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AN OVERVIEW OF THE COMMUNICATIONS TECHNOLOGY SATELLITE PROJECT - EXECUTIVE SUMMARY

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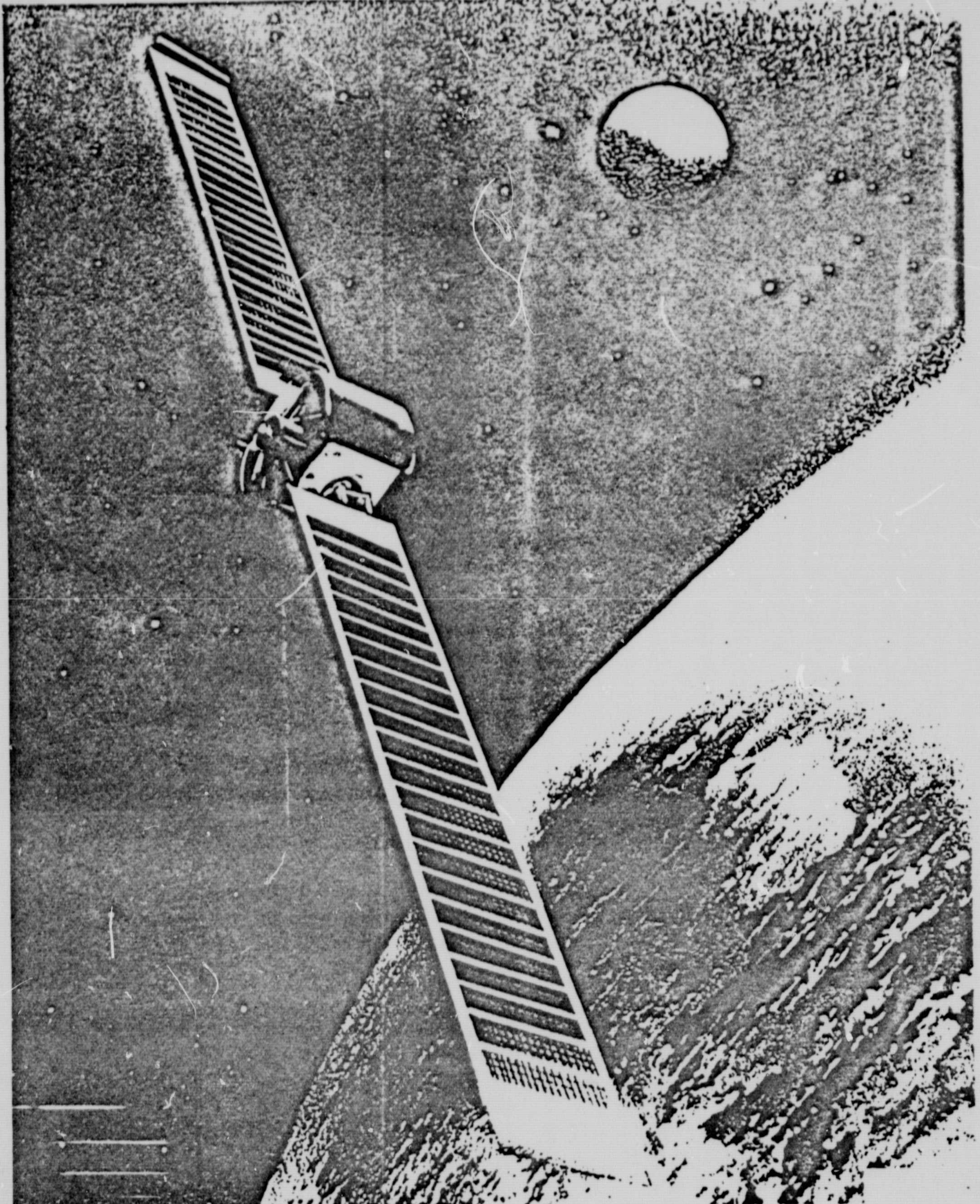


Artist's concept of CTS on station

The Communications Technology Satellite (CTS) project officially began on April 20, 1971 with the joint signing of an agreement between the United States National Aeronautics and Space Administration (NASA) and the Canadian Department of Communications (DOC). The authority for this joint U.S.A. and Canadian effort was Public Law 85-568 of July 29, 1958.

The Communications Technology Satellite was designed to operate at the 14/12 GHz Band. This followed several years of successful experimentation and demonstrations on the Advanced Technology Satellite-6 (ATS-6) which operated at the 4/6 GHz Band.

The principal technological objectives of the CTS program were to:

Develop and flight test a power amplifier tube having greater than 50% efficiency with a saturated power output of 200W at 12GHz.

Develop and flight test a light-weight extendible solar array with an initial power output greater than 1 KW.

Develop and flight test a 3-axis stabilization system to maintain accurate antenna boresight positioning on a spacecraft with flexible appendages.

Conduct satellite communications systems experiments using the 12 and 14 GHz bands and low-cost transportable ground terminals.

Under the agreement Canada undertook to design, build and operate the spacecraft while the United States agreed to provide the launch vehicle, the high-power traveling-wave-tube amplifier, spacecraft environmental test support, and the operational launch support to place the spacecraft in synchronous orbit. Both countries agreed to carry out experimental programs in communications. NASA's Lewis Research Center (LeRC) and DOC's Communications Research Center (CRC) were designated as the two responsible agencies. In May 1972, an agreement was signed between Canada and the European Space Research Organization (ESRO), now the European Space Agency (ESA), under which ESRO agreed to provide two 20W traveling-wave-tube amplifiers and a parametric amplifier, and to develop an extendible solar blanket and associated solar cells.

NASA in the U.S.A. and DOC in Canada invited agencies and organizations to submit proposals for communications experiments. Use of the spacecraft was then allocated to approved experimenters, or users, with each country sharing the use of the CTS/Hermes equally on an alternate-day-basis.

