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ABSTRACT

The Health, Education, Telecommunications (HET) experiment, and the Federation of Rocky Mountain States have collaborated with the National Aeronautics and Space Administration to provide health education and other community service broadcasts to rural areas of the Rocky Mountains. In order to access the signal of the ATS-6 (Applications Technology Satellite) communications satellite, a receiver facility called the Denver Uplink Terminal was constructed. The facility's configuration, specifications, construction, operation, cost, and reliability are discussed in this document. (EMH)

SATELLITE TECHNOLOGY DEMONSTRATION

FEDERATION OF ROCKY MOUNTAIN STATES, INC.

technical report

TR0418

STD UPLINK COMPLEX

JAMES G. POTTER

INTRODUCTION

The Federation of Rocky Mountain States (FRMS) required a 4/6 GHz satellite earth station to conduct the Satellite Technology Demonstration (STD). An overview of the activities undertaken to complete this $366,000 facility--called the Denver Uplink Terminal (DUT)--in the short time available is provided in this paper.

PURPOSE

The Health, Education, Telecommunications (HET) experiment required a satellite earth station capable of originating a single video signal with four associated program channels to each of the seven regions served.* The National Aeronautics and Space Administration (NASA) operated stations having this capability in Rosman, North Carolina, and Mojave, California. The annual cost of leasing terrestrial lines from Denver to Rosman or Mojave for the HET experiment was approximately $762,000 and $561,000, respectively. The option of mailing video tapes to Rosman or Mojave for later playback was unacceptable; a major objective of the HET experiment was to explore the cost-effectiveness of real-time, interactive programming.

To access the ATS-6 in any of the seven coverage modes, it was necessary for the station to interface with the global-beam antenna on the spacecraft. This beam intersects one-third of the surface of the earth, an area 20 times larger than any of the seven regions in which HET terminals are located. The required power and sensitivity of a station designed to access the global beam are approximately 20 times greater that of a station which interfaces with a spot beam of ATS-6. Accordingly, the cost of such a facility is much higher.

Nonetheless, it was determined that a new facility would be considerably less expensive than a year's lease of terrestrial lines to Rosman or Mojave. Moreover, a station designed to provide origination for the HET experiment would have considerable resale value; the technical

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* A different geographical region was served by each of the six HET experimenters. Two regions were served by the STD, the Rocky Mountain East and the Rocky Mountain West.

requirements of the STD uplink are similar to those of stations designed to serve in commercial, domestic-satellite systems.

The National Institute of Education authorized the STD to procure the uplink complex in July, 1973. As ATS-6 was launched in May, 1974, fewer than eleven months remained to procure and integrate the system. Despite a major delay caused by the collapse of the antenna system in December, 1973, the Denver Uplink Terminal (DUT) was operational in June, 1974, when NASA scheduled the first complete test of the HET communications network.

CONFIGURATION AND SCHEDULE

The DUT is located in a valley two miles south of the town of Morrison, Colorado. The natural shielding of the surrounding mountains enables the earth station to share the 4/6 GHz frequency band, which is used extensively by terrestrial systems in the Denver vicinity. The uplink complex complies with all Federal Communications Commission (FCC) requirements pertaining to coordination of fixed-satellite earth stations. The STD retained Compucon of Dallas to perform the analysis involved in meeting FCC and IRAC* regulations. Compucon also cleared the 12.5 GHz microwave relay that interconnected the uplink with the STD's headquarters located 12 miles away in downtown Denver.

The DUT was designed for simplicity and low cost. Ninety-five percent reliability was considered adequate in view of the experimental nature of the program and the fact that NASA stations at Rosman and Mojave were available for backup.**

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* The licensee of the station is DHEW, who subcontracted the STD to prepare the background materials. The Interagency Radio Advisory Committee (IRAC) coordinates spectrum allocations with the FCC in matters which involve shared use by government and nongoverment agencies.

** Commercial stations normally are designed to achieve a reliability of 99.99% or greater. This stringent requirement necessitates a need for complete redundancy of all critical subsystems and elaborate control circuitry to detect failure and institute corrective action. The functional simplicity and lack of redundancy of the DUT kept the cost to less than one-third the cost of a comparable commercial facility.

The station used an 11-meter (36 foot) prime-focus antenna, a three kilowatt transmitter, and a 90°K uncooled parametric amplifier, which provided an EIRP of 84 dBW and a G/T of 29 dB/°K. Radiation Systems, Inc. (RSi) and Farinon Electric, Inc., were the prime contractors. The major subcontractors were Aydin Energy Systems, AIL, and California Microwave. The components of the station were of the highest quality, but there was no provision for catastrophic failure of key subsystems.

