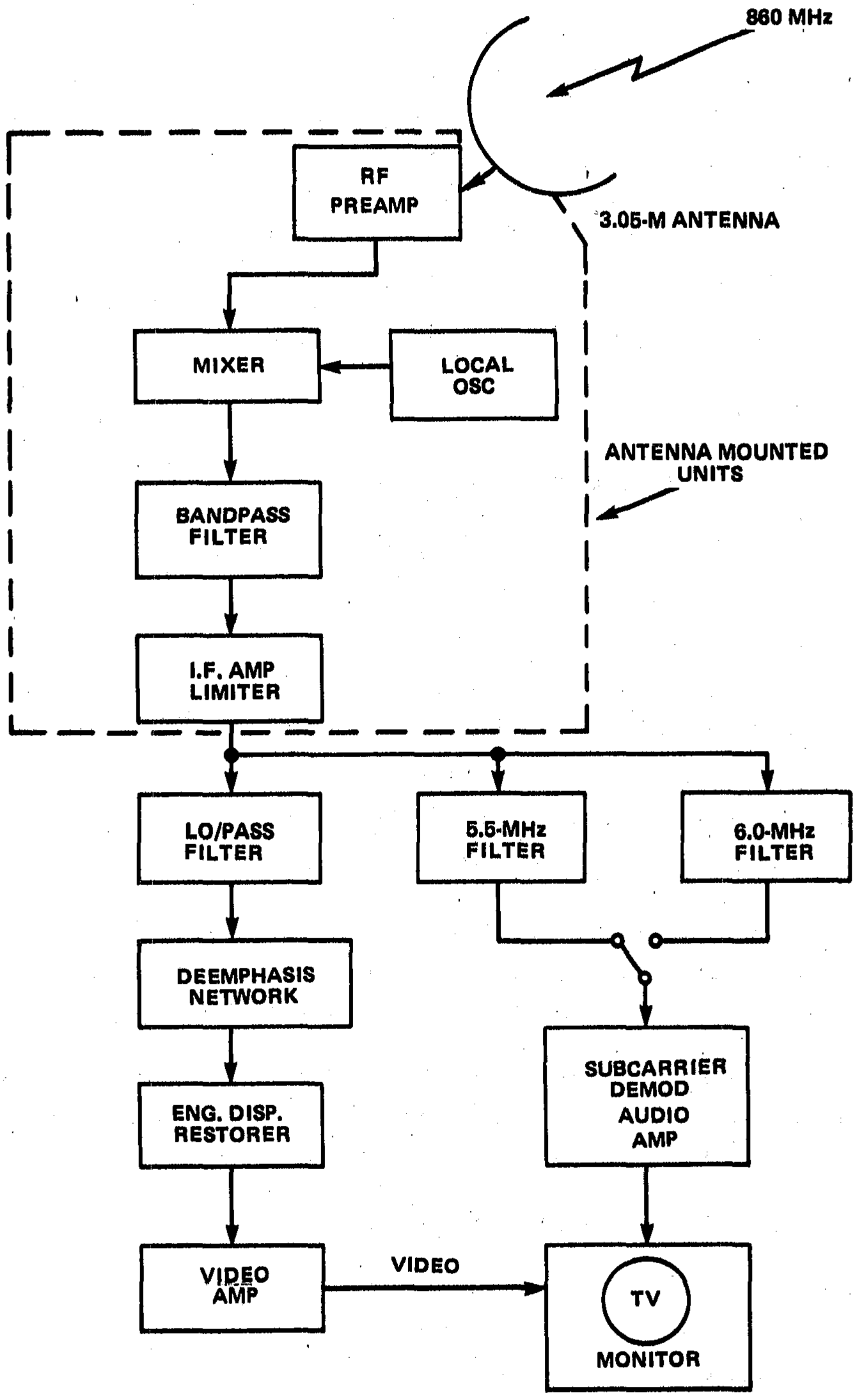


Figure 4-5. Block Diagram of UHF Receiver Terminal

Output Impedance	50 Ω
Size	5.72 cm H X 16.2 cm W X 22.5 cm D
Weight	2.0 kg
Transmitter Power	High – 15 W Low – 1 W
Frequency Control	Crystal oscillator (12 MHz)
Modulation	Variable reactance phase modulation
Frequency Deviation	Adjustable 3 to 16 MHz
Audio input impedance	10 kilohm (kΩ)
Microphone input level	10 kΩ dynamic microphone with push-to-talk switch
Receiver	
Receive frequencies	12 channels in 146-MHz band
Reception system	Double superheterodyne
Intermediate frequencies	1st i.f.–10.7 MHz 2nd i.f.–45.5 kHz
Sensitivity	S + N/N = 12 dB (V_o = 0.5 V)
Spurious response	-55 dB
Squelch threshold	less than 0.3 V
Bandwidth	±5 kHz–6 dB point
Audio power output	2.5 W
Audio output impedance	8 Ω
Frequency control	Crystal (45-MHz)
AC Power Supply	
Voltage Out	Adjustable 10 to 15 V
Load Regulation	2 percent no load to 20 A
Current Output	25 A (50 percent duty cycle) 14 A continuous
Current Limiting	Foldback limiting to 1 A nominal
Ripple	30 mV at 20 A load
Operating Temperature	+65°C max at 14 A load
Meter Accuracy	5 percent of full scale
Fuse	10 A for 117 V, 5 A for 220 V
Dimensions	31.8 cm D X 17.2 cm W X 19 cm H
Weight	10.2 kg

Power Amplifier	
Supply Voltage	13.5 Vdc
Input VSWR	1.4 to 1 (144 to 148 MHz)
Duty Cycle	1 CAS (Intermittant Commercial Amateur Service)
Rf Input Power	10 W (range 5 to 15 W)
Nominal Power Output	140 W
Nominal Current	18 A
Impedance	40 Ω (input and output)
Dimensions	16.5 cm D X 25.4 cm W X 5.1 cm H
Antennas	
Transmit	Vhf circularly polarized
Polarization	Right-hand circular
Gain	11 dB
Receive	Vhf circularly polarized
Polarization	Right-hand circular
Gain	11 dB

MANAGEMENT AND CONTROL

Control and direction of the satellites was carried out by the ATS Operations Control Center at Goddard Space Flight Center through its Rosman Ground Station near Brevard, North Carolina. The network diagram is shown in Figure 4-6.

The site locations for the Caribbean experiment were:

Site	Location	Lat., Long.
Jamaica	Mona Campus	18°02′ N; 76° 48′ W
Barbados	Cave Hill Campus	13°18′ N; 59° 38′ W
St. Lucia	Morne Fortune Campus	14°01′ N; 60° 59′ W

RESULTS

Fifty-one percent of the television time was dedicated to Outreach Programs that included developments in rural medical care in the Caribbean, agricultural research in rural areas, the value of the Nurse Practitioner Program to rural clinics, family-life education programs in the schools, early childhood education (community-oriented attitudes, services, and research) and coordination of university center libraries. In addition to the Outreach Programs, seven course lectures in a variety of disciplines were transmitted and interactive teleconferences took place.

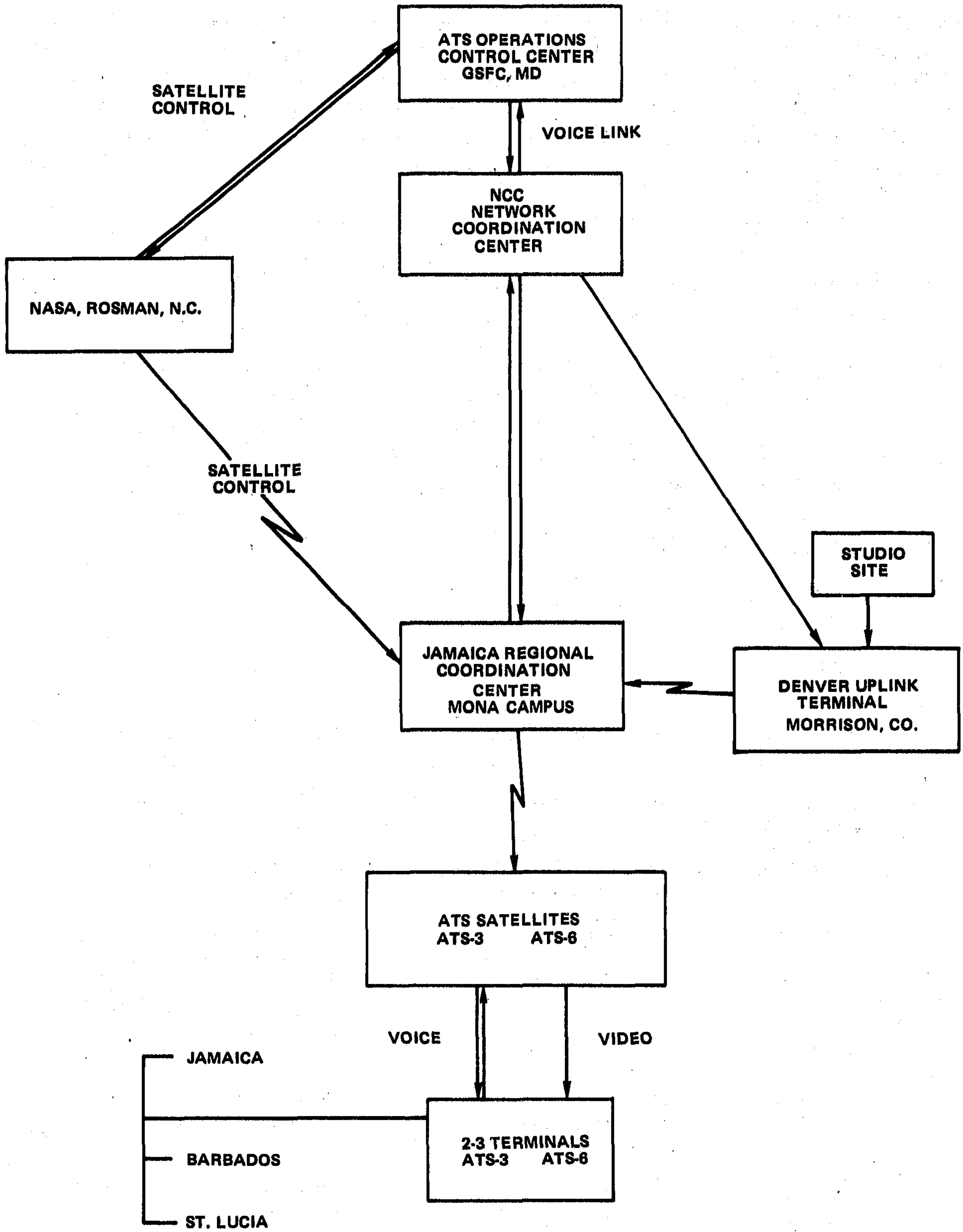


Figure 4-6. Experimental Control Network for the University of West Indies Experiment

Great enthusiasm was generated by the projection of the university to noncampus territories through two seminars offered at St. Lucia. One seminar brought together food producers and professional agriculturalists in discussions concerning improved food production. The second seminar brought together participants from the West Indies, the United States, Holland, and the United Kingdom to work toward a Caribbean model of education for the deaf. Panels at Mona, Cave Hill, and Barbados reacted to papers presented by conference participants and there were interactive discussions.

The following programs were successfully achieved during the University of West Indies Experiment:

- One introductory teleconference, centered on solar energy, was made possible through a linkup with the Solar Energy Research Institute in Denver, Colorado.

- A special radio conference was held to demonstrate communication links over extremely large distances. The Mona and Cave Hill Campuses of the University of West Indies (UWI) held exchanges with Peacesat sites at Wellington, New Zealand; Suva, Fi Niue Island; Rarotonga; Honolulu; Tarawa; and Santa Cruz, California. The linkup between ATS-1, used by the Peacesat group, and ATS-3, used by UWI, was via Denver, Colorado.

- A series of Jamaican campus programs were as follows:

Satellite Demonstration Program

Date	Type of Event	Remarks
WEEK I		
Mon., Jan. 16	Demonstration of Facilities	Demonstration of use of the equipment at each site
Wed., Jan. 18 9:30 to 10:00	Meeting of Board for Post-graduate Studies	Confirmation of time and grant requests
10:15 to 11:00	Meeting of Dean/Vice Deans, Heads of Departments	New degree structure; effects and implications
Fri., Jan. 20 9:30 to 11:00	Opening Function	Speeches included the Vice-Chancellor, campus principals, Minister of Education, Jamaica and Barbados, U.S. Ambassador to Jamaica
WEEK II		
Mon., Jan. 23 9:30 to 11:00	Medical Teleconference (Outreach) Chairman: Dr. O. Minott	Developments in rural medical care in the Caribbean
Wed., Jan. 25 9:30 to 11:00	Librarians' Conference Chairman: K. Ingram	Conference on topics relevant to library services in the university and the Caribbean with emphasis on St. Lucia's Deaf Conference

Date	Type of Event	Remarks
WEEK II (cont)		
Fri., Jan. 27 9:30 to 10:10	Natural Sciences, Course Lecture–Botany Chairman: Dr. L. Coke	Structure and uses of trees
10:15 to 11:00	Faculty of Law Course Lecture–Chairman: Miss D. Whyte	English common law connection and the law of public mischief in some West Indian territories (Part I)
WEEK III		
Mon., Jan. 30	Outreach Program Chairman: Mr. G. A. Southwell	Agricultural extension teleconference on "Rural Integrated Development"
Wed., Feb. 1 9:30 to 10:10	Faculty of Arts Course Lecture–Dr. H. Johnson	Imperial uses of commissions of enquiry–Moyne Commission of 1938
10:15 to 11:00	Faculty of Law Course Lecture–Miss D. Whyte	English common law connection (Part II)
Fri., Feb. 3	Administration Conference	Conference involving vice-chancellor, pro-vice-chancellor, registrar secretaries, bursars, public relations officers, etc.
WEEK IV		
Mon., Feb. 6 9:30 to 11:00	Medical Teleconference Outreach–Chairman: Dr. Mary Scivwright	Nurse Practitioner Program and its value to rural clinics
Wed., Feb. 8 9:30 to 11:00	Conference between Educators of the Deaf Outreach	Teleconference between coordinators of the Deaf Conference in St. Lucia (LDC Outreach)
Fri., Feb. 10 9:30 to 11:00	Outreach Program Chairman–Mrs. S. Francis	Seminar on family life education techniques
WEEK V		
Mon., Feb. 13	Conference on Education Coordinator: Prof. R. Murray	Teleconference involving deans, vice-deans and faculty executives
Wed., Feb. 15 9:30 to 10:10	Faculty of Arts Course Lecture–English Chairman: Dr. M. Morris	
10:15 to 11:00	Faculty of Natural Sciences Course Lecture–Chemistry Chairman: Dr. P. Chan	Discussion on the shape of organic molecules

Date	Type of Event	Remarks
WEEK VI (cont)		
Mon., Feb. 20 9:30 to 11:00	Extra-Mural Tutors' Teleconference–Chairman: Prof. R. Nettleford	
Wed., Feb. 22 9:30 to 11:00	Faculty of Medicine Course Lecture–Chairman Prof. F. Alleyne	Diabetes/Mellitus
Fri., Feb. 24	Outreach Program Course Lecture in Engineering Coordinator: Dr. Chin	
WEEK VII		
Mon., Feb. 27 9:30 to 11:00	International Panel Discussion on Solar Energy	A teleconference involving Denver, Colorado; Barbados; Jamaica; and St. Lucia on the topic of solar energy
Wed., Fri., Mar. 1 to 3	Agricultural Extension 2½-day seminar with 90-minute Satellite Sessions	Participants to travel to St. Lucia: During satellite sessions, Jamaica and Barbados will interact with St. Lucia's participants
Mon., Wed., Mar. 6 to 8	Seminar on Education of the Deaf (Outreach) Coordinators: Mrs. P. Charles, St. Lucia; Mrs. J. Robinson, Jamaica	Similar to agricultural extension seminar. Participants to include international resource persons
Fri., Mar. 10	Closing Activity	

Part B

Satellite Instructional Television Experiment (India)

CHAPTER 5

SATELLITE INSTRUCTIONAL TELEVISION EXPERIMENT (INDIA)

INTRODUCTION

The launch of ATS-6 on May 30, 1974, made possible the performance of the Satellite Instructional Television Experiment (SITE). Through a memorandum of understanding signed by the United States National Aeronautics and Space Administration (NASA) and the Indian Space Research Organization, India became the first country to broadcast mass television using a spacecraft communication system.

