SATELLITE SYSTEMS MANAGEMENT UNDER SEPARATE OWNERSHIP OF SPACE AND GROUND SEGMENTS OF THE CANADIAN DOMESTIC SATELLITE SYSTEM

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Attachments,

Attachment 1. Operating Experience in the Canadian Domestic Satellite System.

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AIAA 78 San Diego

Attachment 11. Systems Aspects of the Initial Telesat Thin Route Satellite Communications Systems
P.Rossiter ICC 73 Seattle

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1.0 Introduction

The engineering and operational management of the Canadian Domestic Satellite System by Telesat Canada has evolved from the concepts postulated by the original Government-sponsored Project Office (pre 1969) to the currently well defined and mature management structure in place today. This management structure has been developed to meet the relatively slow growth of communications services delivered via satellite in Canada and the corresponding low number of earth stations in place today. It has also been structured on the basis of continued sole ownership of the space and ground segments of the system.

In November 1977, the Minister of Communications issued a statement in respect of an Order-in-Council to vary CRTC Decision 77-10 and to approve a proposed agreement for membership by Telesat Canada in the Trans Canada Telephone System. That statement indicated

a) that the "long standing policy of Telesat to lease only complete channels on its satellites should now be revised."

b) that the Government should "review the matter of ownership of satellite earth stations, to identify instances where non-Telesat ownership could be in the public interest."

This study is concerned with the changes which would occur in the Systems Management and the impact on Systems Integrity should the current policy considerations result in separate ownership of the Space and Ground Segments.

The study therefore

- describes the existing Satellite System Management structure in place today;
- describes and comments on its evolution;
- examines the impact on Systems Management and Integrity should separate ownership of space and ground segment arise;
- comments on the advantages and disadvantages of such new policy;
- provides some recommendations to assist policy making.

The advantages and disadvantages are examined from the viewpoint of the Government's objective of "encouraging fullest access to new satellite services."

2.0 Evolution of the Existing System Management Structure

2.1 General

Before describing the existing systems management structure, it is important to consider the various factors which influenced its evolution; to consider the system which is currently being managed and to comment on other technological developments which might considerably affect the future systems management structure.

2.2 Major Factors Contributing in Systems Management Evolution

In 1969, The Canadian Domestic Satellite Project Office were working towards a satellite system to operate in the 4/6 GHz band to serve the North. Traffic planning had determined a need for a satellite with six transponders:

- three for CBC Television
- two for telephone traffic
- one spare.

The contractor selected for the satellite, Hughes Aircraft Company, offered a satellite of:

- twelve channels
- longer lifetime
- improved guarantees
- significantly lower cost.

The offer was accepted by Telesat. It was too good to refuse by a commercial Company whose whole future as a viable operating entity rested in making a mature decision on the first procurement of the major system component.

By early 1973, service was started to the North generally in line with the initial plan which was to use five transponders (three for TV and two for message). In addition, two channels were utilized to effect a high capacity message link from essentially Toronto to Vancouver, and one channel was used to effect a two access message service from the Atlantic cable terminal in Nova Scotia (via Harrietsfield) to Ontario (via Allan Park). These additional services could not have been effected had a six transponder satellite been procured as planned.

It is well known that neither of these two services (the EW message and the Telesat TDMA Service) is competitive with conventional terrestrial technology and they have inflexible service features which prevent optimal network integration.

The system implementation then proceeded so that by 1975, there existed three in-flight satellites with a total of 36 channels still only serving the same market as the six channel satellite initially conceived by the Project Planning Office in 1969. This gross over-capacity, together with the "whole channel" and "sole ownership" policy, influenced the system development in several ways.

1. It provided no real incentive to develop efficient communications techniques which could result in savings to be passed through to the end user.

2. The resulting high cost per channel placed the service outside the reach of potential users.

3. The lack of potential market accentuated the need to keep the cost to existing users as high as possible to ensure even a modest return on investment by Telesat.

It should be noted that these policies have been such as to simplify systems management and maintain equal service tariffs to a small number of institutional customers. The fact that they have inhibited access to the satellite system and suppressed innovation is a reality and a consequence of the policies - not a reason for them.

Thus the System Management Structure of Telesat has been developed in an environment where there exists:

a) a gross oversupply of transponder capacity;

b) a low demand for service;

c) the need to interface only with large institutional customers.

This monopolistic and protected environment clearly must impact on the style and approach of Systems Management which has evolved. That it has, can be no surprise.

2.3 Telesat Systems Management - Current Systems Responsibilities

2.3.1 Existing Operational System

The current system now operational consists of three Anik spacecraft, each of twelve transponders, and a number of earth stations of which some 88 are deployed in fixed locations serving one or more customers and others, of a transportable nature, are reserved for occasional use.

It is to be noted that Telesat have only a few customers - these being:

1. Canadian Broadcasting Corporation - which currently serves 64 locations with Radio Program and/or Television Service.

2. Bell Canada - which uses two transponders to provide public message service via satellite in its territory to 33 communities. Bell Canada provides private service to other customers such as Nanisivik Mines, Imperial Oil, James Bay Corporation etc. A special service to the U.S. Air Force from Hall Beach to an earth station owned and operated in the U.S.A. by others has recently been initiated.

3. Trans Canada Telephone System - which uses two satellite transponders to provide 960 voice channels (duplex) between Vancouver and Toronto.

4. Teleglobe Canada - which uses one transponder to carry 400 duplex channels in a unique TDMA System from Harrietsfield (near the Atlantic Cable Terminal) to Allan Park (near Toronto).

5. Canadian National Telecommunications - which sub-leases a partial transponder from Bell Canada and leases earth station service from Telesat to extend public message service to Sachs Harbour, Holman Island and Snowdrift in the North West Territories.

2.3.2 Developing Satellite Systems - Responsibilities

Near term implementation programs involving the Systems Management staff include:

a) The engineering, management and putting into service of the Anik 'B' satellite. The major single customer for this satellite is the Department of Communications.

b) The development and design of the Anik 'C' system which will largely serve member companies of TCTS and which will represent the second Canadian operational satellite system. This satellite system will not serve the North because of technical limitations on coverage.

2.3.3 Consulting Engineering

In addition to the responsibilities in current and planned systems to maintain and extend service, Telesat also competes for consulting work in Canada and sometimes overseas.

2.3.4 Summary of Existing Telesat Systems Management Responsibilities

The existing technical staff of Telesat Canada have systems management responsibilities concerned with:

a) Maintenance of the existing system

b) Planning and implementation of new systems

c) Consulting engineering activities to external clients.

3.0 Telesat Existing Systems Management Functions

*3.1 General

"As of January 1978, approximately 350 persons, mainly scientific and technical personnel, were employed by Telesat Canada. About 60 people work at our heavy route earth stations at Allan Park, Ontario and Lake Cowichan, British Columbia, both manned 24 hours a day. Smaller manned stations are Harrietsfield, Nova Scotia and Frobisher Bay, Northwest Territories. The remainder of the staff are located at our Head Office in Ottawa, Ontario."

The scientific and technical personnel undertake the responsibilities for maintaining existing and planning and implementing new services and facilities, and are spread over three functional areas of the company -

- i) Planning and Marketing
- ii) Engineering
- iii) Operations.

3.2 Planning and Marketing

There has been little accent in the Planning and Marketing function in the last year or so as the TCTS Agreement was implemented and it seems clear that this

*Quote from Telesat Brochure

function has become more the responsibility of the Engineering and Operations Team.

3.3 Systems Operation and Maintenance

Systems operation and maintenance of the Telesat system is managed from Ottawa. The management structure has been designed to ensure that the high grade of service contracted for can be achieved on a day-to-day basis. It should be noted that of the 88 Telesat earth stations, only two are staffed on a round the clock basis while two others are staffed on a work day only, plus call out basis. The system has been designed to minimize maintenance staffing.

Possibly the most difficult part of achieving the high serviceability standards is the long lead times to repair created by the wide geographical service area covered by Telesat. Much effort has been put into this problem area and a sophisticated and effective reporting and control system has been developed to shorten the mean time to repair. Additionally, where possible, Telesat have contracted maintenance to local agents in remote locations and in some cases to their customers. For example, the maintenance of the Thin Route earth stations in North

West Ontario is carried out by telephone company maintenance staff. Mr. Jack Crawford's Paper "Operating Experience in the Canadian Domestic Satellite System" is reproduced as Attachment 1 and provides a complete description of the Telesat Operations System Management and comments on some typical problems encountered and solutions raised in the first five years of operational experience.

The management structure and operating procedures have evolved gracefully over this first five years to meet the growing number of facilities and to adapt to perceived changes in equipment serviceability performance. It is estimated that of the 350 persons employed by Telesat that about 70-80 are management or technical personnel essential for the day to day operation of the space and ground system. Of the some 70 or so day to day maintenance technician effort, possibly some 20 are associated with the space segment only.

3.4 Engineering Management - Overall

The engineering functions in Telesat are executed in three specific technical areas:

a) Satellite Control Directorate - concerned with effecting the engineering for new launches and supporting the Operational Satellite Control Team.

b) Spacecraft Engineering Directorate - concerned with the design of new spacecraft to meet developing service requirements and maintenance support to day-to-day operations.

c) Communications Systems Directorate - concerned with the systems design, ground facilities design and implementation of communications facilities and maintenance support to the operational system.

In the context of this study the Spacecraft Engineering and Communications Systems Engineering are the areas likely to be affected by any change in the policies of ownership now being considered.

3.5 Spacecraft Engineering Directorate - Current Activity

The current activity of the Spacecraft Engineering activity is focussed on:

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a) The implementation of Anik 'B' due to be launched in November 1978.

b) The execution of the Anik 'C' program for which a contract has just been placed.

c) The definition of the Anik 'D' spacecraft which will be used to serve the North at 6/4 GHz.

This is undoubtedly the most complex work package being undertaken by any satellite operating company in the world in regards to operational spacecraft deployment. The weighting in systems management terms given to the technical complexity and the consequent high investment implicit in this work package may represent a major reason for the gross oversupply of transponders and the difficulty that users have in "gaining fullest access to satellite services". This theme is further developed in the Recommendations.