The satellite was launched on January 17, 1976 by a Thor Delta 2914 launch vehicle. The CTS was designed to operate for two years, and to produce an effective isotropically radiated power (EIRP) of nearly 58.1 dBw. which was significantly greater power than that provided by then existing spacecraft and was representative of levels that could be used by future broadcasting satellites.

NASA provided all launch operations to place the satellite in a geosynchronous orbit and then turned control over to CRC on January 29, 1976 with the satellite on location at 116 degrees West longitude.

The stated objectives were most important in advancing the technology of satellite communications in the scientific communities of both nations. This report focuses largely on the user experiments conducted by the United States experimenters.

The prior ATS-6 experiments demonstrated that satellite communication technology can provide a variety of public service functions and can broadcast with equal success into extremely remote areas, as well as densely populated areas. A variety of medical, health, education and training programs were beamed into remote Alaskan villages, to towns and cities in the Rocky Mountain states, and many target populations throughout Appalachia. The ground terminals were operated successfully by native villagers, teachers, nurses and students. The success of these early demonstration projects generated considerable interest on the part of state and local governments, medical and health organizations, educational groups, and community and special service groups. The success of the ATS-6 technology and the support and interest of many diverse groups served to promote the development of the CTS project. At the same time that United States public service groups were voicing their requests for futher communication experiments, a similar thrust was developing in Canada. The combined interest of the United States and Canadian groups demonstrated a need for further experimentation which led to the development of the Communication Technology Satellite/Hermes projects.

CAPABILITY OF THE CTS SPACECRAFT

The Hermes/CTS satellite which was launched on January 17, 1976, and placed in a synchronous orbit was then the world's most powerful communications satellite. The key component was a transmitting tube 10 to 20 times more powerful than that of any other satellite. Because of this powerful transmitter on the satellite, much smaller and less expensive ground receiving equipment could be used. This ability to utilize small and inexpensive ground equipment made the CTS an especially attractive technique for reaching rural and isolated communities.

The main body of the spacecraft was cylindrical with two flattened sides. The cylinder was 74 inches high and 72 inches across. In the main body was the apogee kick motor. Two wing-like solar arrays which extended from the sides of the cylinder provided 1,250 watts of power. The CTS was stabilized in space by means of a momentum wheel-hydrazine reaction control system. The CTS was equipped with a 200 watt transmitter which operated at high frequencies. It broadcast voice and television signals to many small low-powered ground stations which were often located in remote areas of the U. S. and Canada.

TYPES OF EXPERIMENTS AND USERS

There were five general categories of user experiments. They were:

<u>Health Care</u>

Biomedical Communications

Health/Communications

Decentralized Medical Education

<u>Community Services</u>

Library Networking

Video Teleconferencing

Public Broadcast Services Regional Networking

<u>Education</u>

Curriculum Sharing

Career Education

Elementary and Adult Education

Technology

Transmitter Experimental Package

Link Characterization

Ditigal Communications

Small Terminal Development

Special Services

Emergency Communications

Video Conference

Ice Information

New Communications

There were 35 proposed and approved experiments, of which 20 were completed. There were also 146 approved demonstrations or mini-experiments and 63 single day events proposed. In evaluating a proposed experiment, the Proposal Evaluation Committee examined the technical content, compatibility with the spacecraft, the validity of the experiment, the experimenter's evaluation plan, the experimenter's spacecraft utilization plan, the financial plan, and finally the plan for final evaluation and publication of the results.

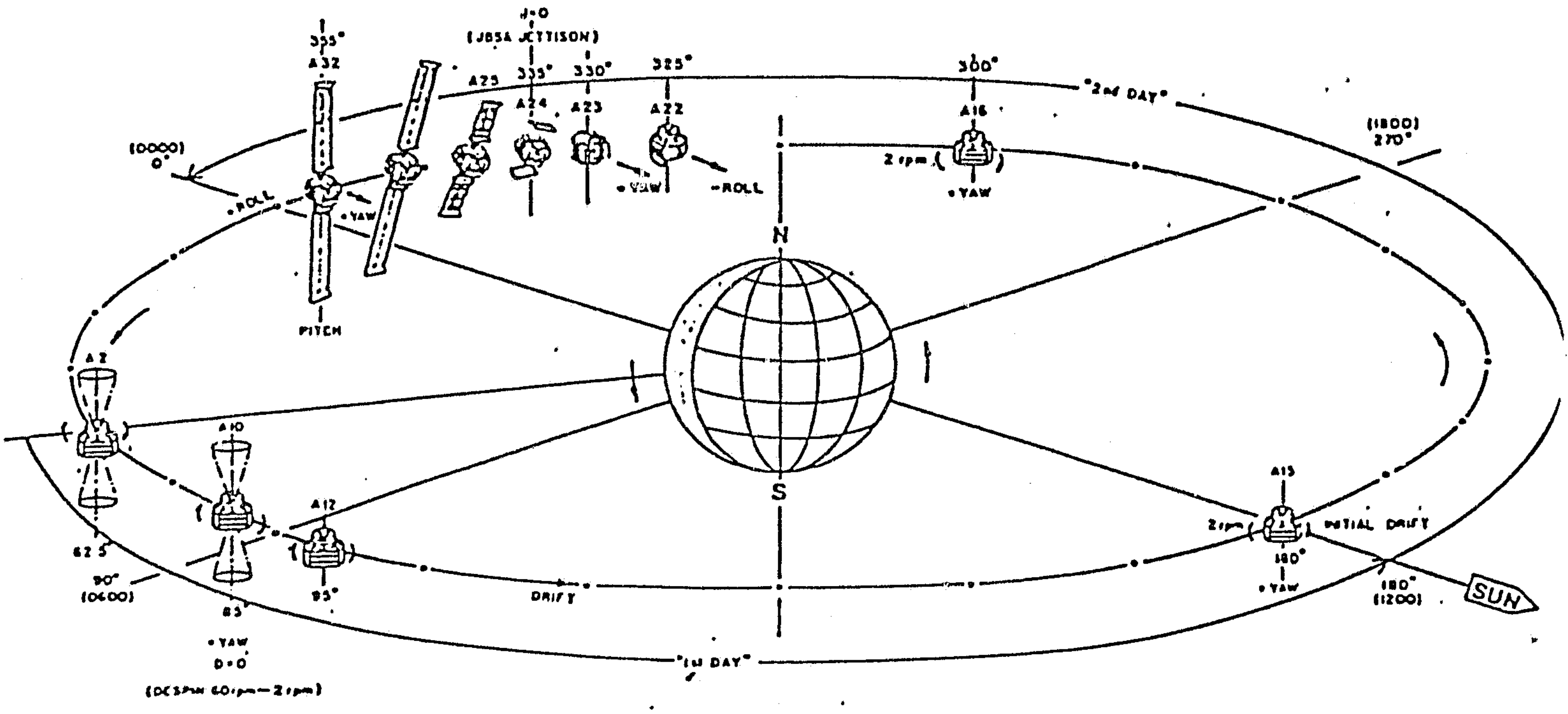
The guidelines for being an experimenter on the CTS/Hermes satellite required that the experimenter obtain funds for the experiment and for ground equipment from outside sources, and NASA would provide the time on the spacecraft without charge. However, this requirement to provide their own funding proved to be a stumbling block for a number of experimenters. These experimenters were approved and had developed plans for very worthwhile experiments, but were unable to secure funding. It is unfortunate that at the time that CTS experimenters were seeking external funding from agencies, industry and foundations that these very funding sources were "drying up."