The enormous effort required to conduct SITE cannot be adequately described in a technical report of this nature. The management of SITE, in itself, would be a subject of a major study. Volumes that consider the social aspects of the experiment will someday be written. Therefore, this report will deal exclusively with the technical descriptions and results of SITE.

As a 1-year experiment, SITE began operation on August 1, 1975, and continued until July 30, 1976. During this time period, approximately 2400 receive-only stations provided 4 hours of television daily to remote villages. These 2400 direct reception terminals were located in clusters of about 400 each in six states of India. In addition, there were about 2600 conventional television receivers located near vhf television transmitters. For many of these villages, this was the first exposure to any type of electronic media.

Figure 5-1 shows the location of these clusters. The numbers under the cluster identification represent the number of villages within the cluster area.

TECHNICAL OBJECTIVES OF THE EXPERIMENT

The technical objectives of SITE were based upon the development of a national infrastructure to build a capability for television broadcast. In a developing country, like India, there existed no national communications network of radio or television, thus making the test of a satellite system vital for satisfying national goals. This also provided an opportunity to perform a total system test, including functions such as program production, hardware development, manufacture, and broadcast distribution.

The technical objectives of SITE are summarized as follows:

- Provide a system test of satellite broadcast television for national development
- Enhance the capability for design, development, manufacture, installation, and operation of television receivers

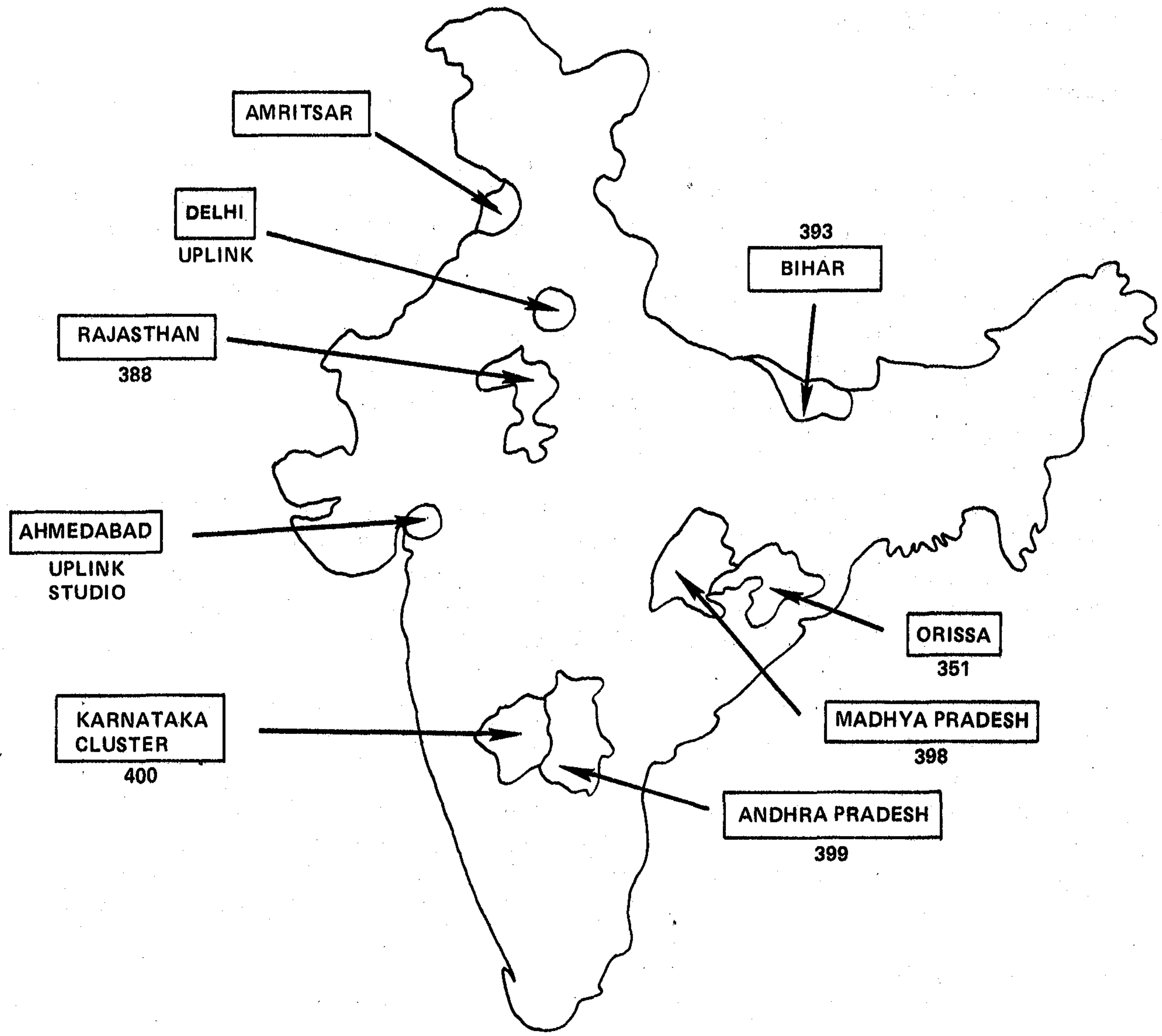


Figure 5-1. SITE Cluster Locations

- Gain experience in the design, manufacture, installation, and operation of television broadcast and distribution facilities to the extent used by the experiment
- Gain experience in determining optimum receiver density, distribution, and scheduling of a national television system
- Gain experience with the techniques involved in developing, preparing, producing, and transmitting television program material.

TECHNICAL DESCRIPTION

System Overview

The overall experiment network is shown in Figure 5-2. ATS-6 was used as the prime television transmitter for the experiment. It received program material at 6 GHz from either the Ahmedabad Earth Station (AES) or the Delhi Earth Station (DES), converted the 6-GHz signal to 860 MHz and retransmitted to the 2400 direct reception systems (DRS) and the special installation for the terrestrial redistribution transmitters located at Delhi, Amritsar, and Pij. The Applications Technology Satellite Operations Control Center, located at NASA Goddard Space Flight Center, was responsible for scheduling and control of ATS-6. The schedule was coordinated with AES, the SITE experiment control center. Coordination of schedule and program handover was accomplished by voice between AES and DES.

The main studio was responsible for the production of the morning program material and also supplied program material for the Pij redistribution experiment. All India Radio (AIR) produced evening program material and special programs at various studios within India. A special science series of programs were produced at the Bombay studios. The AIR transmitter, in Delhi, was used for program redistribution. The final special redistribution system was located at Amritsar.

The 2400 village direct reception systems were operated by appointed custodians who were responsible for turning the DRS equipment on and off, and reporting status.

Programs originating at the SITE studio were fed to the AES transmission system by cable. A microwave system connected the studio with the terrestrial television transmitter at Pij. Programs received at Delhi were simultaneously connected to the AIR transmitter at Delhi. The Amritsar redistribution transmitter was equipped with a special 4.6-meter DRS antenna for program reception.

Direct Reception System

The direct reception systems were installed in the villages selected to participate in the SITE experiment. The DRS consisted of a 3.0-meter parabolic antenna and feed; a preamplifier, mixer, and local oscillator mounted at the antenna; and a receiver system mounted adjacent to the television monitor that had a 61-cm screen.

A block diagram of the direct reception terminal is shown in Figure 5-3. The incoming 860-megahertz (MHz) signal was amplified and downconverted to 70 MHz and passed to the receive system by a cable between the antenna and receiver. The receiver converted the 70-MHz signal to baseband audio and video. A switch was provided to select either of the two audio signals. A