3.6 Communications Systems Directorate

This Directorate is responsible for

- New systems development
- Implementation of Facilities
- Improvements to existing facilities and support to Operations.

The Director has two major groups reporting to him:

i) Systems Engineering

ii) Earth Station Engineering.

The development and implementation of new services and facilities is the prime responsibility of the Director of Communications Systems. Such development is pursued as existing customers' needs arise or new customers' requirements are identified and delineated.

If a new requirement or service need arises which has not previously been implemented, the system is examined in detail and solutions proposed by the Systems Engineering Department usually in close collaboration with the Earth Station Engineering Department. The Systems Engineering Department is also responsible for site coordination and licensing with the Department of Communications.

The system is then refined and a proposal made to the customer in terms of:

a) Service; including channel performance, availability of service, service features, etc..

b) Schedule

c) Annual Cost

d) Special responsibilities of customers.

Other groups within Telesat contribute to the preparation and presentation of items c) and d).

If the customer accepts, then a detailed specification for the facilities is prepared by the Communications Systems Division and issued to suppliers-on a competitive basis usually.

The facilities implementation is the responsibility of the Earth Station Engineering Group. Depending on the type and complexity of the job, a special project team may be formed to ensure an effective project implementation.

4.0 Impact on Existing Systems Management Function

4.1 General

We have commented on how the system management structure evolved and was affected by the acquisition of a satellite of double the initially planned capacity in an environment of low demand and rigid institutional controls. These controls include the decision not to lease partial channels and the monopoly ownership of space and ground segments of the system. This section will examine the impact on the existing system management and system integrity in the event that these major policy aspects are revised.

In particular, we will address the differences in system management created in the areas of:

- Service Standards
- System Management and Control
- Network Evolution.

4.2 Service Standards

The service standards currently in use were agreed mutually between Telesat and its customers. This is a most important aspect. It follows normal practice of the customer making a request for service; Telesat making a proposal; and the normal negotiations on performance, service features, price, duration of service, start of service, etc. being mutually pursued until a Service Agreement is signed.

4.2.1 Television Service Standards

4.2.1.1 Telesat - CBC Service Standards

The initial service agreements between Telesat and the Canadian Broadcasting Corporation called for two television quality standards

- one described as Network TV
- the other described as Remote TV.

In terms of video quality performance specifications

- signal amplitude and stability
- signal to noise ratio
- hum
- baseband frequency response
- field time and line time waveform distortion
- differential gain and phase
- service availability

the two service standards were similar to each other and also to the normal standards requested by CBC from common carriers with two major exceptions. This first exception is that the received signal to noise requirement at remote locations was dropped to not less than 48 dB, and that was expected to be achieved for not less than 99 per cent of the time for any month. The service availability requirement for remote television was also relaxed from the Network TV requirement of 99.98 per cent of the time to 99.2 per cent of the time.

Both of these exceptions were specifically agreed to permit a more cost effective remote station design. The resultant earth station design, therefore, required a lower G/T (which was obtained by reducing the antenna size to 26.5 feet from the larger NTV earth station of 33 ft.) and employed no equipment back up.

Both the Network TV and Remote TV stations exceeded all of the specifications of the service contract at acceptance and have continued to do so over a prolonged period.* Subsequently a slightly lower service standard was introduced called "Frontier TV". This service employs a slightly lower service performance in terms of video and audio signal to noise ratios and service availability.

This offering also has no frequency agility of the receiver.

4.2.1.2 Telesat - Private Broadcasting Service Standards

It has been noted that service standards are usually set and agreed between Telesat and its customers. If

* Measured Communication Performance of the Telesat Satellite System by D.E.Weese and F.H. Smart, AIAA 197·

other than Telesat were permitted to own and operate earth stations to receive the existing CBC service, then they might prefer to construct an earth terminal with different service standards from those common in the broadcasting and common carrier environment.

Such a station might provide a lower service quality (signal to noise) and possibly a higher availability than the Frontier TV offering by Telesat. In essence, the service standard could be set by the user.

If a broadcaster, other than the CBC, were to own and operate an earth station using the Telesat System, then a completely different set of scenarios may be anticipated, arising from the fact that he has:

- a choice of satellites (Anik 'C' or Anik 'A', 'B' or 'D') on which to develop service
- the ability to design a least-cost-to-the-user system by trading earth station performance for satellite resource usage
- no constraints on him imposed by the need to consider an existing operational distribution system where the ground segment is currently owned by Telesat (as is the case in the existing CBC service distribution by satellite).

Regarding service standards, he might well wish to consider a completely different set of service standards than has been traditionally negotiated between broadcasters and common carriers.

If a broadcaster were to determine service standards to meet his need in a satellite environment, then he would concentrate on developing a system to reduce his overall distribution costs. There are many tradeoffs yet to be made in the chain of camera to home T.V. set that can be made by a private broadcaster to reduce his delivery costs. These tradeoffs are difficult to implement without control of the overall distribution system design.

4.2.1.3 Telesat - Cable Television Service Standards

The service standards in the Cable Television industry are significantly lower than those deemed acceptable by, say, CBC. This industry already has performed significant system tradeoffs and shown great ingenuity in the design of multichannel delivery systems which have been well accepted by the paying public.

4.2.1.4 Impact of Television Service Standards on Systems Management

The TV service standards currently in use were agreed between Telesat and the Canadian Broadcasting Corporation prior to the launch of Anik 'A'. These standards were similar to those in being for many years in CBC - common carrier service agreements.

If, by diversified ownership of space and ground segment, more broadcast signals were to be carried by satellite, then there exists the prospect of some broadcaster taking a hard look at system tradeoffs to reduce the cost of the total delivery system from camera/tape/film to the viewer's screen. If a high component of this cost is the satellite transmission path from earth station to earth station, then an exercise in developing standards conducive to delivering an acceptable service to the viewer at a lower cost to the user than might exist by the retention of the existing institutional ownership of the elements of the national distribution system could be rewarding from the user's viewpoint. A consequence of such an exercise might be greater utilization of the satellite system by broadcasters and an increased number of user services. It is to be noted that such an exercise is not within the mandate of Telesat and possibly not in their commercial interest. We, therefore, assume that it could be done by a broadcaster or others with a public interest viewpoint.

The impact of a major revision in service standards on the existing systems management might be:

- increased involvement by Telesat system engineering staff in reviewing any new service standards to ensure that such new standards are developed in Telesat's best interest;

- if new standards are developed, then new system design, operating procedures and possibly testing techniques might have to be developed by Telesat in collaboration with others.

- increased involvement by Telesat in the development of a new style of service agreement concentrating on the protection of space sector and Telesat's commitment to maintain space segment.

However, it seems unlikely that any commercial broadcaster would see any reward in contemplating a major revision in service standards to improve access to or utilization of the satellite system, unless Telesat showed a willingness to participate in an exercise aimed at reducing space sector utilisation and cost.

4.2.2 Telephone Service Standards

4.2.2.1 Voice Channel Service Standards

In the existing Telesat delivery system there are several voice channel service standards in effect such as:

1. That standard necessary to effect a satisfactory means of connecting from the Atlantic Cable to Ontario whilst still maintaining acceptable international circuit performance. This service is carried for Teleglobe Canada and is a very demanding and unusual service standard.

2. That standard necessary to carry high density FDM voice channels from Toronto to Vancouver. This service is similar to Trans Canada Guidelines for voice channel performance. This service is carried for Trans Canada Telephone Systems.

3. That standard necessary to permit acceptable telephone service to remote northern communities.

4. That standard agreed for the developing service to be carried by high speed digital means in the Anik 'C' era.

Regarding the Thin Route Northern Service* to remote communities, there are two basic features which control and limit the voice service:

a) that all north to north service must be double hopped via an Ottawa operator;

b) that the voice encoding is largely delta modulation which provides a different voice quality from either conventional PCM or analog transmission means.

4.2.2.2 Impact on Systems Management

If access to and utilization of the satellite system is to be improved, then it seems reasonable to assume

*P. Rossiter, "Systems Aspects of the Initial Telesat Thin Route Satellite Communications System", ICC 1973, Seattle. Attachment 2.

that technical standards in a telephone company environment would remain similar to those in existence today, since these standards have evolved over a long period to service the public need.

If telephone service were to be effected by other than telephone companies to the public, it seems difficult to contemplate how this could be effectively done and public service and system integrity maintained.

If, however, telephone service were to be effected within a private system utilizing the Thin Route System, there seems little doubt that such a service could co-exist with telephone company service but with some impact on existing systems management. This impact would include:

a) the development by Telesat of system management and control procedures to protect other users' service and ensure efficient use of the satellite.

b) The careful "policing" in service of private users to ensure that they are maintaining agreed technical parameters such as e.i.r.p., bandwidth, modulation format, etc..

c) Some procedure for ensuring adequate equipment standards to ensure continued satisfactory operation of the space sector in terms of e.i.r.p. stability, RF emissions, etc.

The system design, implementation and operation of a multiple access transponder is a most complex operation. It is an operation effectively handled by Intelsat in the context of distributed ownership of earth stations on a daily basis at the expense of elaborate and extensive precautions to ensure satisfactory systems operation.

If private telephone systems were to co-exist in the Telesat Thin Route transponder then possibly a technical planning and management committee similar in concept (but presumably smaller in scale) to that of Intelsat would be an effective method of operation.

4.2.3 Interconnection and System Configuration

For message traffice (voice and data), intending users of satellite service can currently only gain service and interconnection through the telephone companies. If the user were to set up his own system he may have to seek interconnection into the national and international network.

The impact of such a proposal on the existing system management would presumably not be felt for some years, since it is currently a major hurdle to overcome in the existing, well established, national network.

In the case of television distribution service, the interconnection is significantly easier.

In the case of the Canadian Broadcasting Corporation (currently the largest user of satellite service), well developed technical and institution structures are in place. Interconnection is not a problem.

In the case of new broadcasting users of the Canadian satellite, then he has a wealth of choices:

- he can distribute from urban locations via Anik 'C' on a regional and national basis;
- he can utilize the existing 4/6 GHz satellite system plus terrestrial backhaul.