LAUNCH

The satellite was launched on January 17, 1976, by a Thor Delta 2914 launch vehicle. The launch followed a standard Delta synchronous orbit profile. NASA provided all of the launch operations, placed the satellite on location at 116° W. longitude and spinning at a rate of 60 rpm. On January 29, 1976, control of the satellite was turned over to the Communications Research Center (CRC) in Canada.

SPACECRAFT CHECKOUT

To place the spacecraft in operation and to perform a checkout of all systems, the following sequence was followed:



ATTITUDE ACQUISITION EVENTS PROFILE

FIGURE 1. Launch profile of Hermes.

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The satellite was first despun by using the low thrust hydrazine thrusters. The satellite was then turned 90° so that the communications antennas on the front of the satellite faced the earth. Two sections of the body-mounted array covers were jettisoned and the two flexible solar arrays were extended by stainless steel booms. At this point, the satellite appeared as in Figure 2.

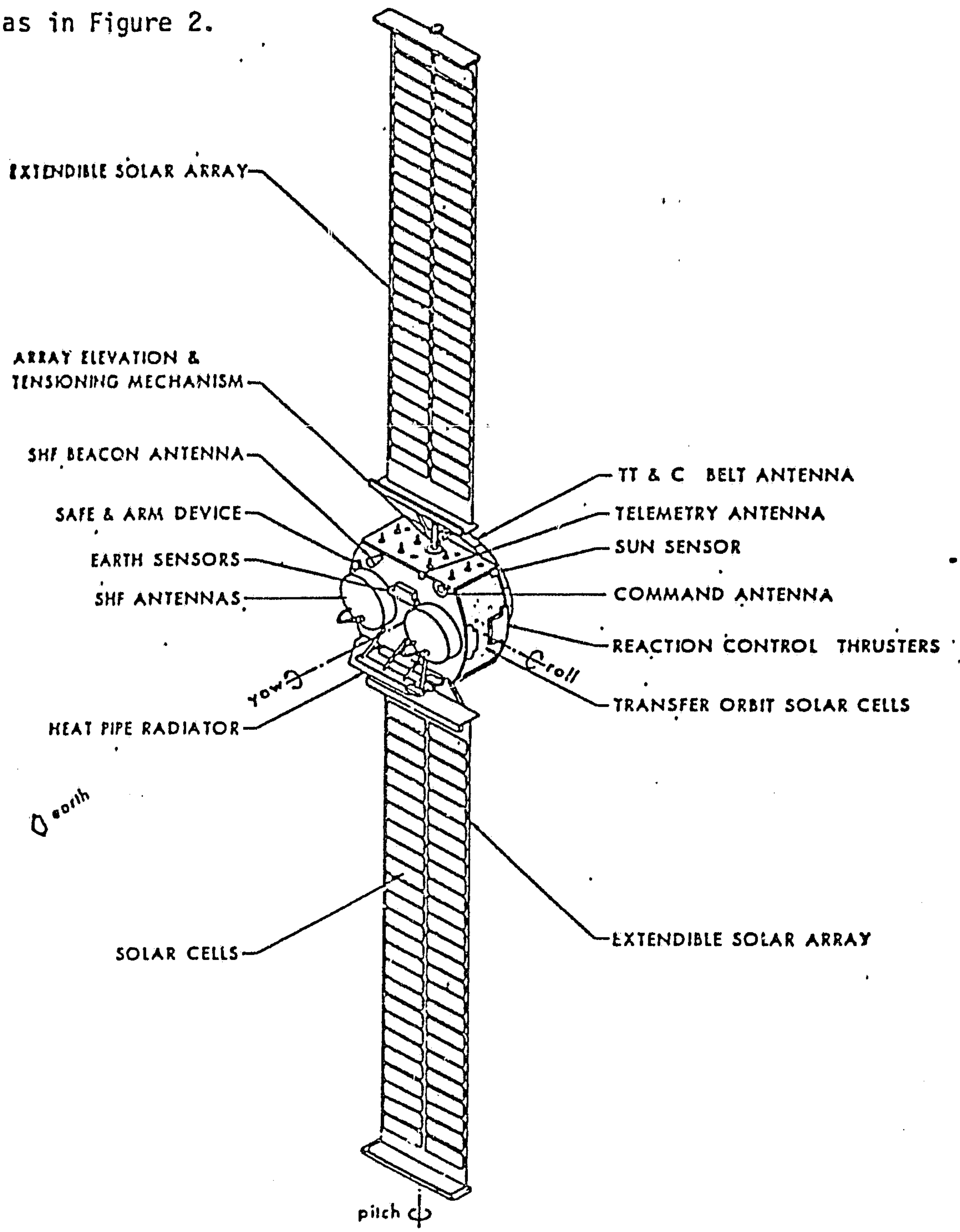
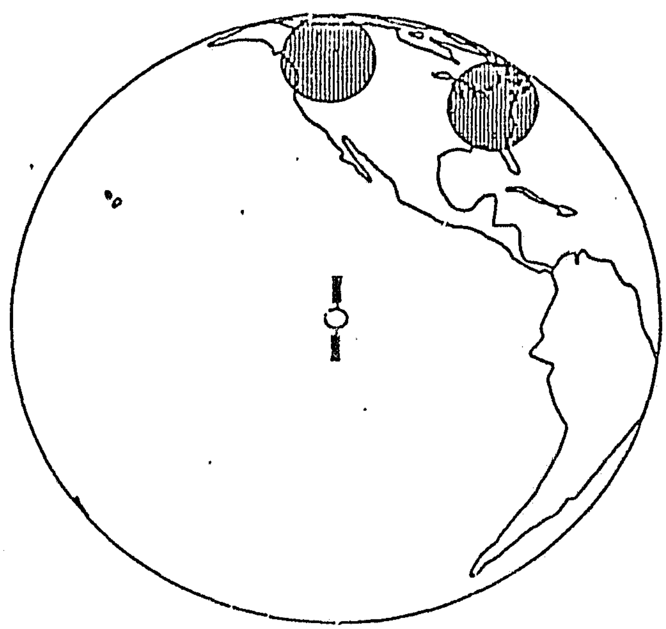