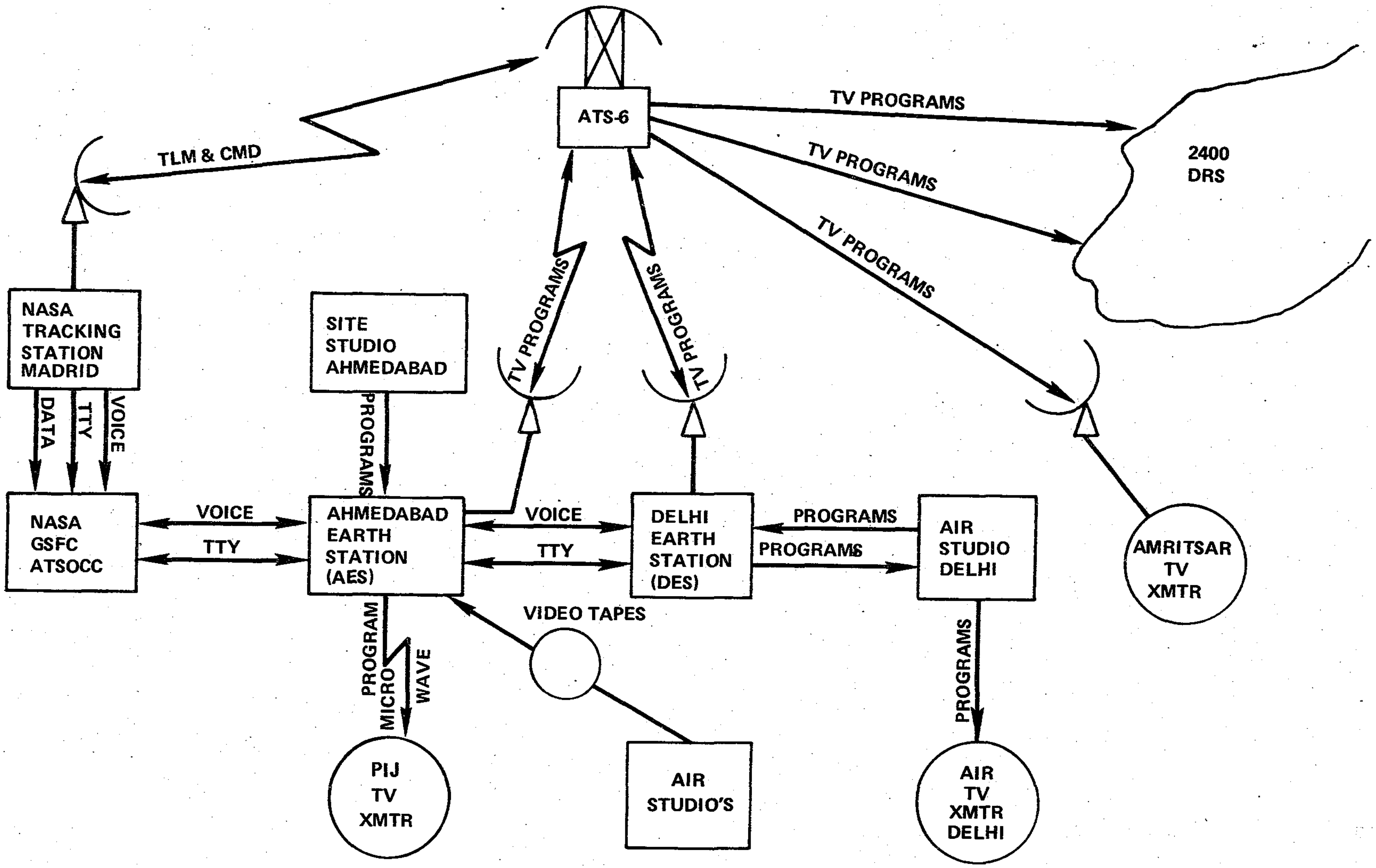


Figure 5-2. Satellite Instructional Television Experiment Overview

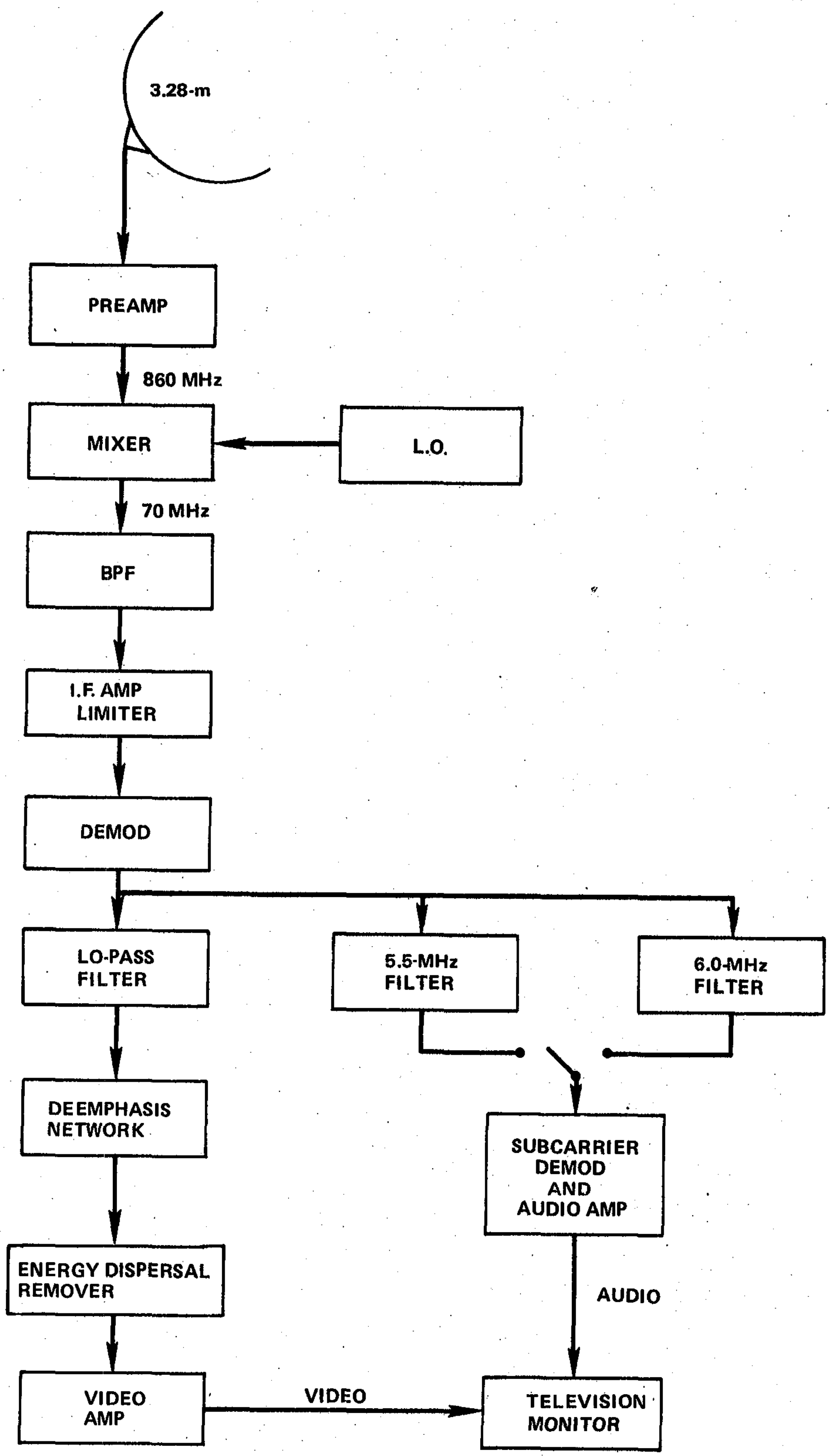


Figure 5-3. SITE Direct Reception Terminal Block Diagram

television monitor with a 61-cm cathode ray tube was used to display the program. The specifications for the DRS were as follows:

Baseband

Television standard	CCIR B format (625-line, 50-field per sec)
Emphasis:	CCIR
Video bandwidth:	25 hertz (Hz) to 4.5 MHz
Audio bandwidth:	50 Hz to 10 kilohertz (kHz)
Emphasis:	75 microseconds
Audio subcarrier 1:	5.5 MHz
Audio subcarrier 2:	6.0 MHz
Subcarrier deviation:	75-kHz peak
Energy dispersal:	25 Hz triangular (point of inflection coincided with sync. tip)

Modulation

Type:	Frequency modulation
Sense:	Black to white with increasing frequency
Deviation:	
Video	6 MHz peak
Audio (carrier by subcarrier)	1 MHz peak
Energy dispersal	1 MHz peak

Uplink Stations

Ahmedabad Earth Station

The prime uplink station was located at Ahmedabad and consisted of a 14-meter antenna with its associated transmission equipment. The Ahmedabad Earth Station had two 3-kilowatt (kW) C-band transmitters and redundant C-band receive channels. Figure 5-4 shows a block diagram of the AES.

The Ahmedabad Earth Station was composed of redundant C-band transmit chains and redundant C-band receive channels. In addition, NASA provided range and range-rate (R&RR) equipment to enable Ahmedabad to perform orbit measurements during the SITE experiment. The C-band receive system was used for R&RR operations and initial alignment of the 14-meter antennas during the SITE setup period. Since the power subsystem of ATS-6 could not support full-time C-band and ultrahigh frequency (uhf), C-band was operated during the SITE setup period and deenergized after turn on of the uhf transmitter. R&RR was conducted during non-SITE periods. Not shown in the block diagram was a DRS equipped with a 4.6-meter antenna that was used to monitor the performance of the transmission system during SITE and to provide the rediffusion signals to the Pij transmitter.

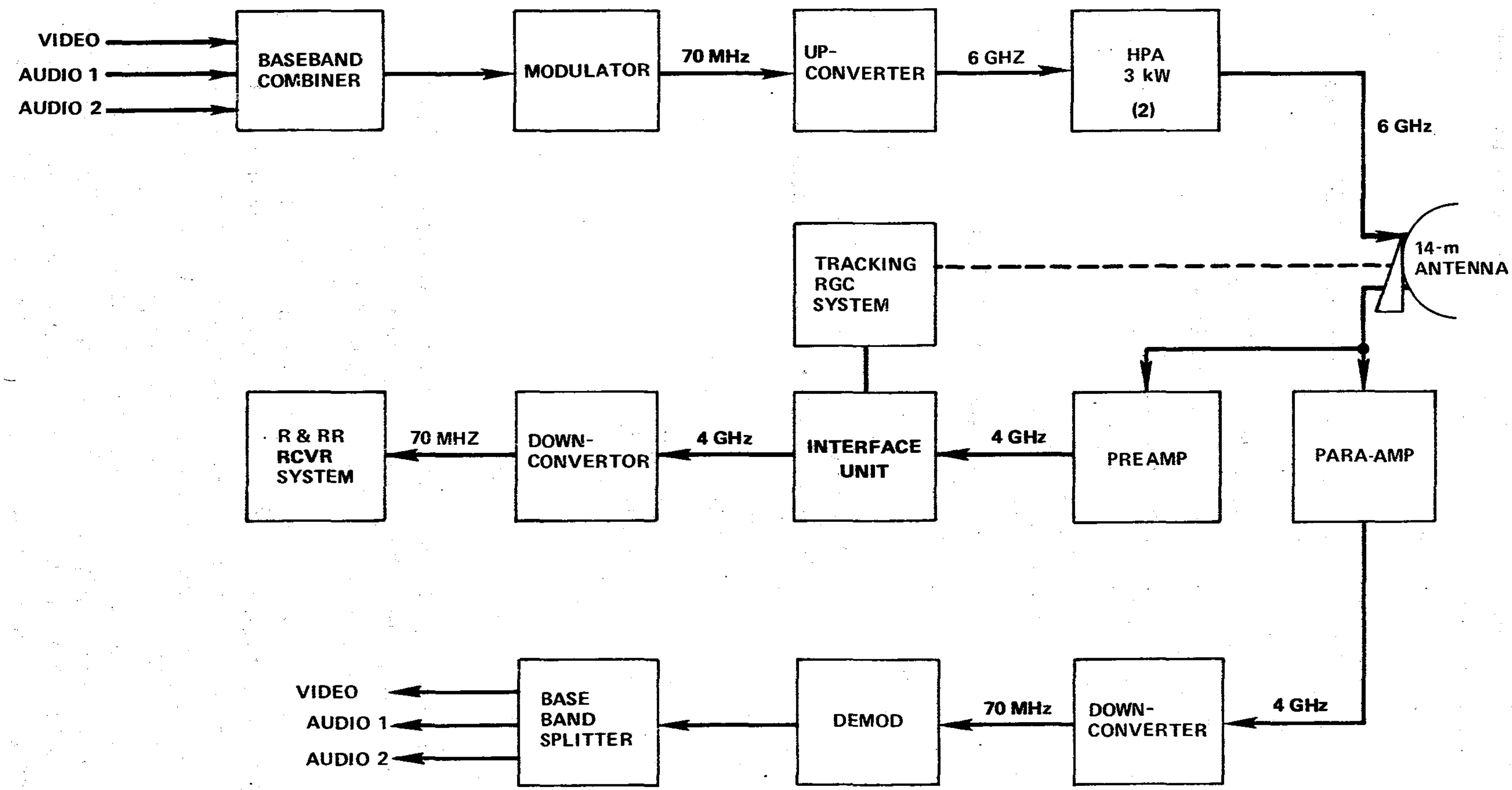


Figure 5-4. Ahmedabad Earth Station

Delhi Earth Station

The alternate uplink station was located at Delhi and employed a 9.5-meter antenna. The DES was also equipped with redundant 3-kW C-band transmitters. It was provided with a uhf receiver system rather than a C-band system to reduce costs. It was considered unnecessary to receive C-band, because the only need for C-band reception was the NASA requirement to perform range and range-rate measurements on ATS-6 for orbit determination. The SITE experiment, itself, did not require C-band receive capability. Figure 5-5 shows a block diagram of the DES.

System Performance

Reliability

A total of 1020 hours of programs were transmitted during the experiment. System reliability for each major system element was as follows:

Ahmedabad Earth Station	0.9976
Delhi Earth Station	0.9999
Amritsar DRS	0.9902
Pij Rediffusion Transmitter	0.9997

Availability

The direct reception systems, installed throughout the clusters, had a combined availability in excess of 90 percent during the second half of the experiment year. At the beginning of SITE, the availability was 60 percent with a steady increase toward the final 90 percent achieved. When the failures per month were compared to the total failures during SITE, a monthly percentage of 7 to 8 percent was obtained. This indicated that system reliability was not influenced by start-up failures and that system failures did not increase with time. The lower availability at the beginning of SITE was attributed to nonavailability of ATS-6 prior to July 25 to perform antenna pointing; monsoons causing village accessability problems during July and August 1975; and start-up of the maintenance system.

Link Performance

The DRS performance was difficult to judge from a technical point of view, since measurements made in villages were not always accurate because of poor test equipment and techniques. From 271 measurements of video signal-to-noise ratio made in the six cluster areas, the values ranged from 33.0 decibels (dB) to 47.5 dB. The average of these measurements showed that 63 percent of the video signal-to-noise values exceeded 43 dB. Even the lowest measurements were at the low end of TASO 2. (TASO 2 is a very acceptable TV picture quality.)

Similar results were noted with audio signal-to-noise measurements. The audio measurements also showed that the 40-dB specification was exceeded 60 percent of the time.

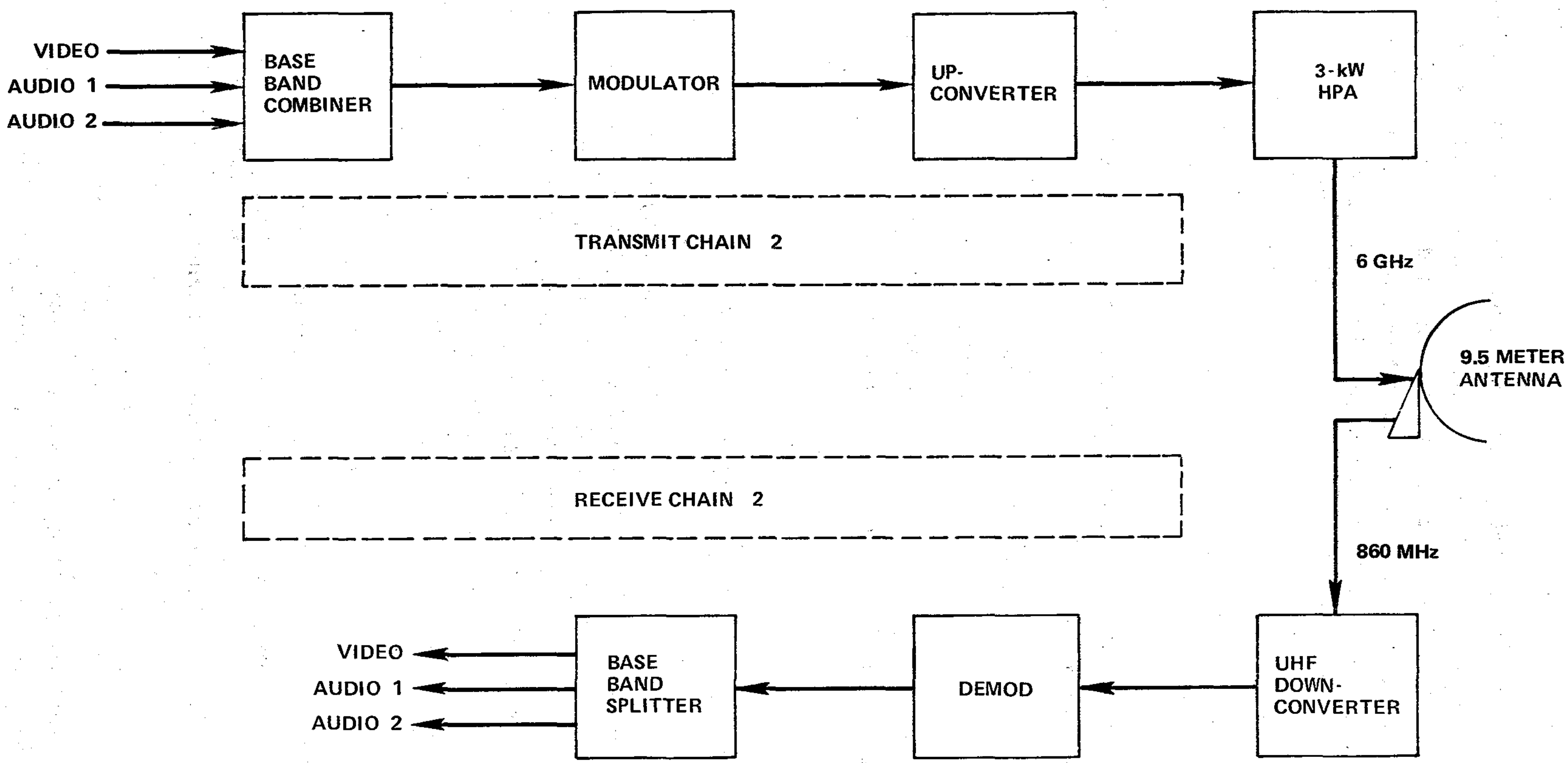


Figure 5-5. Delhi Earth Station

CHAPTER 6

THE GALLOWAY REPORT
SATELLITE INSTRUCTIONAL TELEVISION EXPERIMENT (INDIA)

NASA REPRESENTATIVE REPORT

Mr. Howard Galloway, NASA Resident Representative, was assigned to Ahmedabad for the duration of SITE. Unfortunately, his untimely death terminated the position of NASA Representative early in the program. The following paragraphs are excerpts from his weekly reports. Hopefully, readers will gain insight into the potential social significance of the SITE experiment.