The only nonstandard feature of the uplink complex was the requirement of four, rather than one, audio subcarriers on the video--the same signal format previously had been established in the design of the Receive-only Terminal (ROT) electronics supplied by Hewlett-Packard. [illegible] the impact of this added requirement on the cost and delivery of the earth [illegible] modulator and demodulator were contracted separately. The electronics supplied by the prime contractor of the earth station (RSi) were standard items. Farinon provided the custom FM modulator, and Hewlett-Packard provided the demodulator.

The schedule for implementation of the STD uplink complex was extremely tight, as indicated below. NIE permitted the STD to contract directly with the equipment suppliers, making it much easier to meet the associated deadlines.

Date	Event
February 22, 1973	Request for Quotations Released on 4/6 GHz Station
July 17, 1973	NIE Authorizes FRMS to Procure Station
July 20, 1973	Contract Signed with Radiation Systems, Inc. (RSi)
October 2, 1973	Lease Agreement Reached for Land
October 16, 1973	Contract Signed with Farinon Electric for Microwave Relay
November 16, 1973	Chief Engineer for Uplink Hired by FRMS
November 28, 1973	Contract Signed with American Data Corp. for Modulator
December 1, 1973	Initial Site Preparation Completed
December 17, 1973	RSi's Initial Antenna System Collapsed
February 28, 1974	FRMS Completes Construction of Microwave Towers
April 1, 1974	Power Becomes Available; Site Preparation Completed
April 3, 1974	Final Acceptance of Farinon Microwave Relay
May 30, 1974	Launch of ATS-6
June 16, 1974	Successful Test of Uplink Communications System
July 2, 1974	STD Uplink Commences Broadcasting
August 6, 1974	Contract Awarded for Improved Monitoring System
October 3, 1974	Contract Awarded to Farinon for Improved Modulator
November 5, 1974	Antenna-Heater System Installed
December 10, 1974	Final Acceptance Granted to RSi
May 20, 1974	HET Broadcasting is Terminated

Significant Events of STD Uplink Complex

SPECIFICATIONS AND PROCUREMENT

The STD issued fixed-priced contracts for the key elements of the complex and attempted to avoid the necessity of issuing later change orders that would impact price and schedule. Three drafts of the earth-station specifications, which were reviewed by NASA and private consultants, were prepared before a request for quotations was released on February 22, 1973. Additional modifications were incorporated during subsequent negotiations with suppliers.

The timing of the procurement was ideal, preceding larger orders from common carriers by approximately 12 months. Potential suppliers wished to establish their credentials by installing what appeared to be a comparatively simple, low-risk system. Twenty-three companies attended the bidders' conference, and there were seven serious proposals. Because the bidding was extremely competitive, profit margins probably were minimal.

Negotiations could have been completed by the end of April, 1973; but the NIE's approval of the procurement was withheld, pending a review of Project objectives. The STD, therefore, was given three additional months to conduct an exhaustive review of the prospective suppliers.

The delay proved to be beneficial. Two of the three low bidders had never constructed a satellite earth station. Representatives from companies having prior experience with the prospective suppliers were remarkedly candid in describing the suppliers' strengths and weaknesses. These individuals provided the STD with the benefit of hindsight, suggesting contract provisions which they had not included. Because of the competitiveness of this procurement, FRMS was successful in negotiating the suggested provisions into the final contract.

NIE approved the procurement on July 17, 1973; and FRMS signed a contract with Radiation Systems, Inc., (RSi) on July 20, 1973. RSi was the lowest, technically-qualified bidder.

Procurement of the microwave relay proceeded concurrently with activity on the earth station. The nonstandard signal format required in the HET experiment presented a complication which was not resolved until September, 1973. Six qualified suppliers were asked to bid on three options:

1. A baseband-to-baseband duplex system, providing one video and four audio channels;
2. A system which incorporated the custom signal format, providing a baseband interface to the Network Control Center and an intermediate-frequency interface at the earth station;

3. One baseband-to-baseband link (earth station to studio) and one baseband-to-if link (studio to earth station).

Five of the six suppliers submitted a bid, and all elected to bid only on the first option. FRMS prepared a request for quotations based on this approach and asked the six companies to quote on September 7, 1973.