FIGURE 2. Hermes spacecraft in orbit.

The solar arrays were then turned toward the sun to provide electrical power. The satellite was carefully oriented, the momentum wheel was spun up and the 3-axis stabilization system was activated. The solar arrays initially provided 1365 W of power.

The location of the spacecraft at 116° W was selected to provide coverage for Northern Alaska, Newfoundland, Canada, and most of the Continental U.S.A. The SHF antennas could be independently pointed to any spot visible from the satellite. Figure 3 shows the earth as seen from the satellite at 116° W and illustrates how two beams could be used simultaneously.



EARTH VIEWED FROM SYNCHRONOUS ALTITUDE

116 DEGREES WEST LONGITUDE

FIGURE 3. SHF antenna footprints.

North American coverage is illustrated in Figure 4. Typically, one of these beams would be 200 W and the other a 20 W beam.

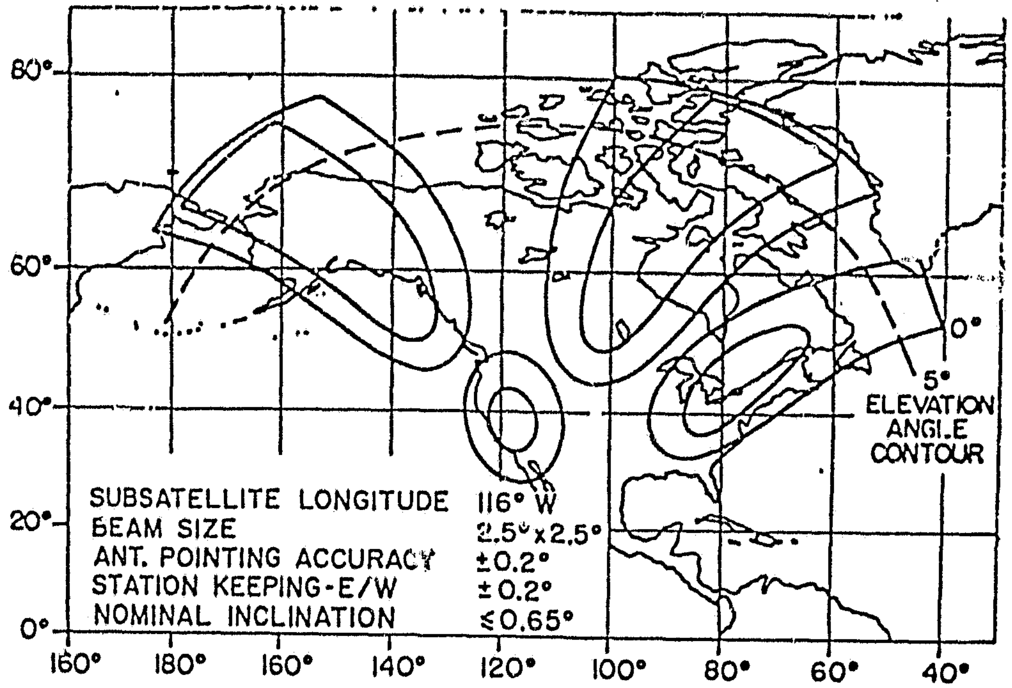


FIGURE 4. Typical SHF coverage patterns.

Figure 5 shows a typical communication system configuration.