Morning Programme (16-27 October 1975)

The village teachers usually have one of the following two types of credentials: degree or certificate. The degree teacher attends a four-year teacher training program at college. The certified teacher attends a two-year Senior Teachers Certificate (STC) course at an STC institution like that found in the village of Goner.

Usually the morning SITE science programme is from 1000 to 1130 IST [Indian Standard Time]. However, the Daseri school holidays were from 14 to 18 October 1975. Instead of wasting this precious satellite time, an STC training program was given from 16 to 17 October 1975.

A large group of user-teachers received 2 days instructions at STC centres like the one in Goner. Then these teachers were placed one per each SITE village. Each teacher had an average of 10 other teachers-in-training for the daily course, which ran from 1030 to 1630 IST.

The training was a multimedia course and worked as follows:

The agenda consisted of lectures, TV programme lectures, radio programme, demonstrations, field trips, discussion group, daily individual exam papers. Each teacher had a work cum notebook. Before the TV programme, the user teacher gave a lecture preparing the group for the TV programme. Then the TV programme was observed. This was followed by another lecture (tell them what you are going to tell them, tell them, tell them what you told them). This was a very good course and was well received.

At each village, the user-teacher explained the programme to me and said that the TV session was by far the best medium-sight and sound. Most of the teachers told me that the TV class was the most interesting that they had ever received.

Hasteda

Although the morning SITE program was over (1130 IST) and we had no fault report on this village, we stopped to check on the DRS. The teachers' training was in session–one resource teacher plus eleven teachers–very good session. The resource teacher was giving his post-TV lecture. He was very intent. Our presence did not even slow him up until he had completed his lecture. Since the rush was over (program off), we accepted their offer of tea. When queried about the usefulness of TV training, the resource teacher replied, "There can be no two opinions about this. The TV is by far the most superior method that we have." This village has a maximum of 600 viewers and the TV was reported to be A-OK.

TV and the People

The advent of the TV in the village has been held to be an important event. Every evening large numbers of people from different settlements come to view the TV. Even though it was the festival of Soma Chakeva (full moon night of Kartik) and all the women were engaged on it, the total attendance on 18/11/75 was 177 (82 male, 38 female, children 57). The agriculturists have taken full advantage of the TV agriculture programs. They have started putting the right kind and quantity of fertilizers and have also adopted a number of improved agricultural practices. It is on account of the TV that the visits of the V.L.W. have become more frequent than before. Before the TV came, nobody in the village recognized the V.L.W. There is also a marked increase in school attendance. Out of 203 children on the rolls 173 or 85% were sent on the 19th November 1975. School children bring even their younger siblings to view the TV and thus there is a growth in the school going habit. Children have learned a number of songs and are interested in the news. So great was their interest that the guardians were alarmed as on most of the evening the children were busy viewing the TV and they had no time to do their homework. So most of the guardians now allow them to see TV only once a week. Then we find a sizeable number of school-going children and some nonschool-going children in the evening in the TV grounds.

The TV had a great impact on the women folk in the village. It is for the first time that they have come out of their homes and insist on viewing the TV every day. There has been a change in the time of cooking. Food is cooked before the TV time. Men are free to eat either before the TV time or after it even though food becomes cold. Some of the younger women have learned cooking of some new dishes and make of condiments.

Linguistic acculturation was also evident in the use of word Namaskar instead of the commonly prevalent term of greeting Pranam. The use of the Khari Boli has become common among the young girls.

Before the coming of TV the local market was the only source of entertainment. People went to the market even if they had nothing to buy. TV provides a new source of entertainment. They also meet their friends and relations in the TV ground.

People in general are more enthusiastic about the TV and are thinking of putting up a shed so that people can sit comfortably on the ground specially during winter. They even talk of raising subscription and donating their labour for this purpose. I am hopeful of the shed coming through because there is a lot of community spirit in the village. The village has also some sources of income which it derives by auctioning the fishing rights in the river which passes through the village and also by levying a small fee from all the merchants who come to purchase the surplus foodgrains.

The TV is kept in the library building which is a place where all the young men have been gathering for many years in the evening. The custodian is an enthusiastic young man in whom the spirit of social service is strong. No honorarium is being paid to him.

The results given below were collected by Mr. Galloway during vists made 17-22 October 1975.

Visit No.	Village	
1	Kapurawala	F
2	Hasanpura-Was Nevta	D
3	Charenwala	E
4	Iuniyawas	A
5	Bhavgarh Bandhya	A
6	Dantli	A

Visit No.	Village		
7	Goner	A	
8	Achrol (MID antenna)	A	
9	Dhand	A	
10	Kookas	A	
11	Pili Ki Tilai	A	"Never failed"
12	Shivadas Pura	A	
13	Belwa	A	
14	Bambala	A	
15	Kanota	F	
16	Vijay Mukandpura	E	
17	Naila	A	
18	Antela	A	
19	Paota	E	
20	Pragpura	A	
21	Muhana	C	
13′	Belwa	B	
22	Bagwana	A	
23	Mahla	A	
24	Dudu	A	
25	Michoon	A	"Never failed"
26	Govindgarh	E	
27	Malikpur	E	
28	Easteda	B	
29	Bhutada	B	
11′	Pili Ki Tilai	A	

Legend:
A = TV ok and program on during visit
B = TV ok, program over
C* = TV ok, but electricity off
D = TV working but in need of adjustment
E = TV out, repaired during visit
F = TV out, not repaired during visit

*In many villages the electric power is scheduled to be available during specific periods each day. These periods were usually scheduled around agriculture requirements. In some cases these periods were adjusted to provide power during the SITE scheduled period.

Total number of DRS that could work (SITE program on) is equal to A + C + D + E = 28

Percent of DRS working on arrival $= \frac{A}{28} \times 100 = \frac{19}{28} \times 100 = 67.86$

Percent of DRS repaired $= \frac{D+E}{28} \times 100 = \frac{6}{28} \times 100 = 21.43$

Percent with electricity out $= \frac{C}{28} \times 100 = \frac{1}{28} \times 100 = 3.57$

Percent still faulty $= \frac{F}{28} \times 100 = \frac{2}{28} \times 100 = \frac{7.14}{100.00}$

Note: Percent working at end of visit = 67.86 + 21.43 = 89.29!

School Teachers and TV:

The school teachers are largely apathetic to the TV programs. They do not take any interest in talking to children about the forthcoming programs or about the programs they have just viewed. The school is in bad shape and the guardians complain that the teachers do not teach. All the seven teachers belong to the same locality and they consider their job secondary to their agricultural pursuits. Three of them belong to the same village and four of them to the neighboring villages. One of them has been in school for the last 30 years and hopes to retire from there. Their relations with the village youth are not good and once they stopped children from attending the school TV program.

The Anthropologist and the People:

The SAC fellow, Shri M. N. Jha is extremely popular in the village. People run to him for the solution of some of their problems. All the responsibility for good and evil of the TV is shouldered by him. Old men decry him for introducing indiscipline among the women in the village, while the young men shower praises upon him for their daily entertainment through TV. Some people want him to arrange for repetition of programs they like best. He is a perspective observer and his daily observation notes are interesting reading.

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A large number of technical papers have been written by the Indian Space Research Organization (ISRO) based on the results of the Satellite Instructional Television Experiment and ATS-6 operations during ISRO's development of their follow-on satellite system "INSAT" (expected to be operational about 1982 or 1983). For this material, the reader is referred to:

The Librarian
Indian Space Research Organization
Ahmedabad, India 380015

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Part C
Independent Television Experiments

CHAPTER 7

AIDSAT

SUMMARY

Although not part of the original plan of demonstrations for ATS-6, the U.S. Department of State, through its Agency for International Development, coordinated a project with NASA titled AIDSAT. This project, which started in June 1976, demonstrated satellite television technology to a series of countries that were accessible as ATS-6 shifted back to the Western Hemisphere after completion of the Government of India's Satellite Instructional Television Experiment (SITE).

These demonstrations included an introduction by an American astronaut, a Bicentennial greeting from the President of the United States, a response from each country's leader, and pre-recorded video tape presentations of natural disaster satellite assistance and Earth resources satellite survey applications. The last part consisted of an in-country panel audience discussion with a counterpart panel of experts in the United States.

AIDSAT encompassed a 90-day period and covered 27 individual countries. Although there were weather and technical problems, the program was so successful that practically every country visited has subsequently invested in a satellite access capability.

BACKGROUND

The Agency for International Development (AID) of the U.S. Department of State was the experiment coordinator for the AIDSAT program. The 27 country demonstrations were divided into two phases with three clusters to a phase as established by geographic association and NASA team assignment capabilities. The planned country phase and cluster association follows.

Phase I

Cluster A Team	Cluster B Team	Cluster C Team
Bangkok, Thailand	Dacca, Bangladesh	Islamabad, Pakistan
Muscat, Oman	Abu Dhabi, U.A.E.	Nairobi, Kenya
Amman, Jordan	San'a, Yemen	Rabat, Morocco
Khartoum, Sudan	Tripoli, Libya	

Phase II

Cluster A Team	Cluster B Team	Cluster C Team
Douala, Cameroon	Bangui, Central African Republic	Abidjan, Ivory Coast
Ouagadougou, Upper Volta	Bamako, Mali	Buenos Aires, Argentina
Montevideo, Uruguay	Santa Cruz, Bolivia	Lima, Peru
Guayaquil, Ecuador	San Jose, Costa Rica	Kingston, Jamaica
Freetown, Sierra Leone		Port au Prince, Haiti
Monrovia, Liberia		Paramaribo, Surinam

The operating philosophy for AIDSAT during Phase I involved the use of the Atlantic INTELSAT satellite and ATS-6. Live United States television, with accompanying audio, originated at NASA Goddard Space Flight Center (GSFC) and was routed over AT&T leased microwave facilities to either the Etam, West Virginia, or Andover, Maine, INTELSAT ground stations. The signal was uplinked to INTELSAT Atlantic and downlinked to the INTELSAT ground station at Buitrago, Spain, operated by the "Companie Telephonica National de Espana (CTNE)" organization. The signal was then transmitted by microwave to the NASA Madrid Hybrid Ground Station for uplinking to ATS-6 at a C-band frequency of 6147.5 MHz. ATS-6 then downlinked the signal to the individual country concerned on an S-band frequency of 2566.7 MHz. Television and audio programs originating from the various Phase I countries followed the same course in reverse. They were uplinked to ATS-6 at S-band (2247.5 MHz), downlinked to the Madrid Hybrid Ground Station on C-band (3947.5 MHz), transmitted by microwave to the INTELSAT Buitrago Ground Station and uplinked to Atlantic INTELSAT for transfer to GSFC in the United States. (See Figure 7-1.)

The operating philosophy for AIDSAT during Phase II deleted the requirements for the Atlantic INTELSAT since the westward drifting of ATS-6 covered the selected African coastal and South American demonstration countries and the U.S. east coast. Again, live television was originated in the United States and accompanying audio was originated at GSFC and routed over leased microwave circuits, but this time to the NASA Rosman Ground Station in North Carolina. Rosman Ground Station provided signal processing and uplink to ATS-6 at C-band (6147.5 MHz). ATS-6 retransmitted to the transmit and receive terminal (TART) and receiver-only terminals (ROT) at S-band (2566.7 MHz). Television and audio programs originating from the various Phase II countries reversed this course with TART-to-ATS-6 uplink at S-band (2247.5 MHz) and ATS-6-to-Rosman downlink at C-band (3947.5 MHz) for connection to GSFC. The distribution of in-country produced programs for in-country audiences was via a downlink at S-band (2566.7 MHz) to the ROT's.

Two modes of operation were established for the AIDSAT series of demonstrations: Mode 1 represented the United States-to-Country-to-United States program transmissions and Mode 2 represented the function of permitting each country, as desired, to originate television programs for in-country reception (Figure 7-2). Each mode required a different ATS-6 antenna pointing and Mode 2 required additional S-band equipment.