The multitude of choices may have a significant impact on the existing system management, since it will now have to consider requests from broadcasters with a large number of service options, thus significantly increasing their workload.

These requests might include:

Space Segment Anik 'C' only

Space Segment Anik 'A' only

Space Segment Anik 'A' and Anik 'C' combined

Total Service from TCTS

Total Service from CN-CP

Variable Number of TV Channels.

In addition, intending broadcasters may be able to sublease say half a transponder from Telesat, TCTS, CN-CP, other users, etc..

4.2.4 Quality and Reliability of Service

Any user instituting either a message or broadcasting service with his own earth station facilities has to make determinations of the quality and reliability of his service.

Such determinations by users may impact on the existing systems management in several ways:

- it could increase the involvement by Telesat communications systems engineers in reviewing user proposals and negotiating service standards, determining system monitoring and control mechanisms, etc.;
- it could involve more network management tasks to ensure service agreement conditions are being maintained;
- it could involve more operational management and possibly sophisticated equipment to ensure day-to-day control of utilization of the space segment.

Currently the service agreements between Telesat and its customers ensure a high standard of system integrity and clearly spell out performance standards. These standards are extremely high as is consistent with the provision of mainly public service.

Any alteration in the quality and reliability standards to reduce cost and thus make access more available, has to be weighed carefully. It has been demonstrated by the Yukon Government that it is possible to reduce signal quality, increase reliability and provide access to a larger number of locations at lower cost without compromising public service. That it can be done in other service areas is beyond doubt.

It is also beyond doubt that these tradeoffs can only be made by others with significant effort from the existing systems management.

4.2.5 Frequency Coordination

There are two aspects of frequency coordination which have to be considered:

a) The development and location of ground facilities to ensure that all terrestrial facilities can co-exist without unacceptable interference.

b) The development of a satisfactory frequency plan on the satellite.

In the event of others locating earth stations, little technical difficulty is foreseen since the methodology is well established for coordinating all radio facilities in Canada. If the user locates his own facility he will simply have to undertake the technical coordination in the normal fashion. This should have little impact on the current systems management. One result of more than Telesat owning ground facilities would be a significant increase in licence applications and frequency coordination activity on a National scale.

The satellite frequency plan could not be established by users and requires no further discussion, except to say that once determined, so it would be expected to remain in effect for a prolonged period (say 10 years) and such would be represented in agreements.

4.2.6 Design and Maintenance Standards

Since 1969, Telesat have developed design standards for earth stations purchased by them to meet the high system performance and equipment availability requirements necessary to achieve and maintain customer service. In many cases manufacturers have developed equipment features and performance specifically to meet only Telesat's requirements. Examples of special designs used by Telesat only include:

- the TDMA system installed at Harrietsfield and Allan Park.

- the single channel per carrier equipment used in the Thin Route stations.

- radio program equipment used to distribute CBC radio to some Northern locations.

- 26.5' earth station antennas.

There are other cases where new equipment designs first developed for Telesat have found application elsewhere.

Examples of "first designs" in Telesat systems applied elsewhere include:

- low noise uncooled parametric amplifiers;
- low noise transistor amplifiers;
- audio subcarrier equipment.

Telesat have also significantly affected design standards throughout North America.

If others are allowed to own earth stations operating in the Telesat system, it is expected that these high design standards would be retained by manufacturers for a relatively short time. This time might be controlled by obsolescence - and earth station equipment has currently a very short "product available" life. It may also be affected by the size and nature of the developing market.

For example, the equipment supplied to the cable T.V. industry does not have the same rigid standards imposed on it as the highly professional class of equipment deployed for ground stations. On the other hand, much of the equipment deployed on ground stations does not have the extensive and exhaustive equipment development usual in high density radio relay equipment.

The purchasers of earth stations then can go to a wide range of manufacturers and contract a wide range of equipment standards from manufacturers who currently:

a) are existing earth station suppliers familiar with the Canadian design requirements evolved during the development of the Telesat System;

b) serve the telephone company with radio equipment which is generally of a higher design standard than earth stations;

c) serve the Cable TV industry which is generally of lower design standards than Telesat designs.

If other than Telesat were to build and operate earth stations, then the standards of designs and quality of equipment may be either higher or lower than that currently in service. Likewise, the standards of maintenance may vary.

Only when a specific proposal for service has been made could the impact on system integrity be established. If public service is proposed, it may be expected that some system of design approval may have to be established as is in operation in many communication areas providing public service.

Design standards which it would be necessary to review are indicated in two categories:

1. Essential to protect space segment utilization such as e.i.r.p. control, frequency control, unwanted emission control, etc..

2. Essential to ensure good received performance
   - availability, maintainability, operability;

   - gain stability, frequency control, etc..

4.2.7 Conclusion on Service Standards Impact

If other than Telesat were to own and operate earth stations, there could be significant variation on how service could be achieved and a consequent large number of possible different systems and equipment deployed. A concern would be the continuation of a high standard of public service.

It cannot be concluded on a blanket basis that service standards would decline. In fact, in many cases they are very likely to improve, especially if the owners of earth stations were competent operating authorities such as CBC, telephone companies and common carriers who already have engineering departments with long experience of system design, setting of standards and ensuring standards are maintained.

An important aspect to consider in the context of service standards is the impact of advancing technology on equipment performance and reliability. Electronic equipment is becoming more reliable with time.

However, without proper regulations and procedures, it could be that system integrity and public service could decline. Due attention therefore would require to be placed on the development of service standards.

The impact on the existing systems management in reaching agreement on different network configurations, quality of service and design standards with a wide variety of intending earth station owners,could be immense especially as the Telesat position is to oppose ownership of earth stations by others (see submission to the Minister of Communications of 10 March 1978, entitled "Earth Station Ownership - The Telesat Canada Position and Recommendations").

It could change the systems management style from one of responding to requests for service to one of merely critiquing detailed service requirements delineated by users who are currently significantly less knowledgeable about the possibilities of service via satellite than Telesat.

In general, the impact may be one of making access to the system even more difficult and laborious than it is now unless an access methodology is carefully spelled out as a guide to intending users of satellite service.

4.3 Systems Management and Control

With others owning ground facilities, the Telesat systems management role would evolve to place more emphasis on the optimum and controlled use of the space segment and possibly providing support to users. The support could include design, planning, implementing and maintaining user-owned facilities.

The impact on the current systems management would be one more controlled by management style and approach rather than an alteration of responsibilities. For instance removal of the burden of network development from Telesat to others might allow Telesat to concentrate on the development of more cost effective satellites to match the perceived needs of an increasing(?) number of users.

However there are two responsibilities which would remain identical:

- Protection of Space Segment
- Administration of the System

4.3.1 Protection of the Space Segment

With others using the system, the current system management activity would have to increase to ensure an orderly and controlled use of the space segment and to ensure continued enjoyment of the resource by all users.

Such increase in utilisation could be accommodated by the development of control procedures and by instituting improved automatic monitoring techniques.

Under diversified ownership there is no technical reason that the space sector would be jeopardized more than expected by the normal increase in traffic providing that proper procedures are established and precautions taken to ensure the competency of users.

There is no reason to believe, therefore, that proper contractional and operational arrangements cannot be made to increase access to the satellites at the same level of technical risk to that which would exist with a Telesat monopoly of facilities. Indeed, this should be an over-riding criterion for the acceptance of a user-owned facility in the system.

4.3.2 Administration of System

With diversified ownership of earth stations, the administration of the system in operational reporting and contractual terms would increase in complexity.

In the case of an existing customer assuming ownership of existing stations or building new stations the impact on the administration should not be great since close working relationships have been established over the first five years of system operation.

Where the user is a new customer, then Telesat's system management would have to adapt to serving this new customer. It may be that administrative complexities may arise as the result of this new customer wishing to initiate a service which is normally wholly or partly provided by an existing Telesat customer.

Such complexities in administration would attract some costs over and above normal costs. The extent of these added costs is probably more a function of management style and approach and would be likely dominated initially by the need or otherwise to hire staff.

4.3.3 Conclusions on Impact on Systems Management and Control

The practices and procedures for Telesat systems management dealing with telephone companies and CBC are well developed. If telephone companies and CBC are permitted to own earth stations, then new procedures of a minor nature will be required to ensure that the system remains well managed. It is concluded that there is no reason to suppose that the integrity of the system or its management would be affected.

If other than the existing major users were to be allowed to own their own earth station, then similar procedures would have to be drawn up to ensure the day-to-day operability of the system. This would be somewhat more complex for new users than for those already familiar with the system.

4.4 Network Evolution

The evolution of the network has developed extremely slowly in the first five years of commercial operation. The evolution of new spacecraft has proceeded at a remarkable pace. The development of new services has been non-existent.

How do/might these factors affect systems management and integrity?

4.4.1 Introduction of New Spacecraft Technology

In the first nine years of existence, Telesat has:

1. Designed a six transponder satellite.

2. Deployed and launched three twelve transponder satellites (Anik 'A').

3. Contracted for a hybrid satellite (Anik 'B') which will be launched this year.

4. Contracted for the Anik 'C' satellites to serve the southern Canadian market.

There is no doubt of Telesat's ability to conceive, design, contract, launch and operate spacecraft to meet the demands of major customers. However, if other than Telesat are permitted to own ground stations, then these users will insist that when they invest in facilities with a useful lifetime of twenty-five or so years, that any spacecraft development will permit them to maintain service without interruption and at an affordable cost.

They will also insist that they be allowed to input into any new spacecraft design to ensure the characteristics of the proposed spacecraft will meet their perceived needs in terms of capacity, performance, cost and timing.

This could be the single most important impact of diversified ownership on Systems Management, i.e. to consider the input of end users in the introduction of new technology.

As an example of how input from users might impact on Telesat systems management, consider what could happen if users had a voice in determining the design of Anik 'D'.

Anik 'D' is presumed to be a spacecraft to provide service primarily to the North at 6/4 GHz. It may be presumed that when Anik 'D' flies in about 1981, that there will be the following users of Anik 'D':

1. CBC - who will be leasing possibly four channels.
2. Bell Canada - who will be leasing possibly two channels.
3. Other earth station owners using services placed on the satellite by CBC, or utilizing Bell Canada's channels.