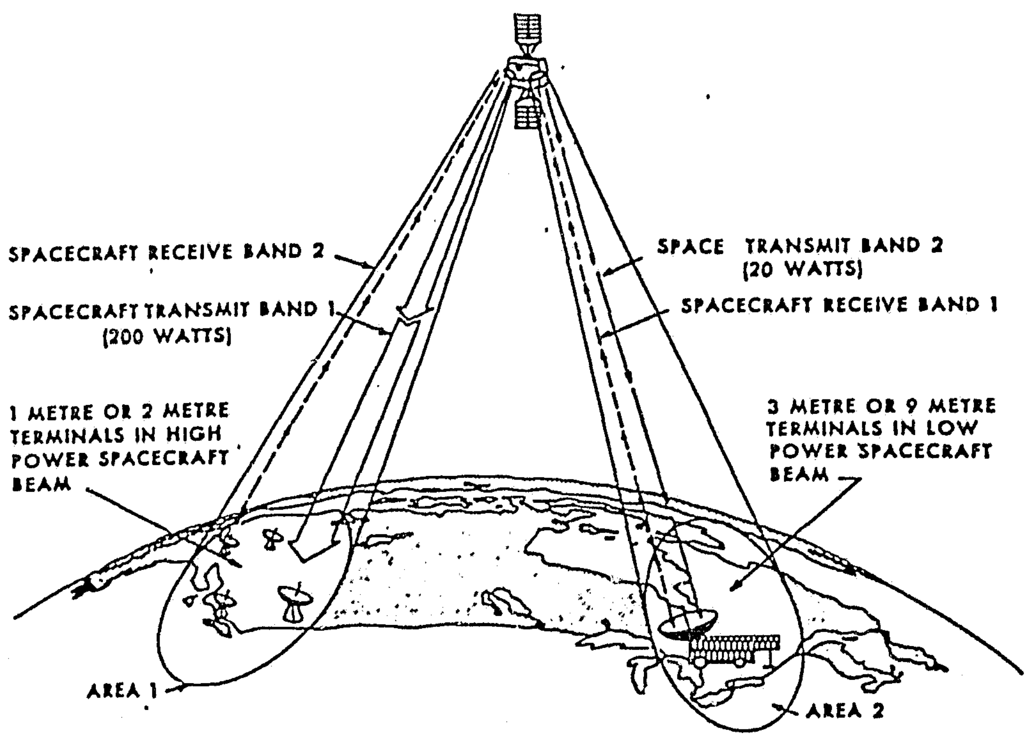


FIGURE 5. Typical communication system configuration.

Figure 6 illustrates the ground terminal sites used during the two-year mission.

FIGURE 6. Ground terminal sites during the two year missior.

EXPERIMENTATION

Experiments were conducted in both the United States and Canada. The experimental capabilities of the CTS/Hermes spacecraft allowed the following general kinds of experiments.

T. V. Broadcast

Educational T. V. with voice or data return

T. V. origination from remote locations

Two-way T. V. for teleconferencing

Telephony (two-way voice)

Radio program broadcasting

Digital communications

Experimental time division multiple access (TDMA)

During the period from January 17, 1976 through January 17, 1978, the satellite was available almost continuously for experimentation. Several exceptions were when the spacecraft experienced the spring and fall equinox eclipses of 1976. During this period, the spacecraft went on battery power for housekeeping functions, but the SHF transponders were shut off. By 1977 enough experience had been gained that communications experiments were continued through both eclipse seasons. On May 21, 1976, D.O.C. and NASA joined in a ceremony ending the checkout and experiment operations mode. See Figure 7 for the time line of operation January 17, 1976, through January 17, 1978.