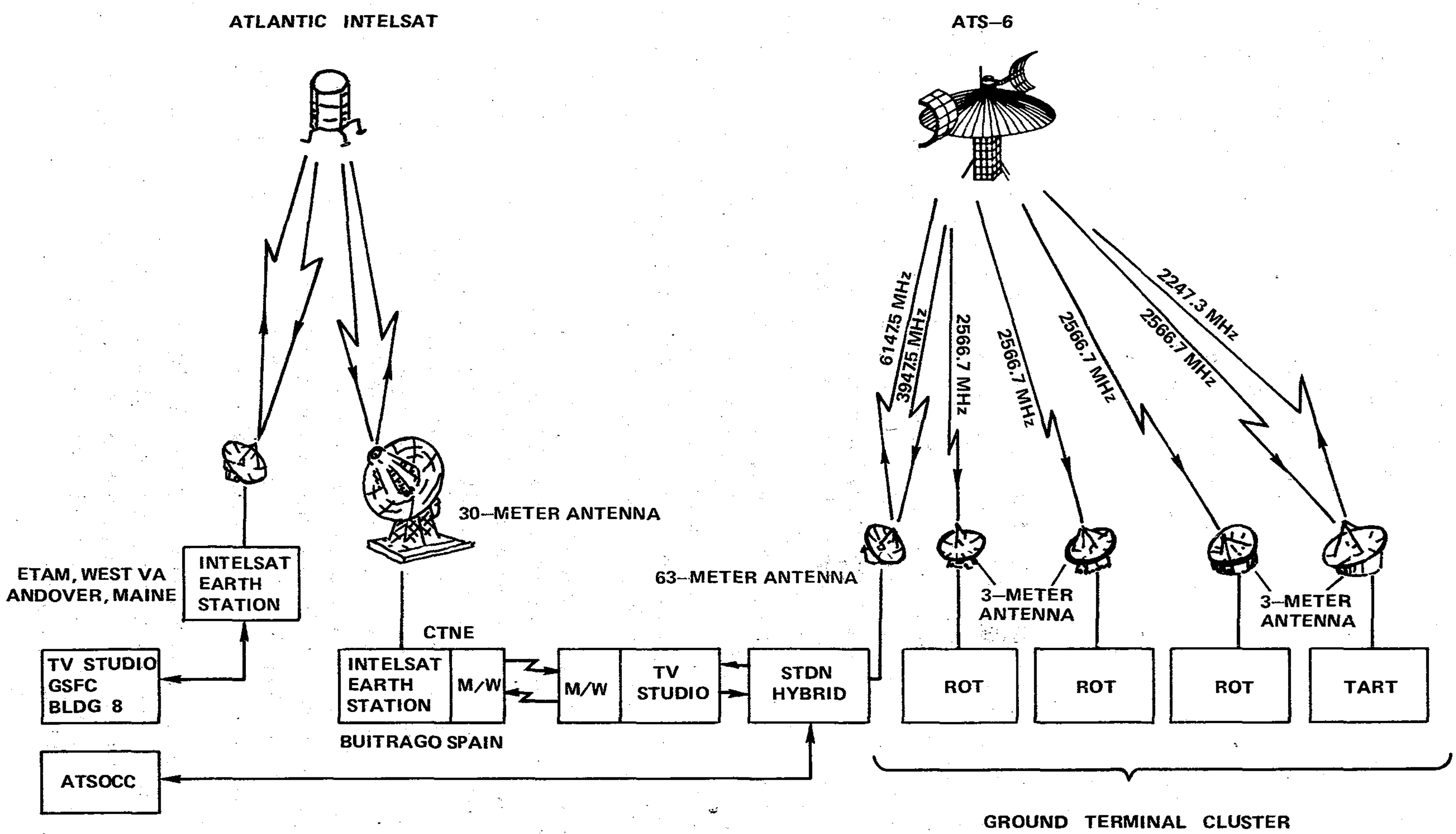

Figure 7-1. Mode I Intercountry Communications Simplified Block Diagram

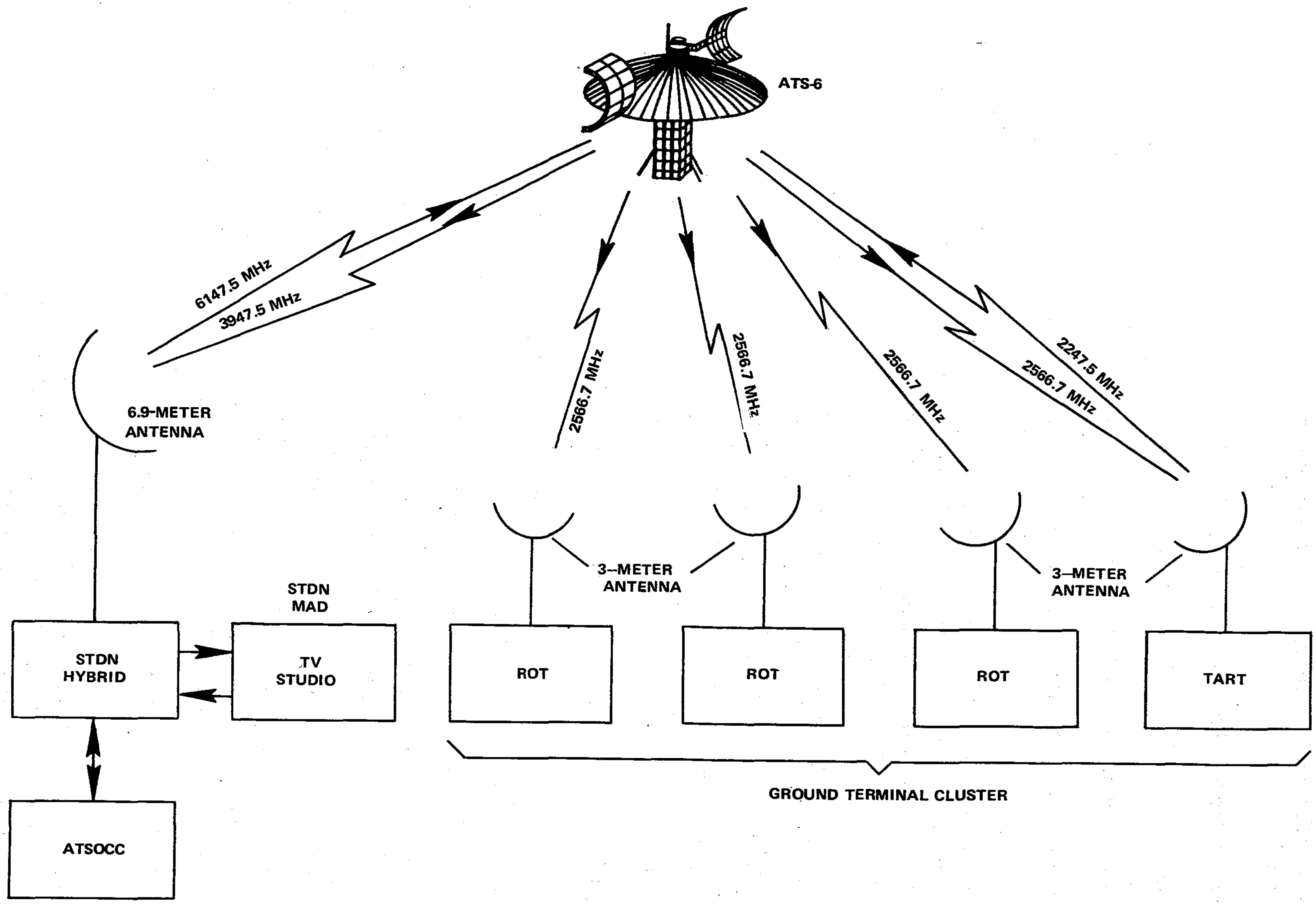

Figure 7-2. Mode II Intracountry Communications Simplified Block Diagram

The NASA/GSFC cluster team configuration was established as a two-element group each consisting of the following:

- One transmit and receive terminal (TART)
- One or up to three receive-only terminals (ROT)

The TART would set up and operate from the capitol city of each country and control the ROT's.

The ROT's would be established at other in-country locations as specified by each individual country.

All program operations followed a three-step procedure: the first being a setup phase titled (country name) AID/setup, followed by a "broadcast simulation" identified as (country name) AID/SIM and concluded by the actual program demonstration called (country name) AID/DEMO. This administrative procedure facilitated technical coordination and effective record keeping.

Because of the demonstration nature of the AIDSAT program and the limited time available per country, the adopted measures of effectiveness were essentially subjective; with broadcast audio reception rated as good, fair, or poor and the video broadcast reception rated as 1—excellent, 2—fine, 3—passable, 4—marginal, 5—inferior and 6—unusable, based on the Television Allocation Study Organization scale.

OPERATIONS

Phase I AIDSAT

	Demo Date	Country	LOCATIONS		
			TART	ROT	ROT
1.	7/31/76	Thailand	Bangkok		

Comment: Demonstration considered fair; video TASO 3, but was not available for the full 2-hour program; audio initially poor but later upgraded to fair.

	Demo Date	Country	TART	ROT	ROT
2.	8/1/76	Pakistan	Peshawar	Lahore	

Comment: Demonstration considered very good, in-country audience receptive, sympathic to technical problems caused by monsoon season very bad weather and enthusiastic; video TASO 2 (with some apparent radar interference streaking); audio fair.

	Demo Date	Country	TART	ROT	ROT
3.	8/2/76	Bangladesh	Dacca	Chittagong	Mymensingh

Comment: Demonstration considered poor, but in-country audience receptive and appreciative in spite of technical (loss of audio and video periods and severe degradation at end of DEMO) and administrative (unscheduled MADRID-TART program conference cut into demo time) problems; video TASO 3; audio fair.

	Demo Date	Country	LOCATIONS TART	ROT	ROT
4.	8/9/76	United Arab Emirates (UAE)	Abu Dhabi	Dabai	

Comment: Demonstration considered very good, but in-country audience appeared disinterested and unenthusiastic. Minor technical problems due to in-country weather conditions (heat), apparent radar signal interference on video (streaking), and audio noise at Madrid-Hybrid; video TASO 2; audio good/fair.

5.	8/10/76	Oman	Muscat	Salala	

Comment: Demonstration considered very good with in-country audience approval and enthusiasm. Minor technical problems (video minor color saturation and audio intermittent fade and drop-out) plus the requirement to establish a temporary ATS Control Center (ATSOCC) at GSFC, because a bomb threat forced evacuation of Building 14 at Goddard until just prior to demonstration start. Video TASO 2, audio fair.

6.	8/16/76	Jordan	Amman		

Comment: Demonstration considered good with fine support by Jordan and A.I.D. officials. In-country audience favorable in spite of technical problems (several total power outages at Amman and loss of the video portion of the in-country broadcast due to fading of the microwave link to Madrid). Video TASO 3, audio fair.

7.	8/17/76	Kenya	Nairobi	Mombasa	

Comment: Demonstration considered fair with lukewarm in-country audience reaction. No technical problems of any import with NASA equipment but problems on the commercial microwave link to Madrid caused complete loss of video for the in-country broadcast portion of the program. Video TASO 3, audio fair.

8.	8/18/76	Yemen	San'a	San'a (TV Station)	

Comment: Demonstration considered flawless and the best to date. No technical problems. In-country audience consisted of government officials at TART and approximately 50,000 viewers during the in-country television broadcast. A standing ovation was presented to the NASA-AID team at the end of the program and the U.S. Yemen AID office stated that this demonstration accomplished in 2½ hours what it has been trying to do in 2½ years. Video TASO 1, audio very good.

	Demo Date	Country	LOCATIONS TART	ROT	ROT
9.	8/24/76	Libya	Tripoli	Benghazi	

Comment: Demonstration considered good. In-country audience interested and enthusiastic. Minor technical problems (occasional video drops and audio distortion). Video TASO 2, audio fair/good.

10.	8/25/76	Morocco	Rabat		

Comment: Demonstration considered excellent. Very minor technical (video interference-herringbone pattern) and administrative (interpreter/translator-Arabic/English) problems. In-country audience of better than 300 people at Rabat, attending the UNESCO sponsored "Castarab" (applied science and technology in the Arab world) conference very appreciative and enthusiastic. Video TASO 2, audio good.

11.	8/26/76	Sudan	Khartoum	El-Obied	

Comment: Demonstration considered very good. Very minor technical problems (occasional noisy video during in-country broadcast). In-country audience very appreciative and enthusiastic. Video TASO 2, audio good.

Phase II AIDSAT

1.	9/27/76	Mali	Bamako		

Comment: Demonstration considered good with some minor technical problems (Rosman Ground Station support delayed because of "over-temperature limit switch" failure in the prime transmitter and gradual degradation of the TART uplink signal due to local temperature conditions). In-country audience appreciative and enthusiastic, with the President of Mali expressing pleasure with program and technical performance. Video TASO 2 and audio fair.

2.	9/28/76	Upper Volta	Ouagadougou		

Comment: Demonstration considered very good. Very minor technical problems when TART briefly lost channel 2 subcarrier. In-country audience, including the President of Upper Volta, was appreciative and enthusiastic. Video TASO 1. Audio good.

	Demo Date	Country	LOCATIONS TART	ROT	ROT	ROT
3.	9/29/76	Ivory Coast	Abidjan	Man	Korhogo	Bouaké

Comment: Demonstration considered very good. No technical problems except ATS-6 required repointing to cover all three ROTS. In-country audience appreciative and enthusiastic—"Demonstration very well received." Video TASO 1, audio good.

4.	10/5/76	Cameroon	Yaoundé	Douala	Victoria	

Comment: Demonstration considered very successful despite formidable technical problems. Approximately 90 minutes prior to program start the TART transmitter went down when circuit-breaker tripped with cause unknown, believed to be heat. After checking, breaker was reset and transmitter came on. This action was immediately followed by loss of Rosman transmitter due to coolant leak in the C-band klystron heat-exchanger. Pending repair, the AIDSAT contingency plan was implemented where the TART transmitted video tapes of the scheduled program in the Mode-2 (intracountry) configuration. Rosman switched to a backup heat-exchanger about one-third of the way through the program and remained operational for the balance of the broadcast. In-country audience appreciative and enthusiastic. Video TASO 2, audio good.

5.	10/6/76	Central African Republic (CAR)	Banqui			

Comment: Demonstration considered very good. Very minor administrative problems because GSFC transmitted a nonscheduled video tape of the CAR Prime Minister (which had been received from TART an hour earlier). In-country audience appreciative and enthusiastic. Video TASO 2, audio good.

6.	10/7/76	Sierre Leone, Liberia	Freetown, Monrovia			

Comment: Joint two-country demonstration considered fair. Technical problems included a failure in the 240/120 Vac power converter at the Freetown TART that blocked origination of local live broadcast. Previously recorded television tapes were substituted using a local gasoline motor generator but this action was not satisfactory due to frequency variations of the generator that caused tape-play speed to vary. In-country audiences were appreciative and understanding. Video TASO 3/4, audio poor.

7.	10/13/76	Uruguay	Montevideo			

Comment: Demonstration considered good in spite of minor technical problems (bad chroma/color reception of tape video of the President of Uruguay). In-country audience was appreciative and enthusiastic. After completion of the demonstration, a NASA employee's family was live telecast to Montevideo. The TART program and this presentation was observed by the President of Uruguay and his wife who were favorably impressed by the family scene. Video TASO 2 (live), 4 (taped), audio good.

	Demo Date	Country	LOCATIONS TART	ROT	ROT
8.	10/14/76	Bolivia	La Paz	Santa Cruz	

Comment: Demonstration considered fair in spite of near catastrophic circumstances. There was an airplane crash into a school house in Santa Cruz the day before the scheduled demonstration. A national 3-day mourning period was declared and all AIDSAT personnel assumed the Bolivian demonstration was cancelled. Seventy minutes prior to the old scheduled start time, AIDSAT personnel were informed that the demonstration had not been cancelled. Both in-country TART and ROT teams had to be alerted, as well as Rosman and GSFC. All personnel worked frantically to start up equipment, access ATS-6 and conduct necessary link checks. The demonstration started 30 minutes late without the GSFC interpreter. To overcome this deficiency until he arrived, programs were transmitted to the TART in English where a local translation into Spanish was accomplished. This Spanish audio was then retransmitted back to Rosman for re-retransmission on the program audio channel back to Bolivia. In-country audience was appreciative. Video TASO 3, audio fair.