Assuming owners of category 3 do not have a significant impact on traffic volume, i.e. spacecraft capacity, then it can be seen that CBC might be a 60 per cent user of the satellite.

Normally where a user takes 60 per cent of the capacity of any resource he usually has an impact on how the service is effected so that he can be sure that the resource is being developed in his best interest.

It may be that a large user such as CBC might prefer a satellite of different parameters and design than that being contemplated by Telesat to meet Telesat's assessment of the growing traffic capacity requirements of Canada's North.

It is worthy of note that the other major user of the Telesat system - TCTS - has had a remarkable recent impact on satellite system design to the extent that a completely new and separate satellite system is now being developed to serve TCTS needs in southern Canada.

As a 60% user of the underutilized 6/4 GHz satellite system to serve the North, it may be that CBC might exercise some impact on future 6/4 GHz satellites to ensure their interests are best served. Given earth station ownership CBC would be in an even more powerful position to ensure cost effective satellite service since they would have to engineer systems and facilities.

4.4.2 Network Growth

The development of new services is urgently required if the benfits of satellite communications are to be achieved. The network growth is relatively predictable with existing services and the framework exists under the TCTS/Telesat agreement to plan for such growth.

However, network growth and thus satellite usage, might be improved if earth stations could be owned by others. There may be some chance that users develop innovative ways to provide new telecommunications services. It is far from apparent what these new services might be, but even one of them could have a major effect. Candidates to provide explosive growth include:

1. Video Conferencing
2. Additional TV Services
3. "Electronic Mail"

It is clear that Telesat cannot develop these new services since they are not permitted to provide end-to-end user services. Ownership of earth terminals by others might stimulate the development of new services.

4.4.3 <u>System Optimization</u>

In the first five years of operation of the satellite, system optimization has been a largely theoretical exercise. There is no real need for system optimization if overcapacity exists. In fact, any effort expended often simply adds expense without increasing a return.

If it can be assumed that earth station ownership by others will increase demand and that the reaction to this demand is to find innovative ways to optimize the system other than simply fly a second satellite system (Anik 'C'), then the impact on systems management will be to concentrate on designing more cost effective systems. This may even lead to the design of cost effective satellites which meet the real needs of Canadian telecommunications.

This would be an important reason for allowing others to own their own earth stations.

We should define system optimization as the process whereby one considers how to serve the user with a service which meets his need at the lowest cost to him. This concept has not as yet been extended into the development of the Canadian Satellite System.

4.4.4 Network Evolution - Conclusions

Unless spacecraft technology is developed to meet perceived user demand for existing and new services, it seems the full benefits of satellite communications will not be achieved.

Permitting others to own earth stations, could provide user input into the optimization of the technology. The extent to which this might impact on the systems management is unclear - the fact that it will, is undoubted.

5.0 Commentary on User Categories

This section makes comment on the impact on Systems Management and integrity in the event that specific users are permitted to own their own facilities.

It has been indicated throughout this study that the major effect of permitting others to own facilities is that user requirements might eventually impact on the design and implementation of future satellite systems to be deployed to serve Canadian needs.

The major influences on satellite systems to date has been in the need to ensure the financial viability of Telesat. In the first few years this has been achieved by passing the costs through to the end user via a forced usage of the system by the Canadian Broadcasting Corporation, the regulated common carriers and Teleglobe Canada. Few other users have found the services to have been sufficiently cost attractive to justify using satellites to effect their service requirements.

Over the last few years even services such as the delivery of television where the satellite has a significant advantage have been extended by conventional technologies such as microwave radio, off-air repeaters and cable. Once this investment has been made, this market cannot be competed for by the satellite system for many years to come.

Likewise, high density message service across Canada is being augmented using digital microwave radio; new data services are being developed on the terrestrial network; high frequency radio technology is being developed; new services are being experimented with. All this represents competition or market opportunity to the satellite system.

Despite this, there has been little or no research or development to establish ways and means of optimizing the initial satellite system. What has been done has been relatively ill directed, poorly supported and in the event, ineffective. The institutional route has been once again taken - with the TCTS/Telesat agreement. It is hoped that this route which represents the integration of the satellite system into the National Telephone System will provide at least the economy of scale to efficiently use satellites without passing unduly high costs through to the end user.

Despite the fact that Telesat are now a member company of TCTS, it is understood that they will still provide service directly to a wide variety of user categories and not just serve users through TCTS. Since there are apparently no customers in Canada capable of recovering or justifying the cost of a complete RF Channel on the satellite, the prospect of using a partial channel might be a cost attractive method of developing and extending satellite usage.

This section of the report examines the various user categories and considers the impact on systems management if each of these categories were to design, control and operate their own earth station facilities.

5.1 TCTS Member Companies

In their submissions to the Minister on the question of earth station ownership, all of the telephone company members of TCTS, except Bell Canada, agreed with the current Telesat Canada position.

The position of TCTS member companies is also clearly portrayed in the Memorandum of Agreement between all TCTS members. It is believed that ownership of earth stations by member companies is inevitable if full and effective use of satellites in a telephone company environment is to be achieved.

There is no doubt that Bell Canada (or any other telephone company) could properly plan, design, implement and operate earth stations. Ownership by Bell Canada would not adversely affect systems management or integrity. It would most likely improve it.

Such improvement in public telephone service could arise through Bell Canada's ability to design and operate a complete system. Such design activity could possibly ensure the containment of all service growth within the space sector currently leased by Bell to effect Northern Service. The savings possible through an efficient systems design with Bell effecting channel assignments in the Thin Route transponder could encourage Bell to serve more communities in the North. With the ability to affect overall systems planning the systems utilization could be improved and it might be expected that a more effective system might result than would be possible with Telesat being involved in the development of switching systems in which they have little experience.

5.2 Non TCTS Carriers

Canadian National Telecommunications currently use the Thin Route System to serve Sachs Harbour, Holman Island and Snowdrift in the North West Territories. Shortly this service which previously terminated at the Lake Cowichan, B.C. earth station, will be reconfigured to terminate at Hay River. This indicates an evolution in planning which should provide improved service.

The ownership of earth stations by CN Telecommunications would be a natural evolution which might be expected to lead to improved usage of the satellite facilities. This improved usage could result for the same reasons as in the Bell Canada case - the control of overall systems design.

In the case of Anik 'C', which is essentially a TCTS planned satellite, it is difficult to see how CN-CP for instance, could be involved without the ability to design, implement and operate facilities providing either a complementary or competitive service to TCTS offering. CN-CP might be able to make use of the inherent advantages of the 12/14 GHz Anik 'C' satellite to provide service between urban locations without the need to effect interconnection through TCTS member companies' facilities. Such service would be assumed to be developed on the second Anik 'C' satellite since the first Anik 'C' satellite appears to be dedicated to TCTS member companies' needs.

As an experienced common carrier, ownership of earth stations by CN-CP should not affect systems integrity. Without ownership development of new CN-CP service would be made extremely difficult since the alternative would be to interconnect with a Telesat/TCTS earth station.

5.3 Broadcasters

There appears to be little interest by commercial broadcasters in gaining access to the satellite system at this time. Few could currently justify the space segment charges currently in effect. It also seems unlikely that the Anik 'C' satellite system will result in reduced space segment changes.

However, if broadcasters were allowed to design their own system to meet their own needs by using a partial transponder, a possibility exists that the satellite might prove out competitively with microwave even on a regional basis.

5.3.1 Ontario Educational Communications Authority (OECA)

OECA have made an interesting submission to the Minister on the question of Earth Station ownership. There is no doubt that the technical strength and scale of operations of OECA would permit them to design, set up and operate an effective delivery system to serve Ontario's needs. Such an arrangement would have no significant effect on existing systems management or integrity.

5.3.2 Canadian Broadcasting Corporation

The CBC are already the largest user of satellite communications in Canada. They are already in control of the complete distribution network and effect switching of facilities and services.

CBC have also found the current institutional arrangements too cumbersome in respect of the utilization of transportable television earth stations.

Ownership of earth stations by CBC would permit:

- improved usage of existing systems
- an acceleration of service coverage
- a more intense use of satellite communications.

Such ownership would probably ease the systems management task since CBC have/would have operations coverage of existing broadcasting facilities in communities served/to be served.

5.3.3 Community Uses of CBC Service

The Yukon Government's initiatives showed how easy it was to provide extended CBC service to Canadians at modest cost.

As indicated in the Yukon Government's submission to the Minister, the continued monopoly ownership of remote T.V. earth stations is preventing extended usage.

Ownership of earth stations at community level would not complicate the systems management task and cannot affect the satellite system. An important requirement for such facilities would be to introduce equipment and procedural solutions to effect broadband restoration in the event of transponder failure. Telesat have effected such a solution in their Frontier T.V. earth stations. The impact on the equipment is the retention of a crystal/filter kit which is easily installed in the event of transponder failure.

5.4 Cable Television

The Cable Television industry have lobbied for several years to own their own earth stations. If a service requirement for Cable Television ever emerges, the Cable industry have the skills and resources to operate their own earth stations.

5.5 Federal Government Users

Many Federal Government Departments have potential requirements for using the satellite system. Unfortunately none of them provided submissions to the Minister in respect of Earth Station Ownership.

Many Government Departments, of course, have owned and do own satellite ground stations operating with a variety of satellites owned by others. These departments include Communications, Defence, Energy Mines and Resources, Environment and Transport.

5. 6 Small Users of Telephone Services

It would seem quite impractical to permit small users to operate in a transmit/receive, multiple access mode through the satellite. Such a move could hazard the operation of a multiple access transponder unless there were significant controls of a procedural and/or technical nature.

A special case of a small user, however, could be made in the servicing of drilling ships and rigs off-shore where it would seem more practical to give ownership of at least shipborne facilities to the oil company. In this case, significant technical and procedural controls would have to be exercised by Telesat to ensure that a satisfactory operating condition would prevail.

5. 7 Conclusions

In the case of large institutional users who have a significant experience in the planning, engineering and operation of communications and broadcasting facilities, there seems little reason to believe that these institutions could not plan, engineer and operate earth station facilities interfacing with the satellite in space. The impact on the existing systems management might be an increase in workload proportionate to the extent of service extension.