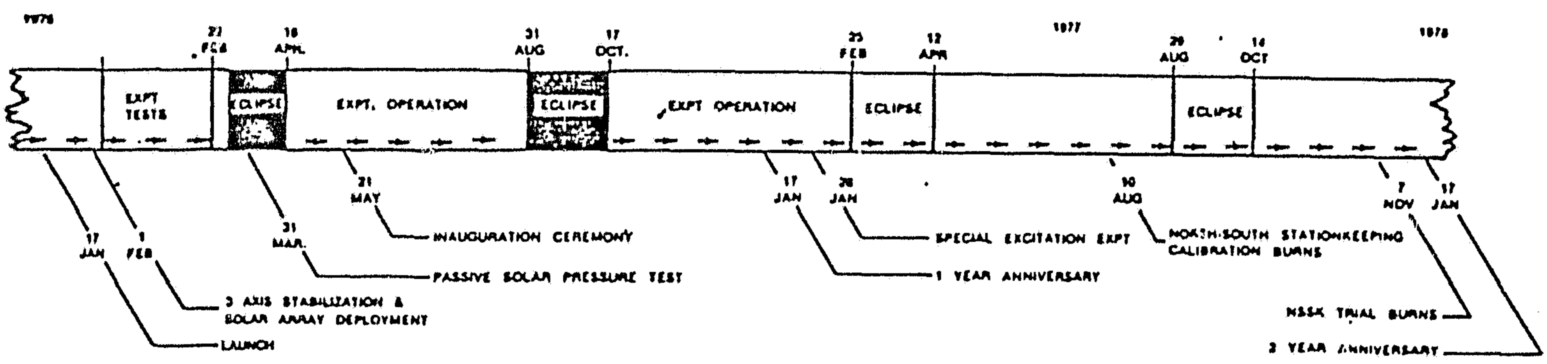
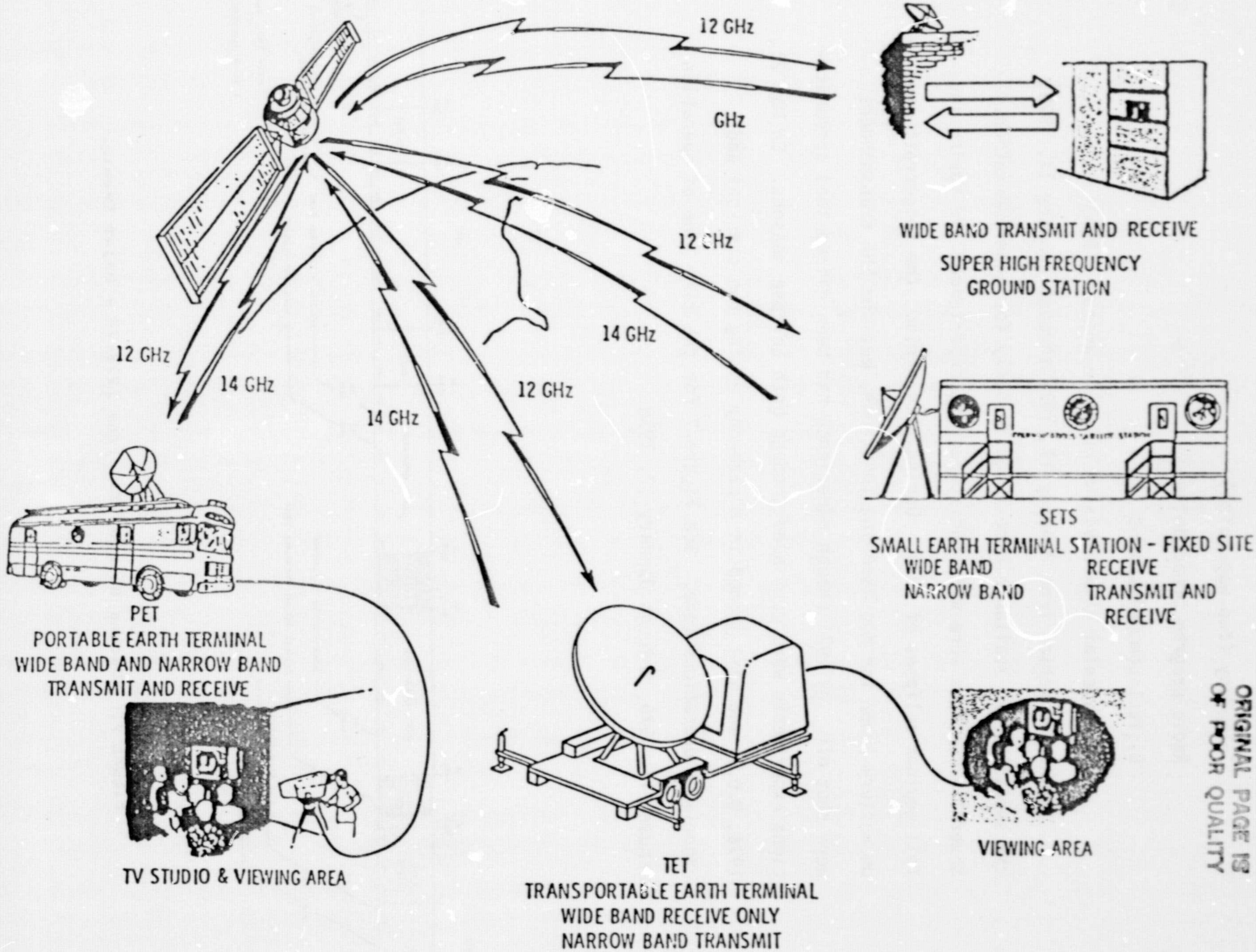


FIGURE 7. Hermes Mission Timeline 1976-78 - Major Events.

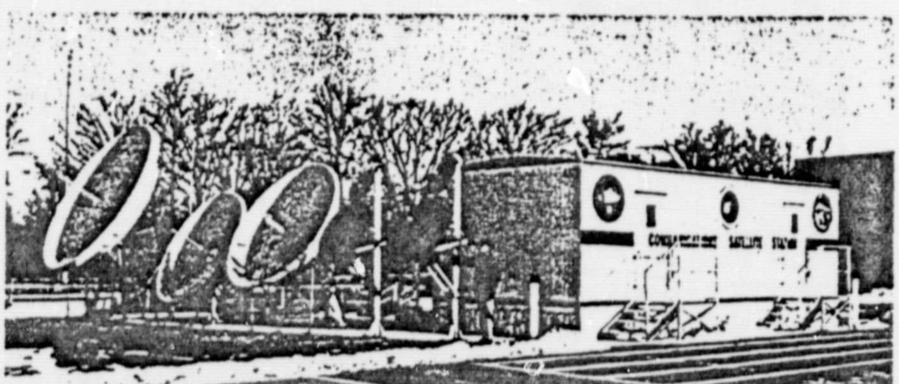
CTS and The Experimental Earth Terminals



SMALL EARTH TERMINAL STATION - SETS

The Small Earth Terminal Station at Lewis was principally used to test and evaluate experimental systems and low-cost wideband receive hardware. The facility also provided narrowband (voice) transmit and receive capability for use with CTS.

The station is at a fixed site and utilizes eight parabolic reflector-type antennas ranging in size from 2 to 15 feet in diameter. It has wide-band receive systems that are fixed frequency (low-cost) or variable frequency. Also available is the capability for voice or facsimile transmission using narrowband equipment. Housed at the station are color monitors, video tape recorders and other audio/video equipment