Farinon Electric was the lowest, technically-qualified bidder. NIE approved the procurement on October 15, 1973; and a contract between Farinon and FRMS was signed on October 16, 1973.

The problem of incorporating the custom signal format at the earth station, which was necessary to interface with the Receive-Only Terminals, was still unresolved. Five companies were asked to bid on the required FM modulator on November 5, 1973. The only company which responded, the American Data Corporation, was awarded the contract. This company had built test sets for FRMS but had no prior experience with FM modulators, which are technically demanding.

The modulator required constant maintenance, necessitating the purchase of a replacement. Farinon agreed to build a replacement on October 3, 1974, and manufactured and installed the modulator in less than 60 days.

IMPLEMENTATION

It was hoped that Western Telecommunications, Inc. (WTCI, a common carrier that intended to operate a satellite earth station in the Denver area) would sublet an appropriate site to FRMS for the duration of the HET experiment. WTCI, however, encountered difficulties acquiring the proposed land, and the Project was forced to obtain its own site.

The land had to be rezoned and processed for frequency clearance. These tasks were accomplished by October, 1973. The land was cleared, an access road was provided, and utilities were installed by December, 1973. All of this work was coordinated with subcontractors.

RSi began erecting the earth station in mid-December, approximately one month ahead of the contract schedule which called for completion of the station by mid-February. Eighteen

hours after the 11-meter antenna was installed, it collapsed in a wind and snow storm, casting serious doubt on the likelihood of completing the origination station in time for the HET experiment.

Subsequent negotiations with RSi were extremely delicate. FRMS and RSi worked diligently to design and fabricate a new antenna structure that was considerably stronger than the earlier model. The station was operational by early June, 1974, 10 days after the launch of ATS-6. Although construction of the second, stronger antenna represented a significant change in the original specifications, the final cost was increased by less than six percent.

Installation of the microwave relay proceeded according to schedule. FRMS constructed the necessary towers, but Farinon Electric agreed to assume responsibility for the complete system. Farinon's performance under the contract was flawless; the microwave relay performed to specification without any on-site debugging. Farinon maintained this standard in their custom modulator.

OPERATIONS

HET broadcasting commenced in July, 1974; and engineering personnel learned to operate the equipment by means of an on-the-job training program. These personnel had extensive background in television broadcasting, but they had no previous experience with satellite earth stations. First priority was to master the basics of the microwave portion of the uplink complex, where there was insufficient funding for spare parts and failures could be catastrophic. This task was accomplished by July, 1974, at which time it was possible to concentrate on baseband video processing.

As the uplink provided a final check on the signal quality of the outgoing programming, additional test equipment was purchased in August to maintain better quality control. Operational experience provided the engineering staff with the perspective necessary to arrange the equipment in a manner which maximized convenience of operation and reliability. The layout of the station appears in Figures 1 and 2.

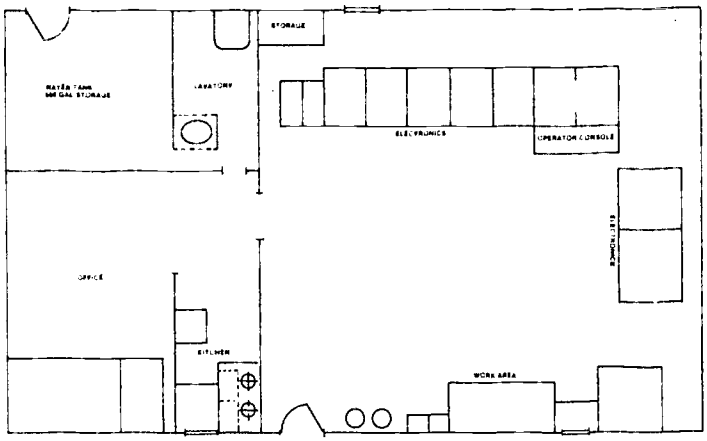

Figure 1. STD Uplink Station Layout

By late September, 1974, operation had become routine. A series of prebroadcast checks and maintenance procedures was instituted which assured quality, reliable operations through the duration of the experiment.

A final modification of the complex occurred in October after an accumulation of wet snow on the antenna reduced the effective isotropic radiated power by 9 dB. Within two weeks, FRMS procured and installed a heater system to prevent snow accumulation.

COST AND RELIABILITY

The capital cost of the STD uplink complex (approximately $366,000, including spare parts and supplies) was very close to the amount projected in July, 1973. Consulting and legal fees well in excess of the original projections resulted from contractural difficulties associated with the collapse of the antenna structure.