In the case of television receive only ground stations owned by users of the CBC service, there would appear to be no increased burden on the existing systems management. It might even be expected that the maintenance of these facilities could be undertaken by Telesat operational staff under contract where such an arrangement would be effective.

In the case of small users desirous of operating, say, a small number of voice channels in a partial transponder, multiple access mode, it seems difficult to conceive a systems effective scenario which would not be either more hazardous or less manageable than the current method of providing service.

6.0 Recommendations for Further Action

General

There are only three major reasons why anyone would wish to own their own earth station

a) To provide a user service on a commercial basis.

b) To reduce his existing (or planned) telecommuniations cost.

c) For strategic reasons where retained ownership by Telesat prevents him from meeting his perceived operational requirements.

We take the pragmatic view that the "open skies policy" practised in the U.S. has no relevance to the Canadian scene but that each case for earth station ownership be studied individually to ensure that the "public interest" in terms of the integrity of the system in the matter of public service be preserved on a cost effective and equitable basis.

We believe that the ownership of earth stations per se is not likely to have a major impact on improving access to satellites or increasing their utilization. However, the ownership of earth stations by major institutions such as broadcasters and telephone companies gives them the significant advantage of control in their long range planning. A consequence of such ownership by institutions might be a more intelligent planning of the space sector development than currently exists, since these institutions would hopefully develop more cost effective communications systems to reduce their costs in the near, medium and long term.

6.1 Planning of Future Satellite Systems

The planning of satellite systems in Canada has been variously done individually or in combination by:

- Department of Communications
- Telesat Canada
- Bell Canada
- Hughes Aircraft Company
- Trans Canada Telephone System
- Bell Northern Research
- Air Industries Association of Canada
- Canadian Broadcasting Corporation.

In the first few years we have seen:

- the design of a six Transponder Satellite;
- the implementation of Anik 'A' (twelve transponder);
- the implementation of Hermes;
- the construction of Anik 'B';
- the contracting of Anik 'C';
- the early design of Anik 'D'.

To date the satellite system closest to matching the need was the one postulated by the Canadian Domestic Satellite Project Office - the Satellite that never was!

<u>It is recommended</u>: That consideration be given to the setting up of a Task Force whose purpose would be to try to re-establish what the real need for satellite communications is in a Canadian context over the next twenty-five years. This Task Force should have representatives from:

- Telesat Canada
- Canadian Broadcasting Corporation
- Teleglobe Canada
- Interdepartmental Committee on Space
- Department of Communications
- Private Sector

6.2 Survey of Potential Users

The ownership of earth stations by users has two possible immediate impacts on the user:

1) He may be more interested in using satellites if he can design, implement and operate a system tailored to his needs.

2) The service economics can be improved by both the system design and ownership of hardware.

It is recommended: That a demand survey be conducted of potential users to establish level of interest under the varying economic conditions prevailing through diversified ownership.

6.3 Small Users - Access Seminars

Since small users will largely obtain services through common carriers and carriers are not incentivised to serve small users, the problem of access for small users will remain.

It is recommended: That seminars be set up by the Department of Communications to assist small users to better understand the potential of satellite communications and how to gain access. These seminars might best be run as an adjunct to the Anik B Program.

6.4 Broadcasting Delivery Systems

The broadcasting of Television both fills a satellite more quickly than voice and data services and happens to be the service representing the most effective use of satellites.

It is recommended: That since broadcasters generally do not have the system design skills to configure and implement a cost effective system using less than half a transponder for TV distribution that DOC issue a statement advising broadcasters of the potential cost savings of designing a system using a partial transponder.

OPERATING EXPERIENCE
IN THE
CANADIAN DOMESTIC SATELLITE SYSTEMS

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Abstract

The objective of this paper is to describe the methods used by Telesat Canada to maintain and operate satellite earth stations, of the unattended mode, throughout the Canadian Arctic. Particular attention is given to the utilization of non-technical personnel in the remoter areas, to ensure a measure of "first-aid" maintenance and to provide dialogue with Telesat technicians in the South, so as to assist in the diagnosis and clearance of problems and service anomalies. It will show that the success of this method of "local" agent activity has contributed considerably in maintaining equipment at the high level of availability thus far achieved.

Introduction

The Canadian commercial satellite network consists of three model HS-333 spin axis stablized satellites, manufactured by Hughes Aircraft Corporation of Los Angeles, U.S.A. Each are designed to receive and transmit in the 4 and 6 GHz bands respectively, with an antenna pattern that encompasses the whole of Canada, across which Telesat has positioned 85 stations to date.

The advent of satellite communications has allowed the distribution of voice, data and teletype services via single carrier per channel (SCPC) equipment as well as television to the remotest regions of the arctic. Other services now carried are Radio Program, Wideband FM and TDMA message systems, Video Teleconferencing and experiemental services such as the Data Collection Platform experiment shared with Comsat.

The Allan Park Earth Station (near Toronto) acts as a central distribution point for most services via a 98 foot (30 meter) step-track antenna. This same antenna also transmits a despin pilot to the main operational satellite. Two smaller stations (fig. 1), with 26 foot and 15 foot antennas and their own up/down links, provide pilots for the remaining satellites. The main Tracking, Telemetry and Command station is co-located at Allan Park and uses the three antennas mentioned. TT&C also has another non-committed precision, continuous tracking antenna used for Saturated Flux Density (SFD) measurements and for satellite antenna despin acquisition. Additionally, this is the main tracking antenna used during satellite launches. TT&C is linked via terrestrial data lines to the computer and satellite control facility in Ottawa.

In this paper, after describing the ground network of stations and methods of control, the evolution of the maintenance system will be reviewed, which, when viewed with the serviceability attained will illustrate the satisfactory results with which Telesat has so far met in the challenge of Operations in the Far North.

Types of Earth Stations

The various types of stations will now be described in more detail. Actually, it has become increasingly difficult to classify stations because of the multiplicity of buildings, antennas, equipment, and the growth of a variety of services and staffing in just about every possible combination. The map Figure #1, shows the current disposition.

Heavy Route

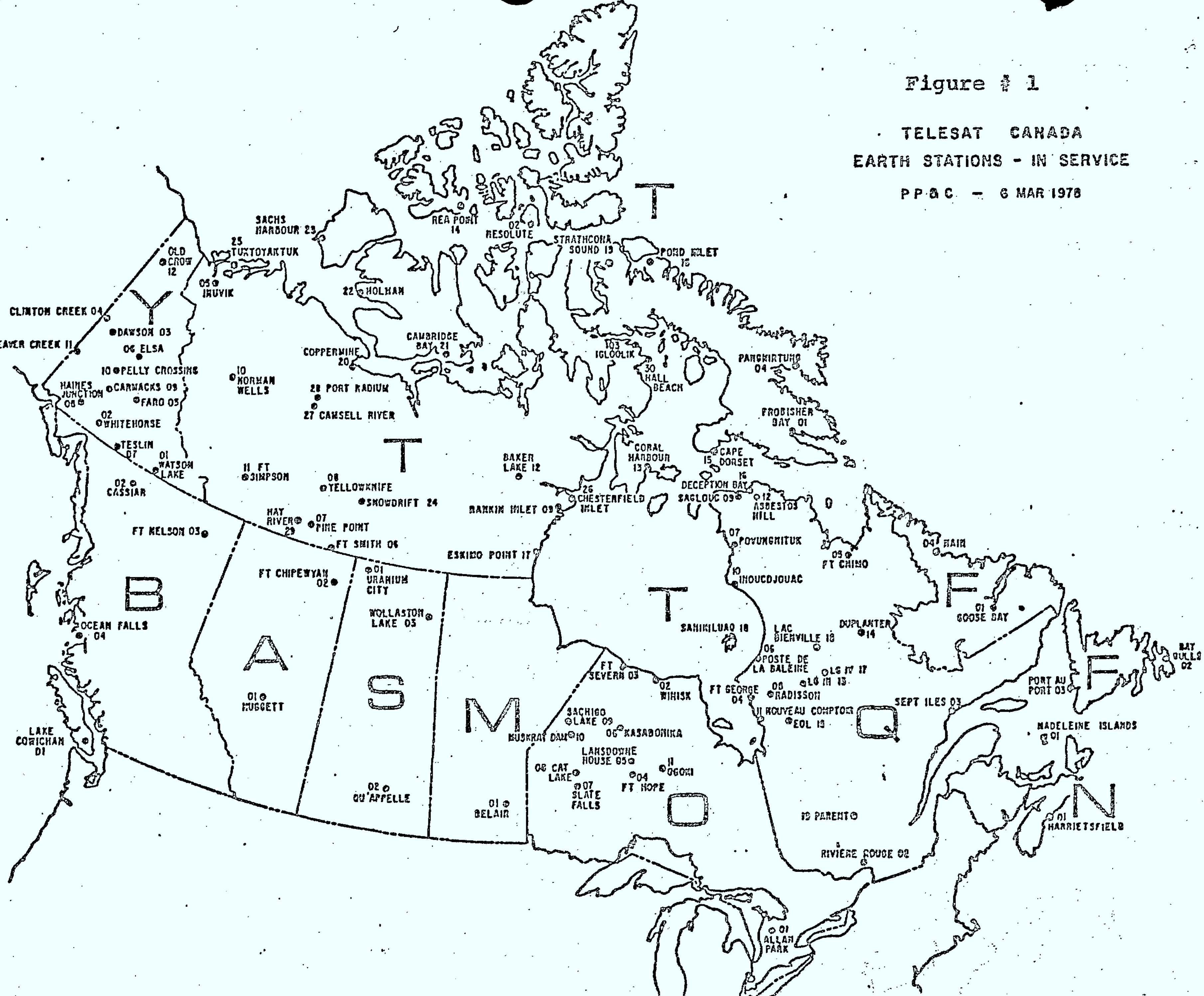
As the name implies, the two such stations carry high quality, high density traffic. Allan Park already mentioned, is the largest of two Heavy Route installations and is complemented by Lake Cowichan (near Victoria, B.C.). Both sites are manned on a 24-hour per day basis, have redundancy on all up and down links and are equipped with standby turbine/diesel electrical generators as part of an Uninterruptable Power System (UPS). Both are also involved in operational control of other stations as discussed in another section of this paper.

