The Use of Satellites in Broadcasting

Since the 1974 Toronto Conference Session on the above subject was reported in the previous, February 1975, issue of the *Journal*, along with two papers from the Session, the following group of four papers has been released in final publication form with special cooperation of the authors. For a full description of the ATS-6 Spacecraft, readers are directed to the paper "ATS-6 Spacecraft Design/Performance" by William N. Redisch of NASA/GSFC and Ralph L. Hall of Fairchild Industries. It is available as paper No. 44, pp. 44, 44A–44G, *Conference Record of EASCON '74*, from Single Copy Sales, Institute of Electrical and Electronics Engineers, 444 Hoes Lane, Piscataway, NJ 08854.—Edit.

Investigation of the Applications of Advanced Communications Satellites

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An experimental communications satellite will be launched later this year to flight-test various subsystems and to investigate the applications throughout society. By agreement in 1971 between Canadian and U.S.A. agencies, Canada is responsible for designing and building the spacecraft and the U.S.A. for supplying the high-power traveling-wave tube, launch vehicle and environmental test and operational support. The investigation will (1) flight-test and evaluate a traveling-wave tube with an efficiency greater than 50% and a saturated power output of 200 W at a frequency of 12 GHz; (2) flight-test a lightweight extendible solar array with an initial power output greater than 1 kW; (3) flight-test a 3-axis stabilization system; and (4) experiment with the use of the 12- and 14-GHz bands. Almost a score of agencies, universities and hospitals will participate in this experiment.

The Communications Technology Satellite (CTS) (Fig. 1) is an experimental communications satellite that is due to be launched in late 1975. It is being developed jointly by the Canadian Department of Communications and the U.S. National Aeronautics and Space Administration (NASA) under an agreement between Canada and the U.S. signed in 1971. The agreement provides for Canada to design and build the spacecraft and for the U.S. to furnish the high-power traveling-wave tube (TWT) and associated power conditioning and thermal control, the launch vehicle, and environmental test and operational support. The use of the satellite for technological and communications experiments will be shared equally between the two countries. Subsequently the European Space Research Organization (ESRO) became a participant under an agreement with Canada to provide certain spacecraft components including a 20-W TWT, a parametric amplifier (paramp) and development of the solar array blankets.

CTS responds to the increasing need to develop the additional channel capacity for satellite communications and broadcasting allocated by the International Telecommunication Union at the World Administrative Radio Conference on Space Telecommunications in 1971. The 12- and 14-GHz frequency bands offer some considerable advantages over the present 4- and 6-GHz frequency bands, particularly in areas of North America and Europe where terrestrial systems are developed extensively. There are no power flux density limitations imposed on the use of the 12-GHz band, permitting the use of earth stations having smaller antennas. Also, because of the absence of terrestrial services in the band, there is no difficulty in the coordination of the locations of transmitting and receiving earth stations. This should allow earth stations to be located in major population centers.

The principal technological objectives of the CTS program are:

(1) to develop and flight-test a traveling-wave tube having an efficiency greater than 50% and a saturated power output of 200 W at a frequency of 12 GHz;

(2) to develop and flight-test a lightweight extendible solar array with an initial power output greater than 1 kW;

(3) to develop and flight-test a 3-axis stabilization system to maintain accurate antenna boresight positioning on a spacecraft having large flexible appendages; and

(4) to conduct satellite communication systems experiments using the 12- and 14-GHz bands.

There are thus two aspects to this program. The first involves the design, construction and launch of a satellite to flight-test various subsystems which will be needed to satisfy the future requirements for satellite communications and broadcasting systems operating in the 12- and 14-GHz bands. The second aspect is the development and coordination of an integrated program of communications experiments to be carried out using the Communications Technology Satellite. These experiments will permit investigation not only of the applications of new technology to communications problems but also of the social, cultural and economic impact of the eventual introduction of services

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that can be provided. These two aspects will be dealt with in turn in the following sections.