FRMS's assumption that no catastrophic failure of critical components would occur during the operational phase of the Project proved to be accurate. The reliability of the complex was exceptional. From October, 1974, through May, 1975, the uplink was on the air approximately 550 hours. Total outages, including power failure and operator error, amounted to 117 minutes.

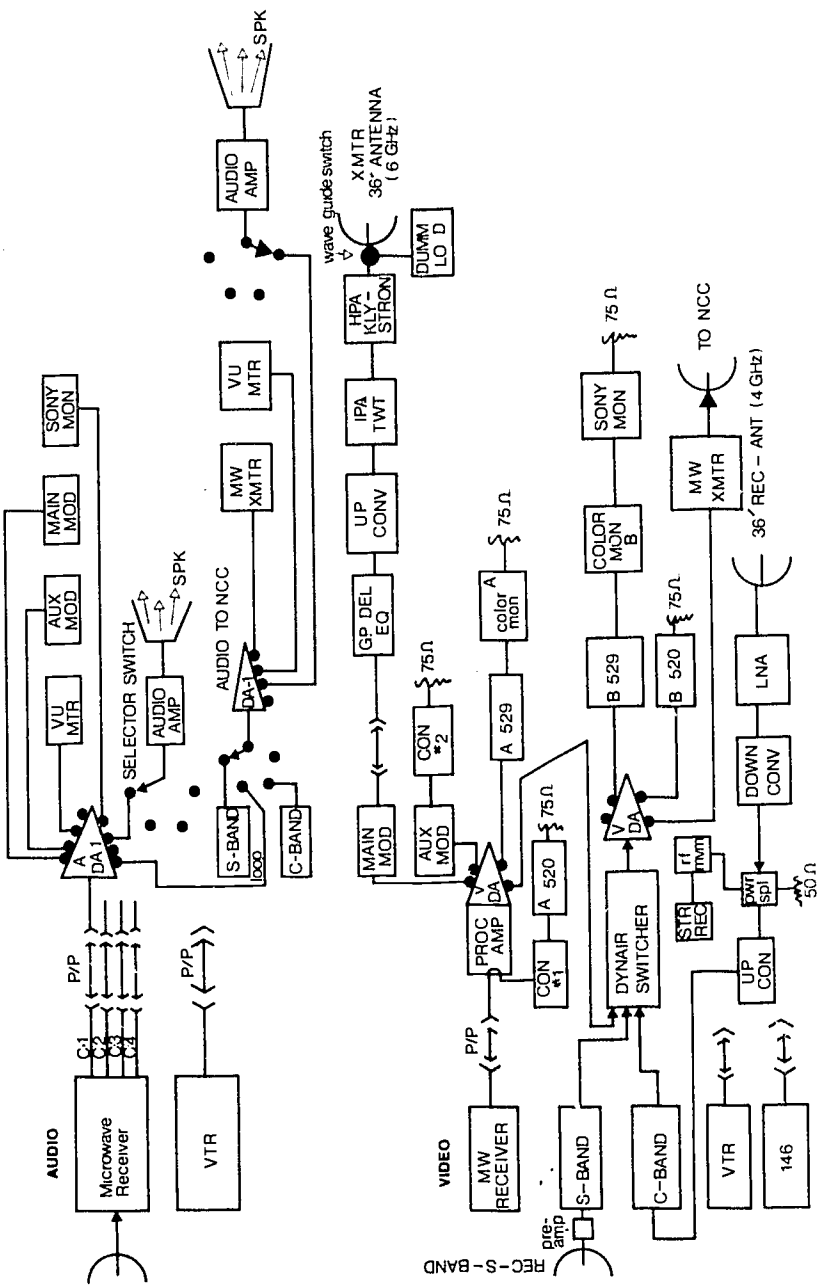

Figure 2. Audio/Video Schematics for STD Uplink

Thus, the station was operational over 99.64% of the time. This accomplishment is remarkable in view of the fact that there was minimal redundancy in the station and that the operators had no previous experience with satellite earth stations.

In conclusion, the uplink operation was highly successful. Although little time was available to procure, integrate, and debug the facility, costs were held to the original projections; and quality and reliability exceeded expectations.*

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* The measured signal-to-noise ratio of video broadcasts received at representative STD sites consistently exceeded 49 dB (peak-to-peak video to weighted, RMS noise).

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