Network Television

These stations are mid-size with 10 meter antennas and all six are located along Canada's southern border. NTVs provide regional distribution of "Network" grade TV in/out of the provincial capitals or major centres. The Barrietsfield station (near Halifax, N.S.) is the eastern terminal for a 400 channel Time Division Multiple Access (TDMA) system to Allan Park. It is the only one which is manned and only on a work-week basis. The other NTVs are maintained by other carriers in the area on a contract basis. They perform preventive maintenance visits and cover troubles. These stations all have diesel/UPS power systems and redundant receive links.

Figure # 1

TELESAT CANADA
EARTH STATIONS - IN SERVICE
PP&C - 6 MAR 1978



Northern Telecommunications

There are two sites in this category, Frobisher Bay and Resolute Bay, N.W.T. and they are very like the NTVs except that they carry medium density message traffic, using Frequency Division Multiple Access (FDMA) and have single TV receive links. Frobisher is manned on a work-week basis and Resolute is attended to by a contracted local agent.

Remote Television

RTV stations were originally equipped to provide one or two "Remote" grade TV receive programs, however, many have since had other services, such as Radio Program and telephony (Thin Route), added. Maintenance is provided by contract with a local agent.

Thin Route (Single Carrier per Channel)

TR stations are similar to RTVs, in terms of shelters, antenna and power, however the radio equipment usually provides two or more single channel per carrier voice circuits with optional teletype and data additions. Where channel units are combined (I.F. and up) redundancy is usually built in.

Frontier Television

[illegible]ites are the simplest packages in use. They [illegible]st of a simple antenna, transistor LNA, and [illegible]gle frequency receiver. The receiver typically is one self-contained equipment shelf, mains powered and housed on the customers premises. Maintenance often means the customer or local caretaker agent, replaces the whole receiver. These installations are usually found at remote mining camps or small communities.

Transportables

Telesat has a number of transportables which have been placed in "semi-permanent" locations to provide TR or RTV service. These stations, known as small Air Transportable Earth Stations (SATES), consist of a knock down antenna, small shelter and a single transmitter/receiver capable of providing two voice circuits, which can be loaded into a Twin Otter type of aircraft. In addition, a unique transportable T.V. transmit receive facility is being used for general purpose TV coverage and consists of a trailer mounted diesel generator with an equipment shelter. Fitted inside the shelter are two frequency agile transmitters and a frequency agile receiver. This equipment complement varies from time to time, depending upon the service requirements. Several different antennas can be used with the separate equipment trailer, such as a 12 foot one which is disassembled and truck or air transported.

In addition to the common features first discussed, some variations in technical detail and services, are shown in the following Table #1.

Table #1

TABLE OF EARTH STATIONS FACILITIES

Facility or Parameter	HR	TTAC	NTV	NTC	RTV	TR	FTV	TACII	TACIII
Antenna	29.8m	10.9m	10m	10m	7.9m	7.9m	3.66 4.5m	7.9m	4.5m
Tracking	step	continuous	Nil	Nil	Nil	Nil	Nil	Nil	Nil
G/T	37	29	28	28	26	22-26	18-22	21	17
S/N	56+	N.A.	54	54	51	N.A.	45	N.A.	N.A.
U.P.S.	Yes	from H.R.	Yes	Yes	Yes	Yes	Nil	from H.R.	from H.R.
T.R. Message	Yes	Nil	Nil	Nil	Some	Yes	Nil	Nil	Nil
TV Receive	Yes	Nil	Yes	Yes	Yes	Some	Yes	Nil	Nil
TV Transmit	Yes	Nil	Yes	Nil	Nil	Nil	Nil	Nil	Nil
Radio Receive	One	Nil	One	Yes	Some	Nil	Nil	Nil	Nil
Radio Transmit	One	Nil	One	One	Some	Nil	Nil	Nil	Nil
Wideband Message	Yes	Nil	One	Yes	Nil	Nil	Nil	Nil	Nil

HR - Heavy Route
TTAC - Tracking, Telemetry and Command
NTV - Network Television
NTC - Northern Telecommunications
RTV - Remote Television
TR - Thin Route Message
FTV - Frontier Television
TACII - Telemetry and Command #2
TACIII - Telemetry and Command #3

Another concept pioneered and proven by Telesat is the centralization of reporting and spares/repair facilities. More details on these aspects are covered in other sections dealing with controls and logistics.

Operations Control

The operations and maintenance of all earth stations is carried out by Telesat personnel located in Ottawa and at four manned stations, and by a number of maintenance agents who are under contract to Telesat to assist in supporting the unattended earth stations. To help ensure that the network is operated and maintained to a standard which is consistent with customer requirements, certain control facilities have been developed and procedures have been implemented for fault location, fault reporting, preventive and corrective maintenance and for day-to-day operations and network control. Field support in the form of standardized procedures and coordination with the Engineering and other departments is provided by the Ottawa based Head Office and associated staff groups.

Throughout the earth station network, two regional offices or reporting points have been established to which customers may report any observed impairments or interruptions to their services. These reporting points process each report, directing the data to other stations, as required, in an effort to locate the problem and to effect service restoration as rapidly as possible. Whenever problems are isolated to remote unattended earth stations the regional offices call in the respective maintenance agent at the location and the agent usually clears the fault. If they should be unsuccessful, the Telesat technical staff who are responsible for the operation and maintenance of the earth station, are advised and dispatched. Upon clearance, full details as to times and cause are passed back to the regional office for documentation purposes.

Telesat regional offices interface very closely with the customers' control offices for purposes of information exchange and for development of a cooperative working spirit. With such a diverse communication network involving not only Telesat, but its customers facilities as well as facilities of other telecommunications carriers which provide backhaul from the earth stations to the customer, close and effective working arrangements between all concerned is essential. An efficient reporting system has therefore been established primarily through consultation between those companies involved. Within communication the Telesat network, the Allan Park Station functions as the control centre having an overall network service responsibility. This centre is called the Network Operations Centre or NOC.

The NOC is primarily responsible for overseeing activities relative to clearance of service impairments. It also has other major responsibilities such as: coordination of the turn-up of new services, authorizing and controlling turn-down or releases of operating equipment or systems for purposes of maintenance, scheduling major work activities at the earth stations, and providing first-line inputs to the Management Information System on all day-to-day operational activities.

In addition, the NOC is the focal point for all wideband restoration activities. Should a satellite transponder, or indeed a full satellite, fail, the NOC in conjunction with the Telesat Satellite Control Centre (a Centre located at the Ottawa Headquarters which monitors and controls the health, positioning and configuration of the satellites) customers, and station staff, effect restoration of service. This may be by means of rerouting traffic via another transponder or by reorientating the antennas of all earth stations to the alternate satellite. Needless to say, if the latter is the case, it becomes a job of major proportion, repositioning over 80 antennas in a coordinated manner.

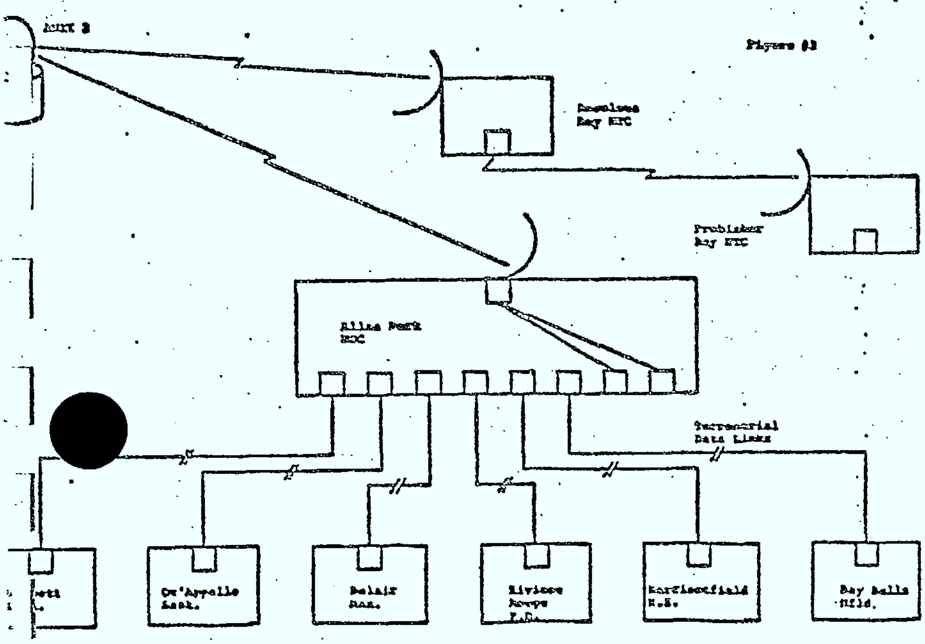
In order to keep Management advised of the status of the network certain types and durations of service impairments have been defined and are categorized as either Major Outages or Hazardous Conditions. A Hazardous Condition is defined as a trouble not directly affecting a service but which jeopardizes the service carrying capability of a station. These selected occurrences are reported by the NOC to the Head Office in Ottawa where the information is processed and distributed throughout the various Management levels. Distribution is effected by two means, i.e. circulation of typed messages and by remoted CRT display units (VDUs) to specific areas. In this way Management is kept aware of significant events within the Network and are able to react quickly when necessary.

A data collection system has been established to provide operating and maintenance information for system control trend analysis with respect to equipment and network performance. In particular two separate systems are in effect. One is related to the collection and analysis of data pertinent to continuity of service or service performance (Serviceability Report), while the other is related to failure of equipment regardless of whether or not it was carrying traffic (Equipment Failure Analysis). Analysis of such maintenance data determines a practical and economical balance between the two basic types of maintenance, preventive and corrective, which is necessary in order to meet specified operating standards in a cost effective manner.

At the Network Television stations and Northern Telecommunications stations, alarm and supervisory systems have been installed. As shown in Figure #2 these systems operate over leased data links or over "order line" on satellite systems, to tie these remote locations into the central monitoring point which is the NOC at Allan Park. Each system is independent, that is, a remote terminal is linked to a corresponding master terminal and all of the masters are co-located at the NOC. Each system has two prime functions:

1) Telemetry of remote site status to the NOC.