Spacecraft Description and Mission (Table I)

The satellite will be launched in late 1975 by a Delta 2914 vehicle into a near-geostationary orbit above the equator at 116°W longitude. The spacecraft will be maintained on station in the east-west direction to better than ±0.2°. It will not be capable of north-south orbital correction but the inclination of the satellite will be less than 0.65° for most of its nominal two-year life.

To generate the power required for spacecraft operation, two large extendible and flexible sails carrying the solar cells are mounted on the spacecraft body, the length of each sail (6.5 m) being over three times the diameter of the spacecraft body. The power which will be available initially from the solar arrays is 1,260 W. Because it is necessary to keep the solar arrays facing the sun and the spacecraft antennas mounted on the body facing the earth, the satellite will be three-axis stabilized on-station and have an on-board attitude control system.

Launch weight of the spacecraft will be about 680 kg; in-orbit weight will be approximately 350 kg.

Communications Subsystem

The spacecraft transponder will provide two RF channels which have a bandwidth of 85 MHz and are separated by 110 MHz. There are two communications antennas of 2½° half-power beamwidth which can be directed, with an error of less than 0.2°, to any position on the earth within line-of-sight of the spacecraft. Each antenna is capable of simultaneous reception of signals in the 14-GHz frequency band and transmission in the 12-GHz frequency band. One channel gives 200 W of transmit power, the other one close to 20 W. A redundant 20 W traveling-wave tube is provided. There are two receive front ends, one a tunnel diode amplifier and the other a parametric amplifier.

Typical coverage areas of the spacecraft antennas corresponding to different boresight positions are shown in Fig. 2. The inner contours illustrate the reduction in coverage due to pointing errors arising from inaccuracies in attitude control and station keeping. The line-of-sight horizon and 5° elevation contour are also indicated.

The transponder design will permit several types of experiment to be carried out, including:

(*1*) *TV Broadcast:* TV broadcast to small communities in remote areas.

(*2*) *TV Remote Transmission:* TV transmission using a transportable terminal of special events from a remote region to a central area for network distribution or for retransmission to other remote regions.

(*3*) *Sound Broadcast:* Broadcast of radio program material to small earth stations.

(*4*) *Two-Way Voice:* Telephony service including voice, facsimile and data, to and between small transportable earth stations.

(*5*) *Digital Communications:* (a) digital data transmission and exchange; (b) investigation of high-speed satellite data transmission; and (c) investigation of time division multiple access (TDMA) techniques.

In combination with a voice or data return channel, the television broadcast capability may be used to provide a video information retrieval capability or, in conjunction with two-way voice, to provide interactive instructional television. Depending on the selection and design of terminals, two-way video or video teleconferencing may be possible.