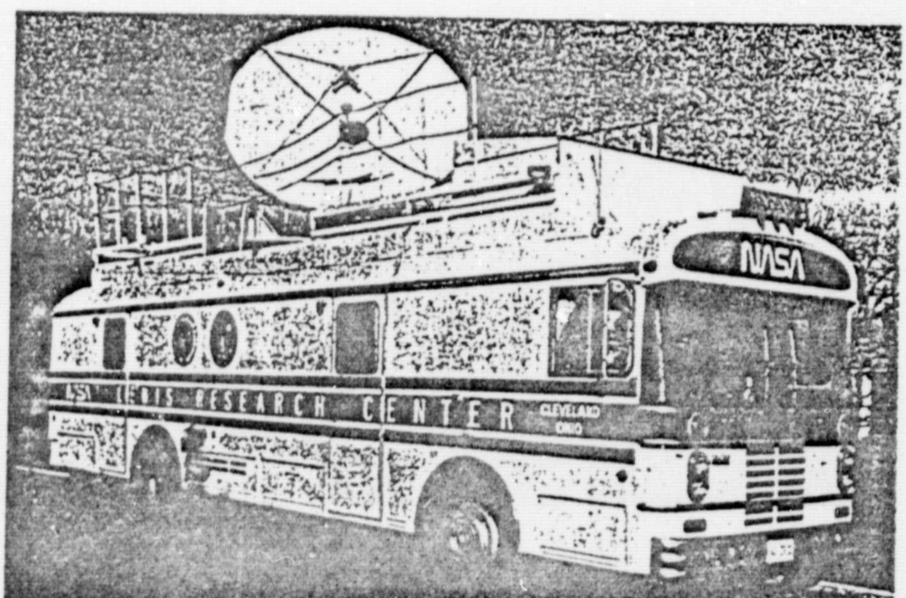


PORTABLE EARTH TERMINAL - PET

PET is a portable satellite communications terminal that was designed by NASA/Lewis. PET is a 35 foot bus equipped with a teleconference room and satellite transmitting and receiving equipment. An 8 foot parabolic antenna is mounted on the roof. PET, which was operated by NASA/Lewis, was loaned to experimenters for satellite communications experiments.

Interior equipment includes color television cameras, color monitors, audio equipment, video tape recorders, 12 GHz receiving equipment and a 500 Watt 14 GHz transmitter.

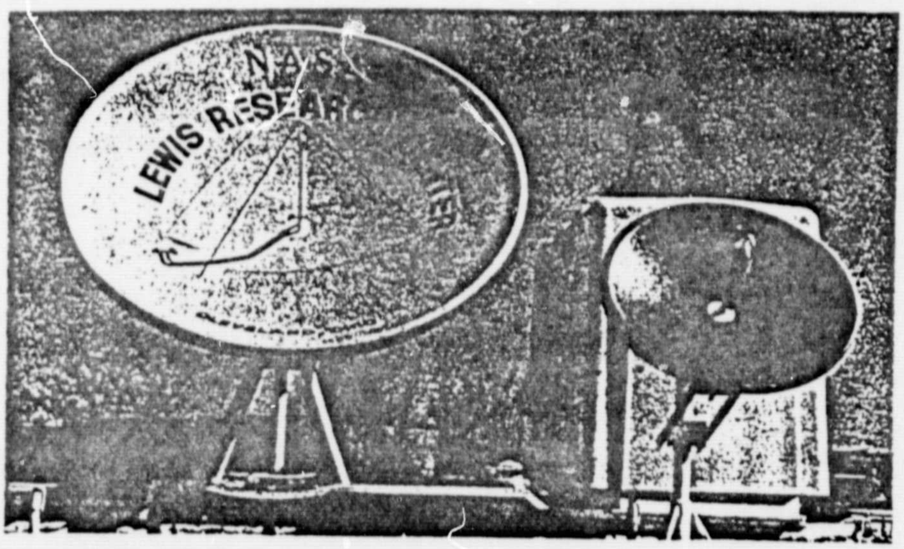
PET's on-board power is supplied by two 12 kw generators, one for operations and one for housekeeping. Equipment may also be run using on-site power.



TRANSPORTABLE EARTH TERMINAL - TET

TET is a 20-foot trailer designed by Lewis as a transportable satellite communications terminal. It is equipped with an electronics shed which houses satellite transmitting (voice only) and receiving (video and audio) equipment. TET has two parabolic antennas, one 4-feet and the other 10-feet in diameter. This facility was operated by Lewis and loaned for satellite communications experiments.

Electronics equipment used includes color monitors, microphones, video tape recording apparatus, and associated signal distribution devices.



CTS USERS

The major categories of users were: Education, Health Care, Community and Special Services and Technology. The following approved experiments which were proposed will illustrate the types of users and disciplines represented.

EDUCATION EXPERIMENTS

College curriculum sharing among universities with a demonstration of digital video compression techniques for both bandwidth and power reduction.

Teacher upgrading by improving teaching skills and development of instructional units and making graduate education available to teachers.

Health education programs using live and videotaped techniques for use by hospitals and health-care facilities.

Exchange of materials and teaching techniques related to computer-aided instruction between diverse areas of the country.

Investigation of telecommunication systems requiring only limited human support and providing data on career development, employment, job preparation, and counseling.

HEALTH CARE EXPERIMENTS

Conducting biomedical clinical and continuing medical experiments among thirty V. A. hospitals.

Demonstration of the feasibility of information exchange between research institutions and the medical community; evaluation of the broadband teleconference as a means of continuing education among health-care professionals.

Investigation of techniques for improving administration and teaching procedures for decentralized medical education.

EXPERIMENTS IN COMMUNITY AND SPECIAL SERVICES

Feasibility of a satellite library information network to improve individual and organizational capabilities for assessing and disseminating information.

Development of techniques for transmission of special services programs world-wide; conversion of analog data to digital for wideband transmission of time-compressed audio at video format speeds.

Determination if a large and geographically dispersed industrial organization can substitute video and audio communication for travel.

TECHNOLOGY EXPERIMENTS

Evaluation of attenuation and signal degradation due to absorption and scattering induced by atmospheric precipitation; measurement and characterization of earth-based, man-made signals which could interfere with the uplink frequency band.

Demonstration of the suitability of transportable earth terminals to relay communications to and from a disaster area.

CTS EXPERIMENTS

NO.	DATES	TITLE	OBJECTIVE
1	2/76-12/78	Communication Link Characterization Experiment (CLCE)	Evaluate attenuation and signal degradation due to absorption and scattering induced by precipitation; measure and characterize earthbased man-made signals which could interfere with uplink.
4	10/76-11/77 11/77-11/78	College Curriculum Sharing	Expand scope of curriculum by sharing classes among universities and countries; demonstrate digital video compression techniques for bandwidth and power reduction.
6	5/76-6/79	Transportable Emergency Earth Terminal	Demonstrate suitability of transportable earth terminals to relay communications to and from a disaster area.
7	6/77	Biomedical Communications	Promote wide dissemination of information between research institutions and the medical community; evaluate broadband teleconferencing to support continuing education among health care professionals.
11	10/77	Health/Communications	Refine and validate applications of satellite-based biomedical communications among thirty V.A. hospitals and surrounding communities for diagnosis, therapy and education.