2) Remote control of on-site equipment by the NOC.



On site status of equipment configurations operating frequencies, and alarms is provided by contact closures from the various transmitters, receivers, and LNAs, as well as the antenna and power systems. A few miscellaneous site alarms such as "open door", "fire" and "Hi-Low temperature" are tied in, and all telemetered for display at the NOC. The remote control functions allow the NOC to perform the following operations at the remote sites:

a) Change the operating frequency of a transmitter or receiver;

b) Switching redundant transmitters, LNAs, on or off line;

c) Run-up of high power amplifiers from cold to on-air or test status;

d) Overriding frequency agility and transmitter drive functions normally under control of the CBC via a separate "network control" system.

No such alarm and supervisory systems have been provided at this time at the Remote Television or Thin Route Stations. In the case of Thin Route the NOC relies on monitoring the RF carriers from each station. All remoted monitoring and control is carried out by the NOC at Allan Park.

Maintenance Philosophy

The intent of any maintenance program is to ensure the serviceability objectives set for individual circuits or the overall system are achieved.

The maintenance approach as adopted by Telesat was structured in the usual way with both Preventive and Corrective maintenance interlocking to form an overall maintenance program.

Corrective maintenance has as its purpose the restoration of service and as such its relationship to serviceability objectives is easily identifiable.

Preventive maintenance is somewhat more difficult to relate to serviceability objectives, as its effect is more long-term and it acts to reduce the amount of corrective maintenance required. Preventive maintenance is considered as having three main purposes.

a) Verification and Optimization of System Performance

Usually related to station-to-station interface patch panel tests. It serves to verify circuit performance to the customer and to identify general areas requiring adjustment.

b) Advance Detection of Failures

Specific checks of units which are expected to fail gradually. The checks range from selected equipment monitoring by built in metering alarms to detailed unit tests or simply meter readings and status indications.

A second application within this category is functional testing of redundancy switching, frequency agility and the testing of alarm circuits.

c) The Prevention of the Accumulation of Errors

In any communications system where complex units are assembled in long chains, errors can build up rapidly. The effect of frequency drift in any one local oscillator would be minimal, however, the combined effect of several oscillators drifing in the same direction could be serious. Errors can, of course, cancel as well as add and while cancellations are bearable on an overall system basis, they complicate trouble analysis and corrective action. Consequently, reliance is placed upon the periodic preventive maintenance program, which checks equipment down to the sub-assembly, to discover and correct such anomalies.

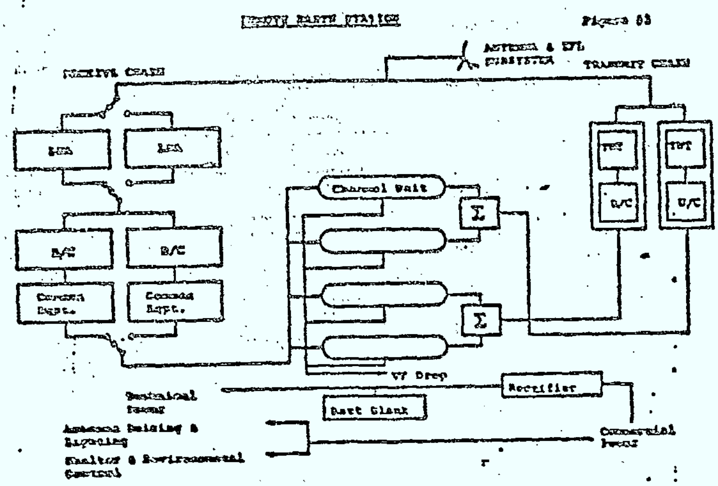
Any maintenance program, while structured to reflect the serviceability objectives assigned to the system, is constrained by the equipment design. The development of a maintenance program is therefore in large part an adaptive process. In considering the operation and maintenance of Satellite Communications Earth Stations in the Canadian Arctic, it is appropriate that we examine the general station configuration.

S[illegible]al Design Considerations

[illegible]onstraint was placed on the equipment supplier t[illegible] wherever possible the equipment would be organized as a series of field replaceable modules. Alarms, or other visual indicators (meters, flags, etc.) were to be provided so that a malfunction could be isolated to a particular module or assembly.

Typically, the earth stations are organized as shown in Figure #3. Single point failures are minimized through the use of redundancy of all common elements with the exception of the antenna sub-system, prime power and the environmental sub-systems. A form of modified redundancy is employed in the transmitter chain such that the failure of a transmitter or upconverter will result in the loss of no more than 50% of station capacity.

The selection of this parallel redundancy configuration has significant cost and operating advantages over switched redundancy.



Parallel transmitter redundancy was selected rather than switched redundancy on the basis that as the stations were remote and unattended, a failure of a transmit chain in a switched redundancy configuration would not be detected. A subsequent transmitter failure would result in the community being isolated.

By selecting parallel redundancy the necessity for a costly telemetry system to report alarms was avoided. Transmitters were loaded to only 50% capacity and the circuits that had operated through a failed transmitter could easily be patched through the remaining transmitter by the local agent, to restore full service.

The Operations group were therefore provided with an immediate indication of partial transmitter failure and repairs could be undertaken before the community was isolated.

The non-redundant sub-systems have extremely low failure rates and thus do not reflect significantly on system availability.

The Local Agent Concept

During the installation phase of the first earth stations in the Arctic, it became evident that the communities where the stations were being developed were not equipped with the facilities we take for granted in the more populated areas. It was a task of significant proportions simply to find a place to sleep and eat. Even more difficult was the hiring of transport to move equipment and supplies from the airstrips or beaches to the earth station site.

It was necessary therefore to have a contact within each community who could arrange the laying on of transport, provision of accommodations and could assist in a general way.

Once this contact was established, the obvious next step was to have the individual who had been so helpful keep an eye on the station when it was turned up for service and our installation and testing crews had moved on.

This then was the beginning of the local agent concept. The agent was expected to look after the physical security of the installation and do the local coordination necessary to accommodate subsequent visits by the maintenance staff.

Meter reading and station check procedures were developed, first for our own use, then adjusted for the local agent. Then followed the procedure for cross-patching to restore circuits when a transmitter failed and as experience was gained by our operating staff in working with the local agents, they were used as an extension of the technical staff to isolate failures and to replace modules.

The reference made previously to the significant benefits of parallel transmitter redundancy here become evident. We were now assured that in almost every instance of equipment malfunction the communities would not be isolated. Further the local agent could be contacted over the remaining circuits and under the direction of a trained technician not only restore service to full capacity but isolate the failure, in most instances, to module level. We were no longer required to dispatch a technician and a substantial number of spares thousands of miles to effect the repair. The module, identified by the technician/agent team was sent by the most expeditious route and on arrival at the remote location installed by the agent.

One main operating restriction was placed upon the agent and that was not to carry out any maintenance activity beyond meter readings without being in voice contact with a Telesat technician. This is to ensure that the Agent is provided with maximum technical assistance during such events, to enable service to be restored expeditiously. Additionally, it also provides measure of safety, by allowing the technician to caution the agent whenever hazardous voltages are present.

Another type of agent is obtained through maintenance contracts between Telesat and other telecommunications companies, such as Canadian National/Canada Pacific Telecon; (CN/CP) and are known as "Maintenance Agents". In this manner employees of the contracted company are used to maintain Telesat equipment on demand.

These employees would normally have an academic background comprised of secondary schooling, technology training, and three to five years of technical experience wherein they would have gained practical knowledge of the latest communications systems and their support equipment.

The duties of this type of agent would include:

a) <u>Preventive Maintenance</u>

The Agent will provide preventive maintenance in accordance with Telesat's established routines and procedures.

b) <u>Corrective Maintenance</u>

The agent shall provide corrective maintenance when required in accordance with Telesat's established routines and procedures. This will normally entail, but shall not be limited to, fault isolation and replacement at the module level. The agent shall in responding to Telesat service outages or potential trouble reports, exert its best efforts to effect the necessary corrective action or repairs in order to restore the service as soon as possible.

c) <u>Response to Service Outages</u>

The agent shall diligently and effectively respond to Telesat service outages or trouble reports related to Telesat satellite telecommunication service to and from the Earth Stations in accordance with Telesat's established operating procedures.

d) <u>Housekeeping and Civil Works Maintenance</u>

The agent shall maintain a high standard of cleanliness and neatness at the Earth Stations. Additionally, the agent will maintain access to the Earth Stations.

e) <u>Reports</u>

The agent shall prepare and submit reports to Telesat in accordance with Telesat's established operating procedures.

Generally, the stations assigned to maintenance agencies are more complex than the Remote Earth Station shown in Figure #3. Typical of this more complex earth station class are the NTV (Network Television) stations at Edmonton, Alberta (Huggett), Winnipeg, Manitoba (Belair) and St. John's, Nfld. (Bay Bulls). These NTV stations and others provide transmission and reception links for regional CBC centres to the nationwide CBC radio and television network. Highly skilled technicians are required to effectively carry out maintenance programs at these locations. The maintenance agencies have effectively provided this service throughout the commercial phase of operations.

Customer Maintenance

Under some circumstances and by mutual agreement, Telesat permits the customer to maintain the earth stations providing the customers service. This is done in accordance with the standing Telesat operating and maintenance procedures, with additional provisos that allows Telesat intervention in the event that service restoration is not effected expeditiously.

In some areas of the country, notably Northern Ontario and the far reaches of the Northwest Territories, the customers have resident qualified technicians in the area. It is of mutual benefit therefore to have a first-line maintenance arrangement whereby the customer's technician assumes responsibility for the technical health of the Station. He obtains technical help, repair and spares support from the Telesat system on an as-required basis and reports to the Network Operations Centre (NOC) through his supervisor, in the usual manner. Critical spares items are often located at a spares depot close to the remote areas of operations, in addition to the central supply depot.

Manpower, Spares and Logistics

The distribution of the earth stations across the Canadian North located in a hostile Arctic climate and accessed via transportation links which are somewhat tenuous, has in itself presented very unique operational and maintenance problems.