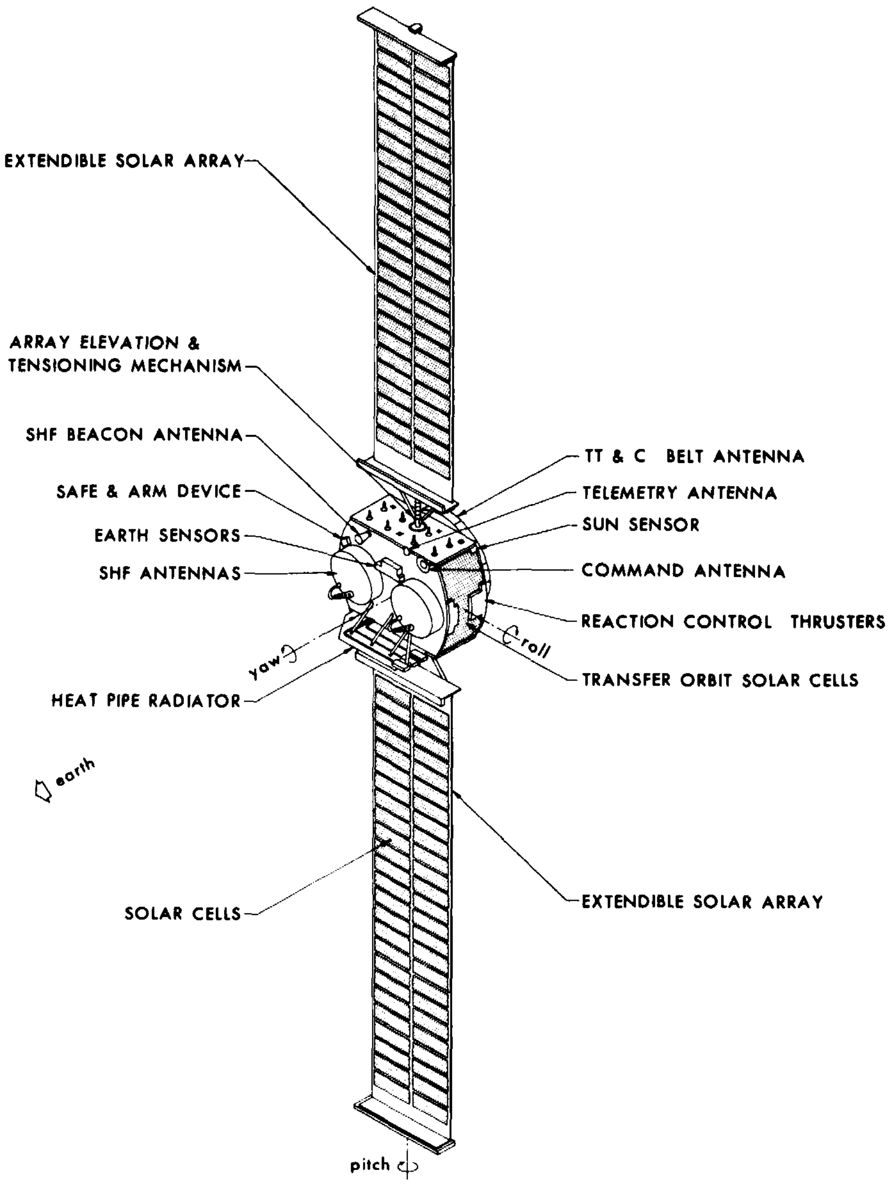

Fig. 1. The Communications Technology Satellite.

Earth Stations

CTS is an experimental satellite and many of the communications experiments involve more than the simple reception of television signals. Therefore, while the terminals to be used in the experimental CTS program for transmission and reception are not necessarily expected to be low cost, CTS, with an effective radiated power two orders of magnitude greater than existing communications satellites, will be the predecessor of operational 12-GHz systems for direct broadcasting from satellites to small low-cost earth stations.

The Canadian earth stations to be used in the communications experiments will be procured and owned by the Department of Communications. They will be built, to the greatest extent pos-

Table I. Communications Technology Satellite Characteristics.

Launch Vehicle	Thor Delta
Satellite Orbit	Geostationary, 116°W
Stabilization	3-axis, on-station
Primary Power	Flexible solar array 1.3-kW (beginning of life)
Receive Frequency	(1) 14.205 – 14.290 GHz (2) 14.010 – 14.095 GHz
Transmit Frequency	(1) 12.038 – 12.123 GHz (2) 11.843 – 11.928 GHz
Spacecraft Antennas	2 2-axis gimballed reflectors 2½° circular beamwidth Linear orthogonal polarization
Transmitters	(1) 200-W high-efficiency TWT (2) 20-W TWT (with redundancy)
Receivers	System noise temperature (a) <1,000 K with paramp (b) <2,000 K with TDA
Beacon	11.7-GHz, Righthand circular polarization, 200-mW RF power

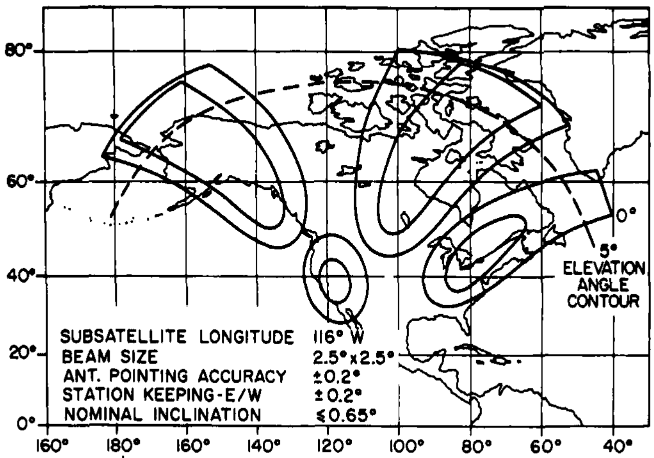

Fig. 2. Typical coverage areas of the spacecraft antennas.