9.	10/15/76	Argentina	Buenos Aires		

Comment: Demonstration considered good with minor technical difficulties (audio line problem at Building 14, GSFC) that caused an 8-minute program start delay. In-country audience was appreciative and enthusiastic. Video TASO 3, audio fair.

10.	10/21/76	Surinam	Paramaribo		

Comment: Demonstration considered excellent. During the setup, some audio problems were encountered that were solved for the demonstration by having Rosman Ground Station accomplish turnaround audio switching that made the entire program a live-telecast from the TART. Upon completion of the demonstration, the President and Prime Minister of Surinam and the U.S. Ambassador escorted the AIDSAT team to stage center and introduced them to the audience. In-country audience was appreciative and enthusiastic. Video TASO 1, audio good.

11.	10/22/76	Ecuador	Quito	Guayaquil	

Comment: Demonstration considered very good in spite of a minor technical problem (Rosman transmitter failed twice, for 2 minutes each failure, because of a faulty multi-pin connection in the transmitter control circuit. Connector was replaced after second failure). In-country audience was appreciative and enthusiastic. Video TASO 1, audio good.

	Demo Date	Country	LOCATIONS TART	ROT	ROT
12.	10/23/76	Peru	Lima	Trujillo Huaráz	Hauncayo

Comment: Demonstration considered excellent, with no problems encountered. In-country audience was appreciative (very impressed) and enthusiastic. Video TASO 1, audio good.

13.	10/28/76	Jamaica	Kingston		

Comment: Demonstration considered very good with only a several seconds loss of the microwave link between GSFC and Rosman at the end of the program. In-country audience was appreciative. Video TASO 1, audio good.

14.	10/29/76	Costa Rica	San Jose		

Comment: Demonstration considered excellent in spite of a minor technical problem and the lack of an English to French interpreter during the first phase of the program. In-country audience was appreciative. Video TASO 1, audio good.

15.	10/30/76	Haiti	Port-au-Prince	Port-au-Prince Local's Facility of Medicine; Facility of Science	

Comment: Demonstration considered excellent. Minor programs included slight echo in the TART transmitted audio that caused some difficulty for the GSFC French-to-English interpreter and a noisy listening environment at the Facility of Medicine ROT. In-country audience (including President of Haiti) was appreciative and enthusiastic. Video TASO 1, audio good.

ACCOMPLISHMENTS

In reviewing the accomplishments of the AIDSAT program, the benefit of introducing advanced space technology to underdeveloped countries and peoples is obvious. The method of this introduction, which illustrated the practical applications of such technology in the forms of in-country natural resources investigation, crop and produce control, and disaster assessment and assistance, was ideally chosen. In this context, it is significant to note that by 1980, every country participating in the AIDSAT program has established in-country ground satellite terminals with associated access to one or more spacecraft or has active plans underway to accomplish such facilities.

The AIDSAT teams visited 27 countries, on two continents covering almost a third of the world's surface, in 66 days of on-station time with a 25-day equipment refurbish and personal rest break. This 90-day operation ranks as a considerable achievement in its own right.

ATS-6 performed superbly throughout the demonstrations and the technical problems encountered were minor. No individual demonstration failed.

CHAPTER 8

PROJECT LOOK UP

INTRODUCTION

Background

Project Look Up (PLU) was a societal experiment that was included in the third year experiments on ATS-6 and continued until the end of the life of the experiment. The principal investigator was Project Look Up Inc. This organization was created in January 1976 by the International Christian Broadcasters, Clearwater, Florida. As organized, PLU represented a number of social, religious, medical, educational, and noncommercial radio and television agencies who expressed an interest in participating to varying degrees in an experiment that offered the potential of communicating with people in isolated and remote areas of third world nations.

Goals

The goals of Project Look Up were to direct:

- A concentrated effort in helping the whole man in health, education, employment, culture, and morals

- An experiment on the performance of low cost antennas and receiving stations in the tropics

- An experiment in opening new areas of exchange for culture, ideas, and manufactured products.

This was accomplished by one-way telecasting of preprogrammed material through ATS-6 to receive-only terminals (ROT) at selected sites in targeted countries.

The initial thrust of this effort was directed toward the populations in rural and remote areas in the South American countries of Columbia and Ecuador. However, negotiations with those host countries proved too lengthy for inclusion in the 1977 experimental year and the target area was changed to the U.S. possessions of Puerto Rico and the Virgin Islands. The PLU proposal submitted for telecasting in this area was approved by the National Aeronautics and Space Administration (NASA) in September 1976.

Objectives

The objectives of the approved experiment were to:

1. Use controlled and noncontrolled groups in a developing country to help them with the use of ATS-6
2. Place low cost antenna and receiving sets in remote areas and train nationals to assemble, operate, and care for this equipment
3. Choose select rural persons for training in the use of satellites and measure the results
4. Provide cross-cultural programming and strengthen mutual ties and international respect
5. Provide limited internal communication in the host country
6. Provide emergency communication between the host country and the United States where it did not interfere with commercial carriers.

CONCEPT OF EXPERIMENT OPERATIONS

Project Look Up

Receive-Only Terminals

Under guidance and direction of the technical staff of the International Christian TV, El Paso, Texas, Project Look Up would fabricate and test low cost ROT's and install them at the receiver sites with the assistance of local PLU engineers.

Programs for Telecasting

Programming materials would be generated at PLU headquarters, Clearwater, Florida, and be forwarded to International Christian TV, El Paso, for television tape production. The finished tapes of 60 to 90 minutes duration would be forwarded to the NASA uplink facility for telecasting according to a mutually agreed schedule.

National Aeronautics and Space Administration Facilities

ATS Operations Control Center

Satellite control, positioning, pointing, and configuration would be accomplished by the ATS Operations Control Center (ATSOCC), Goddard Space Flight Center, Greenbelt, Maryland. The satellite would be configured to C-band uplink and uhf downlink so that the downlink could be received on inexpensive 860-MHz television receivers.

Rosman Ground Station

The NASA Rosman Ground Station would provide the primary and secondary backup uplinks for the telecasts. Transmission of the video tapes would be at C-band with L-band backup.

Technical Assistance

NASA engineers would perform the systems operational checkout and provide technical assistance and advice to PLU on an as-available basis to assist PLU engineers in the fabrication, installation, and operational performance of the ground terminals.

Scheduling

Spacecraft

Spacecraft time would be requested as needed for checkout and evaluation of Earth terminal receivers, pilot television tapes, and demonstrations. When operational, the telecasting schedule in the target area would be 1½ hours Monday through Friday and 2½ hours on Saturday and Sunday during prime time viewing hours.

Program Materials and Tapes

Sufficient TV tapes for one weeks programming would be prepositioned at the NASA Rosman facility well in advance of the intended air time, and a schedule indicating the sequence in which they would be transmitted would be provided at least one week in advance.

Operational Target Date

PLU established a tentative operational target date of early 1977.

PREEXPERIMENT ACTIVITIES

Project Look Up Inc.

PLU spent approximately a year in designing the program, developing initial pilot programs, surveying receiver sites, negotiating the site locations, and in fabricating and installing the receive-only terminals.

NASA Support

NASA provided a wide range of technical support, advice, and spacecraft operations to assist PLU in meeting an early as possible start-up date. Some of the major support activities are set forth in the following paragraphs.

ATS-6 Operations and Results

Joint GSFC/City of Miami UHF Interference Test—Due to the concern of the Miami Department of Communications, a joint Goddard Space Flight Center (GSFC)/City of Miami, ATS-6 ultrahigh frequency (uhf) television test was conducted on January 31, 1977, to determine if uhf television transmissions from ATS-6 for Project Look Up would interfere with a uhf land mobile communication system in Miami, Florida. The test was coordinated with personnel of the Miami Department of Communications. The evaluation in Miami, under their direction, consisted of monitoring the limiter and discriminator outputs of a mobile unit and listening for interference with normal audio usage.

A baseline set of measurements were made with ATS-6 pointing directly at the Rosman Ground Station with the spacecraft in the CX UHF FT mode. A television signal was uplinked from Rosman in the Project Look Up format and the following measurements were made:

Spacecraft transmitter frequency	860 megahertz (MHz)
Spacecraft transmitter power	49.6 decibels, referred to 1 milliwatt (dBm)
Spacecraft effective isotropic radiated power (e.i.r.p.)	83.1 dBm
Frequency deviation	11.0 MHz peak-to-peak
Rosman video $\frac{S\ (rms)^*}{N\ (rms)}$	46.0 dB
Rosman audio channel 1 signal-to-noise ratio (S/N)	43.0 dB
Rosman audio channel 2 S/N	46.0 dB

A subjective evaluation of the picture (color bars) at Rosman indicated reception of a good quality picture.

With the spacecraft transmitting as above, the Miami Department of Communications made observations for the following sequence of events:

Spacecraft Pointing	Transmitter On	Frequency	Miami Observation
Rosman	Yes	860 MHz, ±5.5 MHz	Some sporadic noise burst
Miami	Yes	860 MHz, ±5.5 MHz	Some sporadic noise burst

*rms–root-mean-square

Spacecraft Pointing	Transmitter On	Frequency	Miami Observation
Miami	No	–	Some sporadic noise burst, possibly not as frequently as above
Miami	Yes	850 MHz, ±5.5 MHz	Some sporadic noise burst

Pointing results in flux density in Miami was at least 6 dB higher than expected during normal Project Look Up operations.

The noise burst noted by the Miami Department of Communications was not significant enough to disrupt the Miami communication system. However, it was decided to change the spacecraft transmitted frequency so that it would be closer to the Miami system receiver frequency of 851.012 MHz to more conclusively measure the effect of ATS-6 on the Miami system. The sporadic noise bursts noted did not appreciably change with the ATS-6 transmitter on or off or as a function of the ATS-6 transmitted frequency.

As a result of the observations, it was concluded that NASA would be able to relay Project Look Up transmissions by ATS-6 to Puerto Rico without significantly interfering with the City of Miami uhf land mobile service.

UHF TV Reception Test, Rosman—A test was performed on January 31, 1977, to determine the quality of ATS-6 uhf television reception at the Rosman Ground Station with the spacecraft pointed at San Juan, Puerto Rico. A C-band uplink was provided from Rosman in the Project Look Up TV format. The baseband signal was video and two audio channels on 4.64 MHz and 4.83 MHz subcarriers. The composite signal frequency deviation was 11.0 MHz peak-to-peak.

A set of measurements were made with ATS-6 pointing directly at Rosman with the spacecraft in the CX UHF FT mode. The parameter measurements were as follows:

Spacecraft received power (i.f. 1)	-67.7 dBm
Spacecraft transmitter frequency	860 MHz
Spacecraft uhf 1 transmitter power	49.6 dBm
Spacecraft e.i.r.p.	53.1 decibels, referred to 1 watt (dBW)
Frequency deviation	11.0 MHz peak-to-peak
Rosman measured carrier-to-noise density ratio (C/N_o)	94.0 dB-Hz
Rosman video S (rms)/N (rms)	46.0 dB
Rosman audio channel 1 S/N	43.0 dB
Rosman audio channel 2 S/N	46.0 dB

Color bars were transmitted and Rosman evaluated the quality of the picture displayed on the TV monitor as good.

The spacecraft was pointed to San Juan, Puerto Rico, and the following measurements were made:

Spacecraft received power (i.f. 1)	-67.2 dBm
Spacecraft uhf 1 transmitter power	49.2 dBm
Rosman measured C/N_o	86.0 dB-Hz
Rosman video $\frac{S(rms)}{N(rms)}$	46.5 dB
Rosman audio channel 1 S/N	38.5 dB
Rosman audio channel 2 S/N	30.0 dB

Rosman noted that the display of color bars on the monitor was slightly noisy but the quality was sufficient for monitoring Project Look Up transmissions at Rosman.

Ground Testing of PLU ROT's—During February and March 1977, spacecraft time was made available for ground testing of the receiver breadboard during fabrication of the "low cost" receive-only terminals at International Christian TV in El Paso, Texas. NASA participated in conducting the tests and in evaluation of the results.

Although PLU used the NASA-provided basic design for the ROT's, they incorporated some slight modifications. The initial test results were unsatisfactory but after considerable testing and adjustments two prototypes were eventually completed that produced acceptable results. Keeping the receiver and preamplifier/downconverter at the receiving stations properly aligned and tuned was of continuing concern to PLU throughout the first few months of operation.

Demonstrations—During February, March, and April 1977, several simulations and systems demonstrations were conducted to assist PLU in equipment and program checkout. They were highlighted by demonstrations using PLU generated test TV tapes at the Vieques site for the PLU South Baptist Group, the San Juan Cable TV site, and at both sites for the PLU Board of Directors. These simulations and demonstrations were conducted during the times originally scheduled for PLU operations. In general, both color bars and TV tapes were received and the quality assessed was good.

Summary of ATS-6 Preexperiment Utilization—There were some 23 spacecraft operations for a total of 31.81 hours of ATS-6 operations time in support of Project Look Up preexperiment activities. There were no unexpected interruptions of spacecraft availability.

ATS-3 Operations and Results

During setup, testing, and demonstrations conducted in Puerto Rico, it became evident that a more direct means of communication, other than telephones, would be highly desirable to coordinate the activities of the experiment. Thus, NASA provided PLU very high frequency (vhf) radio equipment on a temporary loan basis that provided direct communication between Puerto Rico and the ATS Operations Control Center through ATS-3.

The radio equipment was actually installed on June 6, 1977, after the start of the experiment. Contact was made with ATSOCC by telephone and a vhf carrier was requested for aligning the antennas. Difficulty was initially experienced in establishing good link performance. Eventually all of the problems were resolved and good communication was established in both directions.

The vhf system was checked again on June 7, 1977, between San Juan and Goddard Space Flight Center and good communication was obtained. During the evening hours, normal PLU operations time, the vhf reception at San Juan was unintelligible. Propagation phenomena, with characteristics of ionospheric scintillation, was apparently causing communication outages during the first hour of PLU operations. A final check of the vhf system was made on June 8, 1977, and good communication was achieved.

PROJECT LOOK UP EXPERIMENT OPERATIONS

Project Look Up experiment operations began on May 30, 1977, with the telecast of a one and one-half hour program to receive sites located at San Juan (lat. 18° 25′10″ N., long. 66° 3′2″ W.)., and the Vieques Baptist Church (lat. 18° 8′35″ N., long. 65° 27′5″ W.).