CTS EXPERIMENTS - (Continued)

NO.	DATES	TITLE	OBJECTIVE
13	6/77-6/79	Communication Support for Decentralized Medical Education	Refine uses of satellite-based communications in support of teaching, administration, and improved patient care in multi-state medical education environment.
15	5/76-6/78	Communications in Lieu of Transportation	Assess the applicability of video and audio communication (i.e., teleconferencing) as an economic alternative to travel in a large, geographically-disperse, industrial organization.
16	3/76	Project Interchange	Demonstrate continuing exchange of materials and teaching techniques related to personalized instruction and special education among classroom teachers in diverse areas of the country.
18	4/76-6/79	Interactive Techniques for Intra-NASA Applications	Develop and demonstrate interactive communications techniques between NASA centers and headquarters in support of agency management and administrative functions.
19	12/76-6/79	Satellite Distribution Experiment	Demonstrate distribution of educational television materials originating at a central location to non-commercial T.V. stations for broadcast use.

CTS EXPERIMENTS - (Continued)

NO.	DATES	TITLE	OBJECTIVE
20	6/76-1/78	Advanced Ground Receiving Equipment Experiment (AGREE)	Determine system performance under field conditions of Japanese-built small, low-cost, low-noise, 12 GHz receivers.
21	11/76-6/79	Advanced U. S. Public Service Telecommunications Activities on CTS	Encourage and assist maximum public service usage of the CTS Communications Network; provide technical support to public service users who require such support; develop an information system which will collect, process, and make available data on organizational, technical, and financial effect; analyze the organizational, technical, and financial elements of CTS experimenters who choose to cooperate.
22	8/77-9/76	Arctic Ice Information	Demonstrate the capability and usefulness of relaying near real time ice information via CTS to a joint military-civilian vessel operations center located in Barrow, Alaska, in support of vessel-barge resupply operations along the Alaskan North Shore.

NO.	DATES	TITLE	OBJECTIVE
24	6/77-6/78	Digitally Implemented Communications	Develop and demonstrate a digital communications capability accommodating a mixture of information systems using minimal channel requirements in order to demonstrate the practicality and feasibility of satellite link implementation by digital techniques for the distribution of T.V., voice, and data via small earth terminals.
25	4/77-7/78	Videoconferencing for Congress	Design and implement real-time demonstrations of Congressional videoconferencing using two-way audio-video (full duplex) communications between a member of Congress and/or Congressional staff and small groups of staff or constituents.
26	9/77-2/78	Project Prelude	An experiment/demonstration to test and show the ability of state-of-the-art communications and terminal equipment to provide various high speed digital communications applications and evaluate usefulness.

CTS EXPERIMENTS - (Continued)

NO.	DATE	TITLE	OBJECTIVE
30	3/78-1/79	Terminals of Tomorrow	To conduct an independent experiment with terminals from other sources.
31	7/78-12/78	Two-way Time Transfers Between NRC/NBS and NRC/USNO via the Hermes (CTS) Satellite	To test two-way time transfers between NRC/NBS and NRC/USNO via the Hermes (CTS) satellite.
32	10/78-12/78	Digital Testing Via CTS	To characterize the performance of newly-developed digital communications equipment.
33	2/78-1/79	CTS 11.7 GHz Propagation Measurements	To measure satellite-to-earth rain attenuation.

SUMMARY

As the Communications Technology Satellite project began on April 20, 1971, one of the service oriented objectives was to conduct satellite communications systems experiments using the 12 and 14 GHz bands and low-cost transportable ground terminals.

As we look back on the CTS communication experiments, we must conclude that the CTS/Hermes project was a success. The CTS experiments provided a wealth of technical data relating to the management and operation of communications spacecraft. The knowledge gained is being used daily and has helped to create one of the country's newest and fastest growth industries--satellite communications.

The satellite industry would not be experiencing this rapid growth were it not for the users, and it is in this area, "user development", that the CTS/Hermes project made perhaps its greatest contribution. There were 35 proposed and approved experiments, of which 20 experiments were completed; additionally there were 146 demonstrations and 63 events proposed and approved. Each of these maxi or mini communications projects touched new user groups and demonstrated to the various publics involved the feasibility and cost effectiveness of satellite communications. Many of the CTS users moved directly from being a CTS Experimenter to being a commercial satellite user. Hundreds of persons involved in CTS experiments are now engineers, technicians, program developers, teleconference specialists, etc., in this new industry. New job descriptions are emerging and a whole new vocabulary has come into being as a result of the satellite industry.

Among the many CTS experimenters, there were many successes and many frustrations, and each experiment or mini-event added to the growing body of knowledge and created new user groups. It is unfortunate that many well-planned experiments were not funded and therefore did not get their programs on the spacecraft. These experiments would have added substantially to the body of knowledge and created additional groups of users.

One Experimenter, The Public Service Satellite Consortium, continued to work with public service groups in the development of satellite communications. Over 50 percent of the public service groups that participated with PSSC in CTS Experiment 21, have arranged for domestic satellite usage on an occasional or continuing use basis.

NASA's CTS program provided the economic and psychological support for many organizations to become satellite users. Many of these [illegible]nizations would not have ventured into satellite communications on th[illegible] The CTS program has proven that satellites are viable and an economically cost effective means of addressing many of our societal needs. The CTS program in the United States, and the companion Hermes program in Canada, have already had a positive effect on the quality of life on the North American continent, and, as satellite technology continues to expand, the contributions made by the CTS/Hermes program will become even more significant.