sible, by Canadian industry. Information on the planned terminals is summarized in Table II. The Communications Control Terminal is located at Ottawa and uses a 9-m high-precision antenna. It can, of course, perform any of the functions already described but is primarily intended for television broadcast to remote communities or as a network control terminal for multiple-access two-way voice experiments.

The Remote Transmission Terminal will have the capability to transmit a network-quality television signal from a remote location to the main earth station at Ottawa or a lower-quality picture directly to the community television receive stations. In addition these terminals, which will have an antenna 3 m in diameter, can be used for the reception of television, for two-way voice and time-division multiple access experiments and for network control. The Remote Transmission Terminal will be transportable by road, rail and, with some limitations, by air.

The 2-m television receive stations are capable of receiving an excellent-quality television signal (with a luminance signal-to-noise ratio of 46 dB peak-to-peak video to weighted rms noise, and an audio test tone-to-noise ratio of 50 dB) with the satellite transponder operating at 100-W output power. Even this performance could be improved, or the antenna diameter decreased, if cheap, rugged and reliable 12-GHz uncooled parameteric amplifiers become available. The 2-m antennas will also be equipped for two-way voice; this channel can be used for exchange of voice or data for interactive educational television.

One-meter diameter antennas will provide a telephone quality two-way voice link with the 9-m Communications Control Terminal or 3-m Remote Transmission Terminal. A two-way voice circuit between two 1-m earth stations will require a double hop via the 9-m or 3-m earth stations.

Because of the slight diurnal variation in satellite position which arises from the lack of north-south station keeping, it will be necessary for highly directional earth stations to follow the satellite motion. Thus, while the 1-m antenna will be fixed, some sort of manual adjustment will be required for the 2-m antenna. Step-track will be provided for the 3-m antenna and autotrack for the 9-m antenna.

It is planned to purchase two 3-m transportable transmission terminals and seven each of the 2-m and 1-m earth stations.

Canadian Communications Experiments

As stated previously, the Communications Technology Satellite is intended to permit investigation not only of the applications of new technology to communications problems but also of the social, cultural and economic impact of the eventual introduction of such services. Because the data to be derived from the communications experiments program will contribute to the planning of future systems, it was decided early that users should participate with the Department of Communications in the planning, organization, implementation and evaluation of the experiments.

Invitations to submit proposals for communications experiments were sent out to various Canadian organizations and a Committee, the CTS Communications Experimenters' Committee, was set up to promote the exchange of information amongst the various experimenters and the Department. In addition, an independent Evaluation Committee, consisting of three distinguished scientists from different disciplines, was established to review all proposals and to make recommendations to the Minister of Communications concerning the experiments which would be considered to merit support in terms of satellite time, earth stations and intellectual resources.

Table II. Summary of Planned Canadian SHF Terminal Characteristics (12 to 14 GHz).

	Properties							
	Antenna			Receiver				
Terminal	Min. diam. (m)	Peak gain (dB) (12 GHz)	3-dB beam-width (°)	Type	System noise temp. (K)	Fig. of merit (G/T, dB/K)	Max. trans. power (W)	Antenna control
Control (Ottawa)	9	58	0.2	Uncooled paramp	425	32.8	Up to 300	Autotrack
TV Remote Transmission	3	49	0.5	Uncooled paramp	425	19.5	Up to 1,000	Steptrack
TV Receive Only & Two-Way Voice	2	47	0.7	TDA	1,150	16.5	20	Manual adjustment
Two-Way Voice	1	37	1.8	TDA	1,150	7.8	20	Non-tracking

Proposals were received from many organizations which included Federal government departments and agencies, provincial governments and educational authorities, industry and native associations. The proposals from about 20 organizations were recommended for support by the Evaluation Committee and accepted by the Department. These proposals, listed in Table III, relate generally to the use of satellites for medical and educational purposes, community development, data communications, and technology (including multiple access, broadcasting and propagation).