The Vieques Baptist Church was equipped with a 2.1-meter parabolic antenna (provided by PLU) and San Juan had a 3-meter parabolic antenna.

The ATS-6 antenna footprint on the surface of the Earth for Project Look Up is shown in Figure 8-1.

Summary of Project Look Up Activities

From May 30 through July 21, 1977, 52 of the scheduled spacecraft times were used for a total of 78.73 hours of operation.

There were no unexpected interruptions in operations or the availability of ATS-6 during this period of time. Breaks in the schedule were primarily due to downtime of one or both of the ROT's.

On July 21, 1977, it was decided to temporarily stop scheduled PLU operations due to recurring equipment problems at the ROT sites, delays in establishing new field sites, and, in general, to provide PLU the opportunity to review and evaluate all aspects of their experimental program. This review resulted in some internal organizational changes and consolidation of program activities that were aimed toward obtaining and improving quality control of hardware, production of new programs, acquisition of new ROT sites and broadening their financial base. A major effort was directed toward upgrading and updating the ROT's. ATS-6 support was provided for tests and evaluation of the hardware changes, TV programs, and system checkouts. NASA engineers and technicians provided advice and on-site assistance during setup and checkout of the ROT's.

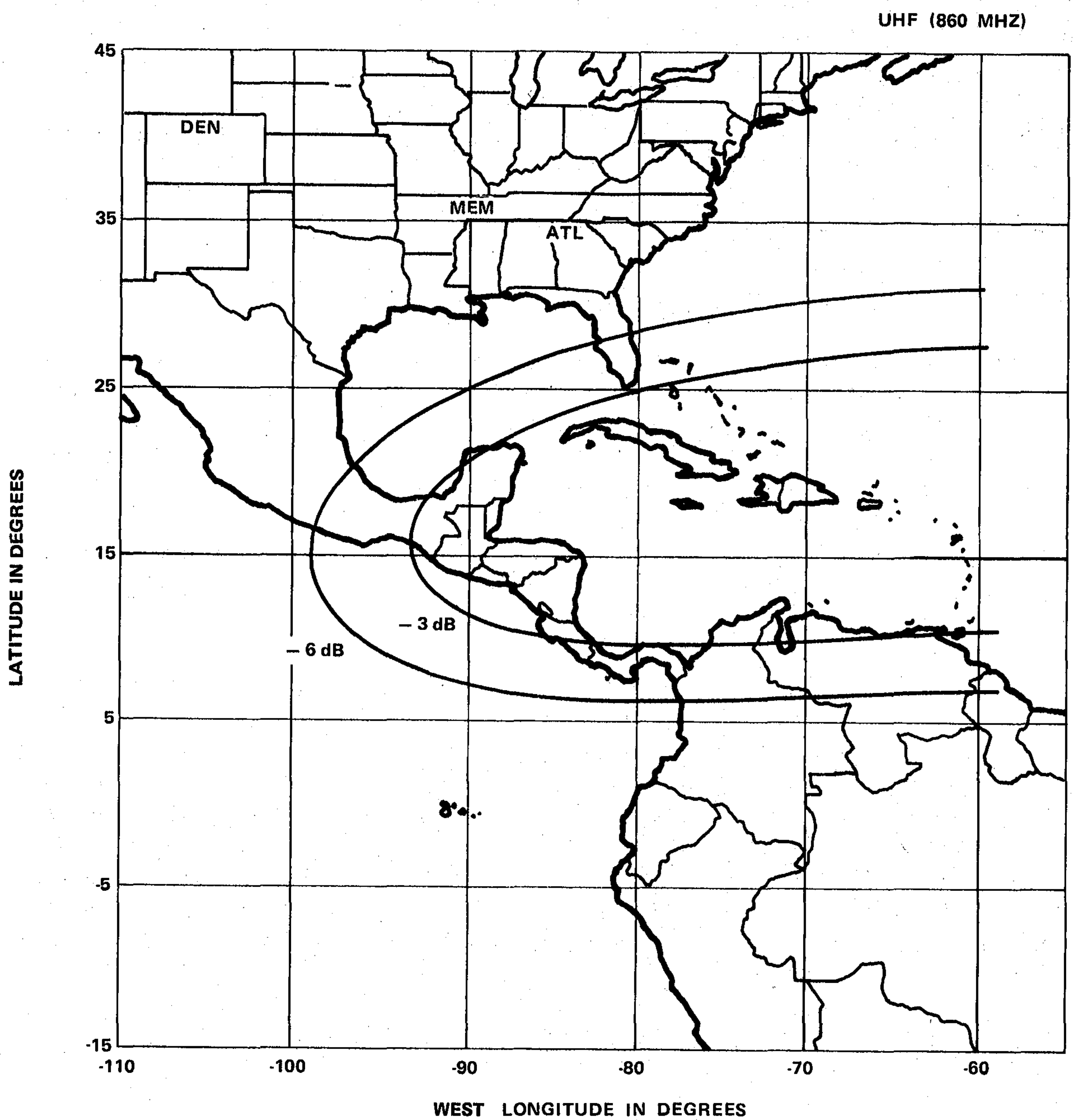

Figure 8-1. ATS-6 Antenna Footprint

From August 1977 through December 1978, there were 22 spacecraft operations for a total of 23.25 hours of spacecraft time used for the foregoing efforts.

On January 8, 1979, Project Look Up resumed regular scheduled broadcasts to the following four sites: C-RAN Corporation plant in Largo, Florida; Levittown, Puerto Rico; Isle of Vieques; and Granada. A fifth station was added in Feburary 1979 at the new location of San Juan Cable Television, Moca, Puerto Rico.

From January 8 through termination of ATS-6 operations in July 1979, 268 hours of the scheduled spacecraft time was used for a total of 285.83 hours of operation.

SUMMARY OF PROJECT LOOK UP ACCOMPLISHMENTS AND CONCLUSIONS

PLU Accomplishments

The accomplishments of PLU can essentially be divided into three phases: Phase I began in the fall of 1975 with the inception of the project followed by start-up activities, alignment of organization, development of hardware and software, testing, installation of two ground terminal receiving stations, and culminating on July 21, 1977, after six weeks of effort to maintain a schedule broadcast of the pilot television programs.

Phase II was a hiatus during which time all aspects of Phase I operations and results were evaluated and the indicated improvements implemented. New programs and hardware were developed and additional receiver sites were added and tested.

Phase III began on January 8, 1979, wherein regular scheduled programming operations were maintained on five ground stations until spacecraft termination in July 1979.

The accomplishments of PLU were compared against their stated objectives and are summarized below. The major source of the information presented was derived from the Project Look Up Final Report dated August 31, 1979. The references to time constraints indicated that the plans and ongoing activities to bring other countries into the project with the installation of a number of additional ground stations (100 planned with 30 completed but not installed) extended well beyond the actual spacecraft termination date. Hence, some of their objectives were not met as completely as had been originally envisioned.

PLU Objectives

Objective A

The first objective was to use controlled and noncontrolled groups in a developing country and thus establish whether a developing people could be helped by satellite technology.

Project Look Up placed five downlink receivers in the Caribbean during the seven months of testing (Phase III). The receiver locations were as follows:

- The Cable TV System–San Juan, Puerto Rico
- Vieques Baptist Church–Vieques, Puerto Rico
- Christian Training Center–Levittown, Puerto Rico
- Open Bible Standard Church–Moca, Puerto Rico
- Grenada Television System–St. George's, Grenada

Of the five systems, three were located in rural areas. The cable system experiment was located in the city of San Juan. The Grenada rebroadcast signals covered both rural and urban areas.

Data gathering teams were sent to several sites served by Project Look Up. The programming used was material obtained from several sources. One was the public service television stations and public libraries in the United States. Another source was material produced by Project Look Up for its audience. Except for the locally produced programs for the foreign market, most public service and religious programming was oriented towards the U.S. market.

Where a control group was located, the viewer's response to the programs indicated considerable interest in receiving instruction by satellite television but wanted more programming tailored to their needs.

Where noncontrol groups were located, like the viewers of San Juan and the island of Grenada, the reception was much more enthusiastic. For instance, during the initial test of several weeks that had been run in 1977 in San Juan at the Cable TV Station, strong viewer interest was indicated by many requests for more programming.

In Grenada, the island public television station rebroadcasted the Project Look Up TV programs. These were nonbusiness, nonpolitical, and nonsectarian programs that were both welcomed and endorsed by the Government.

In each case, Project Look Up learned that television was a viable way to assist the educational and social development of the emerging nations of the world.

Objective B

The second objective was to place receiving sets and the necessary antenna in remote areas so as to train the natives by hands-on experience in the assembly, operation and care of this equipment which will become his eyes and ears to the world around him.

The problem of developing reliable hardware to perform well in remote areas was a significant challenge and much of the Project Look Up efforts were concerned with this problem.

The original design for the receiving equipment was developed by NASA, and the prototype units were built by International Christian Television of El Paso, Texas. Major design changes had to be made for the units to operate properly.

Several antenna types were used. Commercial units were used in some cases. Several surplus antennas were donated and, in one case, an antenna was built using a configuration of curved aluminum pipe in the shape of the parabola and facing it with chicken wire. It worked well.

These original prototypes proved to be functional but unstable, so the next phase was upgrading these units several times and testing them under rigid conditions to assure that the receivers would operate reliably in the field.

Modular construction techniques were applied to the entire downlink receiver components so that changes could be easily made.

The sensitivity of the receiving systems proved to be very good. A site that was located at the very outer edge of the antenna coverage area, where the signal from the satellite was weakest, provided exceptional performance. The receiver performance results for both voice and picture were of such excellent quality that the usable footprint was enlarged by about 200 miles in each direction. These receivers, built by Project Look Up, cost about one-tenth of the commercial equivalent. In the end, Project Look Up offered complete downlink receiver units to mission organizations for substantially reduced cost.

A new receiver that functioned on 12 volts direct current was developed so that the receiver and a television monitor operated from an automobile battery. This enabled PLU to go into villages that had no electrical power.

These new receivers were designed to perform with other existing satellites.

PLU reported that the training of local personnel to handle the equipment was not a real problem.

Objective C

The third objective was to choose outstanding persons in select rural population centers, train them in specialized fields by satellite, and then measure their achievement level.

An effort was also made to choose these persons for leadership training in specialized fields via the satellite.

An agricultural series, called the "Grow-Box Program," was also developed by the project to train people in underdeveloped countries on the proper methods of growing vegetables in a nonsoil medium. These programs were transmitted without ground personnel at the downlink sites. Follow-up studies showed that without on-site personnel such a program is not successful.

Objective D

The fourth objective was to provide some people-to-people programming, cross-culturally produced, that would strengthen mutual respect and ties.

The conditions discovered by Project Look Up in prospective host countries presented opportunities for the application of many constructive programs.

Each government contacted invited Project Look Up to develop health and education programs with their people and indicated that they would welcome religious programs.

Most of the programs were American produced. In urban areas these programs were welcomed, especially in San Juan. In rural areas the people were more critical and asked for rurally developed programs. The cross-cultural aspect of the program material could not be completed in the time available.

Objective E

The fifth objective was to provide internal communication capability for a government to reach some of its remote areas.

While this objective was developed through its planning stages only, sufficient information was obtained that clearly indicated a mass program could be initiated within each country. This program would reach people on the entire socio-economic and spiritual spectrum at various levels of program involvement.

Objective F

The sixth objective was to provide emergency communication between the host country and the United States where it did not interfere with commercial carriers.

This objective was not addressed other than to recognize that two-way communication existed through other satellite capabilities. PLU was using receive-only terminals.

COMMENTS AND CONCLUSIONS

To provide satellite communication missions requires a large effort on the part of many organizations. There are not many organizations large enough in the United States with the capability of supporting satellite missions. The finances, the personnel, the expertise needed were provided, in part, by missions and church agencies, but none could meet all the requirements. Recognition was given to the research team assembled from across the country that demonstrated the capability to provide new developments in receivers, antenna, and satellite systems.

The experimental phase of PLU was successfully demonstrated. When PLU first faced the challenge of drawing people together for the ATS-6 experiment, the task appeared tremendous, but all the goals were accomplished.

APPENDIX

ACRONYMS AND ABBREVIATIONS

A

A	ampere
Å	Angstrom
ABC	analog backup controller
AC	attitude control
a.c.	alternating current
ACE	actuator control electronics
ACP	acquisition control program
acq.	acquisition
ACS	attitude control subsystem
ACSN	Appalachian Community Service Network
A/D	analog to digital
ADC	analog-to-digital converter
ADPE	automatic data processing equipment
ADS	automatic deployment sequencer
ADSS	auxiliary digital Sun sensor
ADVM	adaptive delta voice modulation
A/E	absorbtivity to emissivity
Aerosat	aeronautical satellite
AES	Ahmedabad Earth Station
AESP	Appalachian Education Satellite Project
af	audio frequency
AFC	automatic frequency control
AFTE	Advanced Thermal Control Flight Experiment
AGC	automatic gain control
AGE	aerospace ground equipment
Ah	ampere-hour
AID	Agency for International Development
AIDSAT	Agency for International Development Television Demonstration
AIR	All India Radio
ALC	automatic level control
ALED	Alaska Education Experiment
am, AM	amplitude-modulation
AMP	amplifier
AOS	acquisition of satellite
APM	antenna pattern measurement

APT	automatic picture transmission
ARC	Appalachian Regional Commission
ASC	Aerospace Corporation
ASP	automated sequential processor
ASSY	assembly
ASTP	Apollo-Soyuz Test Program
ASTP-TV	ASTP television coverage experiment
ATA	automatic threshold adjust
AT&T	American Telephone and Telegraph (Spacecraft)
ATC	air traffic control, active thermal control
ATFE	Advanced Thermal Control Flight Experiment
atm, ATMOS	atmosphere(s)
ATS	Applications Technology Satellite
ATS-6	Applications Technology Satellite-6
ATSOCC	ATS Operations Control Center
ATS-R	ATS ranging
ATSSIM	ATS simulator
Atten	attenuator (attenuation)
Aux	auxiliary

B

B&E	Broadcast and Engineering
BAM	building attenuation measurement
BB	baseband
BER	bit error rate
bps	bits per second
BRC	Balcones Research Center
BSA	bit synchronization acquisition
BTC	binary time code
BTE	bench test equipment
Btu	British thermal unit
BW	bandwidth