To illustrate more clearly the nature of the proposals, a brief description of some of them appears to be in order. The Newfoundland Communications Technology Committee has proposed an experiment to transmit a number of television medical programs by satellite to practicing physicians in isolated areas and to utilize audio feedback to increase their participation. The interest of the physicians and the knowledge gained will be compared with the results achieved using videotape and special short courses. The experiment will involve physicians in three or four isolated communities. The Newfoundland Committee also plans to investigate the use of the satellite for community development programs. This experiment will study the effects of introducing satellite communication into the existing development programs of the Extension Department of Memorial University. These programs are currently conducted using videotape.

The experiment proposed jointly by Carleton University in Canada, Stanford University and the NASA Ames Research Center will examine the use of the satellite in the sharing of curriculum material in real time between widely separated universities. The transmissions will employ a digital video compression technique and efficient channel coding and modulation. The experiment will permit the development and evaluation of a variety of techniques for presentation of material, feedback of response and strategies for resolving associated problems.

The University of Western Ontario in London, Ontario, under contract to the Federal Department of National Health and Welfare, now sends medical consultants on a regular basis to visit the government hospital located in a remote community in Northern Ontario. The University is undertaking an experiment to evaluate the use of a satellite video link to permit remote consultation from a large medical center. They also propose to experiment using voice links between the remote hospital and isolated Indian villages to enable a visiting nurse to transmit diagnostic information for immediate analysis. The diagnostic information will include, for example, ultrasonic images to permit early recognition of possible complications in pregnancy. In this way, the University will be able to investigate the use of satellites in health care delivery to forestall the need for later emergency decisions.

In another experiment, the Alberta Native Communications Society (ANCS) plan to supplement their present program of radio broadcasts, a native newspaper and films for Indians in the Province of Alberta with satellite video transmission. Their goal is to establish viable and effective interactive communication techniques, primarily with Native People in remote and isolated northern regions of the Province. The experiments will assist the Society to determine the most effective communications techniques to use after the experiment is completed. The Society will have from three to five communities involved in the experiment.

Table III. CTS Experimenters.

Communications Research Centre	Propagation, TDMA, demand assignment, high-rate data, small-terminal evaluation
Canadian Broadcasting Corp.	Signal reception in metropolitan environments, applications of radio broadcasting, TV special demonstration
Newfoundland Communications Technology Committee	Community interaction, telemedicine
Province of Quebec	Telemedicine, education, administration
Government of Ontario	Multi-ministry administrative and operational experiments
Prov. of Manitoba, Management Committee of Cabinet	Government teleprocessing network
Carleton U/Stanford U/NASA ARC	Digital video curriculum sharing
Queen's University	Train location
University of Toronto	Very long baseline interferometry
McMaster University	Digital modems for high-rate data
University of Western Ontario	CAI in native languages
University of Western Ontario	Telemedicine
University of Waterloo	Signal processing techniques for data communications
Lakehead University	Upgrading mathematical competence of elementary school teachers
University of Saskatchewan/Quebec	Cultural exchange
Bell Canada/Telesat	Transportable terminals
Queen Charlotte Islands General Hosp.	Health care delivery to remote areas
Alberta Native Communications Society (ANCS)	Communications in native communities

Concluding Remarks

Because of the large number of proposals, and the limited available resources of satellite time and communications earth terminals, the accommodation of the various experiments represents a difficult task. The development of an integrated experimental plan for optimum use of the satellite necessitates continual interaction amongst experimenters and with the Department.

In spite of the many uncertainties in an undertaking of this nature, the widespread interest and the willingness of the experimenters to make substantial commitments to the program clearly reflect the social, cultural and economic needs in Canada for the various services that could be provided by future satellite communications systems of this type.