C

C	Celsius
Cap Com	Capsule Communicator
CCIR	International Radio Consultative Committee
CDD	command/decoder distributor
CEE	designator for "career education course for elementary-grade teachers"
CES	designator for "career education course for secondary-grade teachers"
CESP	computer executive system program
CFSS	coarse/fine Sun sensors

CIC	command interface control
CIE	cesium ion engine
C/L	capacitance-to-inductance
cm	centimeter
CM	communications module
C/M	carrier-to-multipath
CMD	command
CMOS	complimentary metal oxide semiconductor
C/N_o	carrier power to spectral noise density ratio
CNR, C/N	carrier-to-noise ratio
cntr	center
Comsat	Communications Satellite Corporation
ConUS, CONUS	Continental United States
CONV	converter
COSMOS	complimentary symmetry metal oxide semiconductor
CPI	cross polarization isolation
CPR	cross polarization ratio
CPU	central processing unit
CRT	cathode-ray tube
CSM	command-service module
CSP	command service program
CSS	coarse Sun sensor
CTNE	Companie Telephonica Nacional de Espana
CW	carrier wave, continuous wave

D

DA	design adequacy
D/A	digital to analog
DACU	data acquisition and control unit
DAF	Data Acquisition Facility
dB	decibel
dBi	decibel isotropic (gain relative to an isotropic antenna)
dB/K	decibel per degree Kelvin
dBm	decibels referred to 1 milliwatt
dBW	decibel (reference level 1 watt)
DC	downconverter
d.c.	direct current
DCP	data collection platforms
DDDF	duplex digital data formatter
DDS	digital Sun sensor
DECPSK	differentially encoded coherent phase shift key (modulated)
DEG, deg	degree

DEM	digital evaluation mode
Depl	deployment
DES	Delhi Earth Station
DESA	double electrostatic analyzer
DIB	data input buffer
div	division
DIX	data interface transmitter
DJS	Dzhusaly (designator)
DLO	dual local oscillator
DM	docking module
DOC	digital operational controller
DOD	depth-of-discharge
DOT	Department of Transportation
DOT/FAA	The Department of Transportation/Federal Aviation Administration
DOT/TSC	The Department of Transportation/Transportation Systems Center
DPRI	diagnostic and prescriptive reading instruction
DR	Copenhagen (designator)
DRR	data recorder/reproducer
DRS	direct reception system
DSS	digital Sun sensor
DSU	data switching unit
DTS	data transmission system
DUT	Denver Uplink Terminal

E

EBU	European Broadcast Union
ECH	Earth-coverage horn
ECI	Earth centered inertial
e.d.t., EDT	eastern daylight time
e.i.r.p.	effective isotropic radiated power
EME	Environmental Measurements Experiments
emi, EMI	electromagnetic interference
EML	equivalent monomolecular layer
enc	encoder
Eng.	engineering
EOL	end-of-life
EPIRB	Emergency Position Indicating Radio Beacon
EPS	electrical power subsystem
ERP	effective radiated power
ES	Earth sensor
ESA	Earth sensor assembly, European Space Agency
ESA/PSA	Earth sensor assembly/Polaris sensor assembly
e.s.t., EST	eastern standard time

ETR	Eastern Test Range
eV	electronvolt
EVM	Earth-viewing module
EVT	Eupatoria (designator)

F

f	frequency
F	Fahrenheit
FAA	Federal Aviation Administration
FCC	Federal Communications Commission
FCHP	feedback-controlled variable conductance heat pipe
FCP	flight computer program
FCT	fixed calibration terminal
f/d	ratio of focal distance to diameter
FDM	frequency diversity modulation; frequency division multiplexer
fm, FM	frequency modulated
FOV	field-of-view
FOWG	Flight Operations Working Group
Freq.	frequency
FRMS	Federation of Rocky Mountain States
fsk	frequency shift keying
FSS	fine Sun sensor
ft	foot, feet
FT	frequency translation
ft-lb	foot-pound
FTO	functional test objective
FTS	Federal Telecommunications System

G

g	grams, gravity
G	gain
GAC	ground attitude control
GEOS-3	Geodetic Earth-Orbiting Satellite-3
GFRP	graphite fiber reinforced plastic
GHz	gigahertz
gm	gram
G.m.t., GMT	Greenwich mean time
GRD	ground
GRP	group
GSFC	Goddard Space Flight Center
G/T	dB/K antenna gain over system noise temperature
GTT	ground transmit terminal
GVHRR	Geosynchronous Very High Resolution Radiometer

H

HAC	Hughes Aircraft Company
HDRSS	high data rate storage system
HET	Health, Education, Telecommunications (experiment)
HEW	Department of Health, Education, and Welfare
hf	high frequency
HGA	high gain antenna
HI	Honeywell International
HPBW	half power bandwidth
HR	hour
HSE	high-speed execute
HTR	heater; high-time resolution
Hz	hertz

I

IBM	International Business Machines
IDT	image dissector tube
IEB	interface electronics box
i.f.	intermediate frequency
IFC	in-flight calibration
IHS	Indian Health Service (Alaska)
IHSDL	interferometer high speed data link
IM	intermodulation
IMF	interplanetary magnetic field
IMP	Interplanetary Monitoring Platform
in.	inch
in.-oz	inch-ounce
Intelsat	International Telecommunications Satellite
INTF	interferometer
I/O	input/output
IPD	Information Processing Division
IR	infrared
IRAC	Interdepartment Radio Advisory Committee
ISRO	Indian Space Research Organization
IT	intensive terminal
ITS	Institute of Telecommunications Sciences
ITU	International Telecommunications Union
I-V	current voltage
IW	inertia wheel
IZMIRAN	Institute of Terrestrial Magnetism, Ionosphere and Radio Wave Propagation

J

JAM	jet-assist mode
Joburg	Johannesburg (designator)
JSC	Johnson Space Center

K

K	Kelvin
kbps	kilobits per second
keV	kiloelectronvolt
kg	kilogram
kHz	kilohertz
km	kilometer
KSC	Kennedy Space Center
kW	kilowatt

L

lb	pound
LC	inductive-capacitance
LD	linear detector
LFT	long form test
LIC	load interface circuit
LLD	lower level discriminator
LO	local oscillator
LOS	line-of-sight
LRIR	limb radiance inversion radiometer
LSB	least significant bit
LT	local time
LV	local vertical
L.V.	latch valve

M

m	meter
m^2	square meter
mA	milliamperes
Mad	Madrid
MAD-HYB	Madrid Hybrid
Mage	U.S./U.S.S.R. Magnetometer Experiment
Marad	Maritime Administration
MASEP	main sequential program
Max.	maximum

MCC-H	Mission Control Center, Houston
MCC-M	Mission Control Center, Moscow
MDAC	McDonnell-Douglas Aircraft Corporation
MDHS	meteorological data handling system
MESC	magnetoelectrostatic plasma containment
MeV	megnelectronvolts
MHz	megahertz
μf	microfarad
μm	micrometer (micron)
μs, μsec	microsecond
MILA	Merritt Island Launch Annex
min, MIN	minute
mlb	millipound
MMW	Millimeter Wave Experiment
mN	millinewton
MOCC	Multisatellite Operations Control Center
MOCR	Mission Operations Control Room
MONO	monopulse
MOR	Mission Operations Room
MOS	metal oxide semiconductor
MSB	most significant bit
ms, msec	millisecond
m/s	meters per second
MT	multitone
mV	millivolts
mW	milliwatt
MWE	Millimeter Wave Experiment
MW XMTR	microwave transmitter

N

N	Newton
NAFEC	National Aviation Facilities Experiment Center
NASA	National Aeronautics and Space Administration
Nascom	NASA Communications Network
NBFM	narrowband frequency modulation
NCC	Network Coordination Center
NCE	normal command encoder
NDR	Hamburg (designator)
nm	nanometer
NMRC	National Maritime Research Center
NOAA	National Oceanic and Atmospheric Administration
N/P	negative/positive
NRL	Naval Research Laboratories

ns	nanosecond
NTSC	National Television System Committee color (U.S.)

O

O&M	operations and maintenance
OC	orbit control
OCJ	orbit control jet
OCP	operational control program
o.d.	outside diameter
OD	Operations and Distribution (Center)
omni	omnidirectional
OSR	optical solar reflectors
OSU	Ohio State University
OYA	Helsinki (designator)

P

PA	power amplifier, preamplifier
PAL	phase alternation live color (Europe)
PAM	pulse amplitude modulated
PAO	Public Affairs Office
PARAMP	parametric amplifier
PB	phonetically balanced
PBS	Public Broadcasting Service
P_c	course phase measurement
pcm, PCM	pulse code modulation
pcm/fsk/am	pulse code modulation/frequency shift keying/amplitude modulation
PCT	portable calibration terminal
PCU	power control unit
PDM	pulse duration modulation
pf	picofarad
PFD	power flux density
PFF	prime-focus feed
PGE	PLACE ground equipment
PIC	power interface circuit
PLACE	Position Location and Aircraft Communications Experiment
PLU	Project Look-Up
PM	phase-modulated
PN	pseudo-noise
POCC	Project Operations Control Center
p-p	peak-to-peak
PPK	Petropavlovsk-Kamchatski (designator)
ppm	parts per million

P_R	reference (phase) signal
P_{rgi}	power received at ground into an isotropic antenna
P_{rsi}	power received at spacecraft into an isotropic antenna
PRU	power regulation unit
PSA	Polaris sensor assembly
P_{SE}	probability function
psia	pounds per square inch absolute
PSK	phase shift keyed
Pv	vernier phase measurement
pW	picowatt
PWR	power

Q

QCM	Quartz-crystal microbalance contamination monitor
Q-M	quadrature phase modulation

R

Radsta	U.S. Coast Guard Radio Station
R&RR	range and range rate
RBE	Radio Beacon Expriment
RCA	Radio Corporation of America
RCC	Resource Coordinating Center
RCV	receive
RDA	rotating detector assembly
REC	receive
Ref., REF	reference
Rel	release
RESA	Regional Education Service Agency
rf	radio frequency
RFC	radio-frequency compatibility
rfi	radio frequency interference
RFIME	Radio Fequency Interference Measurement Experiment
RGA	rate-gyro assembly
RME	Rocky Mountain East
RMPBN	Rocky Mountain Public Broadcast Network
rms	root mean square
RMW	Rocky Mountain West
ROT	receive-only terminal
rpm	revolutions per minute
RR	rain rate

S

S/A	solar array
SAPPSAC	Spacecraft Attitude Precision Pointing and Slewing Adaptive Control (Experiment)
SAR	search and rescue
S&R	surveillance and ranging
Satcom	Satellite Communications
SC	sudden commencement
S/C	spacecraft
SCAMA	switching, conferencing, and monitoring arrangement
SCAMP	small command antenna medium power
SE	system effectiveness
sec, s	second
SECAM	Sequential Couleurs a Memoire (III) color (U.S.S.R.)
SEL	Space Environment Laboratory
SENS	sensor
S.G.	signal generator
SITE	Satellite Instructional Television Experiment
SITEC	sudden increase in total electron content
SIU	squib interface unit
S-IVB	Saturn IB second stage
SMSD	spin motor sync detector
SNR, S/N	signal-to-noise ratio
Spec	specification
SPS	spacecraft propulsion subsystem
SPU	signal processing unit
sr	steradian
SR	Stockholm (designator)
SRT	SAPPSAC remote terminal
SSC	sudden storm commencement
SSEA	Sun sensor electronics assembly
SSR	Staff Support Room
STA	station
STADAN	Space Tracking and Data Acquisition Network
STDN	Spaceflight Tracking and Data Network
STRUCT	structural
SWBT	Southwestern Bell Telephone Company
SYN	synthesizer
SYNC	synchronous
SYSSIM	system simulator

T

TACH	tachometer
T&CS	telemetry and command subsystem
T&DRE	Tracking and Data Relay Experiment
TART	transmit and receive terminal
TASO	Television Allocation Study Organization
TBC	time base corrector
TCD	transponder command decoder
TCS	telemetry and command subsystem, thermal control subsystem
TDA	tunnel diode amplifier
TDRE	Tracking and Data Relay Experiment
TEMP	temperature
THIR	temperature-humidity infrared radiometer
TID	traveling ionospheric disturbances
TLM, TM	telemetry
TORQ	torquer
TRUST	Television Relay Using Small Terminals
TSM	thermal structural model
TSP	telemetry service program
TSU	temperature (control) and signal (conditioning) unit
TT/N	test-tone signal-to-noise ratio
TTY	teletype
TV	television
TVOC	Television Operational Control Centers
TWT	traveling wave tube
TWTA	traveling wave tube amplifier

U

UC	upconverter
UCLA	University of California at Los Angeles
UCSD	University of California at San Diego
uhf	ultrahigh frequency
UK	United Kingdom
UKTV	University of Kentucky Television
ulf	ultralow frequency
UNH	University of New Hampshire
U.S.	United States
USA	ubiquitous spectrum analyzer
USAF	United States Air Force
USCG	United States Coast Guard
USK	Ussuruisk (designator)

U.S.S.R.	Union of Soviet Socialist Republics
UT	universal time
UV	ultraviolet

V

v	velocity
V	volt
VA	Veterans Administration
VCA	voltage controlled amplifier
VCHP	passive "cold-reservoir" variable conductance heat pipe
VCXO	voltage controlled crystal oscillator
Vdc	volts direct current
V/deg	volts per degree
Vert.	vertical
vhf, VHF	very high frequency
VHRR	very high resolution radiometer
VIP	versatile information processor
VIRS	vertical interval reference signal
VITS	vertical interval test signals
VPI	Virginia Polytechnic Institute
vs.	versus
VSWR	voltage standing-wave ratio
V/T	voltage/temperature
VTR	video-tape recorder
VU MTR	VU meter

W

W	watt
WAMI	Washington, Alaska, Montana, Idaho (medical education)
WBDU	Wideband Data Unit
WBVCO	wideband voltage-controlled oscillator
WHL, WH	wheel

X

XMIT	transmit
XMTR	transmitter
XTAL	crystal
XTAL DET.	crystal detector

Y

YIRU	yaw inertial reference unit

Z

ZAZ	Z-axis azimuth
Zcoel	Z-coelevation

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The Applications Technology Satellite 6, an experimental communications spacecraft operated for five years in a geosynchronous orbit. The six volumes of this report provide an engineering evaluation of the design, operation, and performance of the system and subsystems of ATS-6 and the effect of their design parameters on the various scientific and technological experiments conducted.

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