Station locations, along with main transportation links are shown in Figure #4. (See next page)

The Operations staff are deployed at three main centres (Ottawa, Allan Park and Lake Cowichan) and two subcentres (Frobisher Bay and Harrietsfield), shown respectively as * for the main centres and # for the subcentres. Currently, only the Allan Park and Lake Cowichan stations are staffed on a 24-hour basis, while the Frobisher Bay station and the Harrietsfield station are on an 8-hour per day basis. As the network expands and becomes more complex, the staffing of other stations may be required.

Regional responsibilities are similarly shown as Earth Stations West, Central and East.

Earth Stations Central Group at Allan Park, Ontario maintains a common logistics and supply centre as well as an equipment repair depot for the total system. Critical spares are stocked at regional centres, at Frobisher Bay and other sub-depots.

In general, field repair of modules are restricted to repairs of a simple nature with all other repairs being handled by the repair depot. Equipment supplier warranty provisions of from 12 to 18 months provides a buffer for the repair depot, insulating them from the impact of equipment infant mortality rates, but nevertheless all repair items route through the central depot.

A limbo clause, where the warranty clock ceases to tick upon the return of a failed warranted item and recommences after repair and return, has eliminated substantial losses of warranty time where the repair time is extensive.

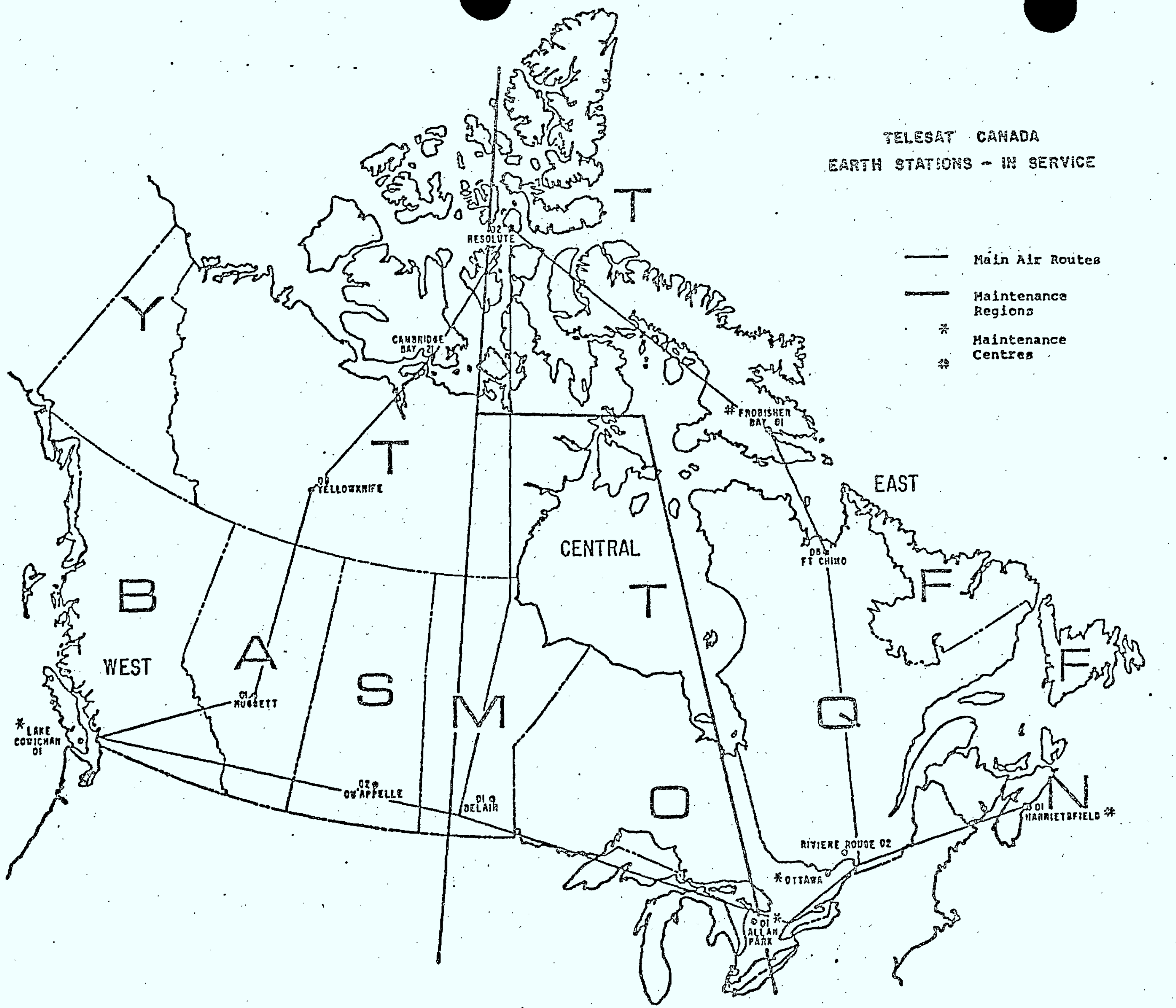
Spares levels are maintained at a minimum as a result of the policy of modular construction. As an example, a channel unit failure can be corrected by dispatching a replacement for the particular module that failed rather than sending the entire channel unit. The balance of the modules which constitute a channel unit remain available for failures at other locations.

The use of sub-depots has a limiting effect on the flexibility of the spares inventory. Sub-depots are used, however, to reduce the detrimental effect of irregular or infrequent commercial transportation.

System Performance

Effective service control over the large and complex network is exercised through a Network Operations Centre (NOC) located at the Allan Park earth station.

Trouble reports are processed through the NOC before being referred to the individual maintenance groups responsible for the maintenance of the earth stations.



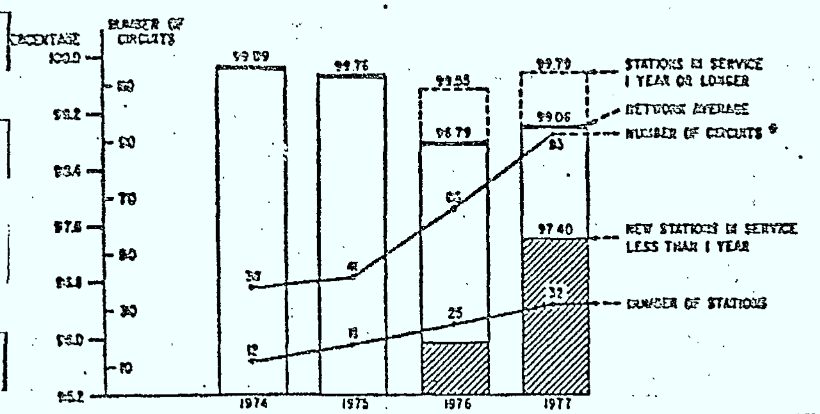
Satellite Earth Station Network and Major Air Transportation Routes

Figure #4

Objectives are reviewed each year and set in accordance with prevailing conditions. Contractual obligations are reflected in the objectives only insofar as they are always inferior to the revised objectives set.

NORTHERN SERVICE NUMBER 2 LOCATION SERVICEABILITY
SITE ISOLATION AVERAGE FIGURES

FIGURE 5



1976/77 REFLECTS START-UP OF NORTHERN ONTARIO STATIONS WITH ASSOCIATED EQUIPMENT INFANT MORTALITY
* INCLUDES TELETYPE

Experience has shown that new equipment can be expected to realize a high initial failure rate for the first year of operating life. A meantime between failures on a circuit basis can be anticipated to be in the order of 5,000 hours. In subsequent years this figure should improve steadily, leveling off in the region of 10/15,000 hours between failures.

An objective, over a five year period, of 99.8% is therefore a reasonable goal provided maintenance groups are organized to restore service on average within 24 hours of failure.

Considering that this figure translates to an outage time of only 1,057 minutes per year (approximately 17½ hours), it can be readily appreciated that a lot of extraordinary effort is required to maintain standards at the specified levels.

Figures #5 and #6 illustrate the serviceability and average outage duration experienced in Northern earth stations from 1974 to October of 1977. Overall serviceability has been improving steadily throughout 1977 and on a monthly basis reached 99.98% in December.

We have considered in some detail the telephone services provided by Northern earth stations. Other services provided by these stations include the distribution of both television and radio programming throughout the North.

NORTHERN SERVICE No. 2

FIGURE 6

SERVICE OUTAGE DURATION BY CATEGORY	1976	1977
A	57 (2.68)	23 (1.03)
B	6 (0.25)	9 (0.25)
C	6 (0.24)	17 (0.04)
TOTAL	79 (3.16)	53 (1.84)

Notes: 1. Category A is less than 24 hours duration.

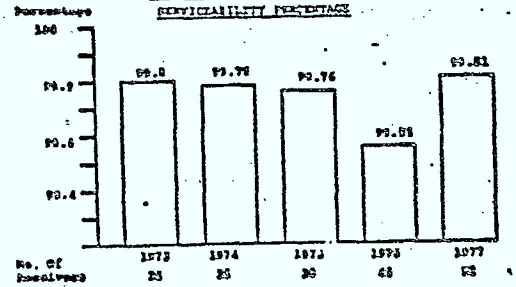
Category B is 24 - 48 hours.

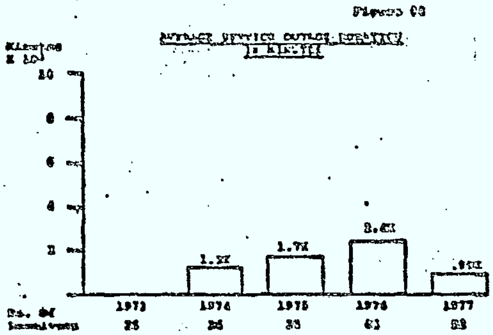
Category C is more than 48 hours.

2. Figures in parenthesis indicate number of outages per locations served.

Figures #7 and #8 illustrate the serviceability and average circuit outage duration for RTV services.

Figure #7





The stations added to the network during 1976/1977 have been predominantly located in Northern Ontario. A new station design was employed and in order to differentiate between this station type and those originally installed, they are generally referred to as Northern Ontario type stations.

Availability for these stations was calculated in the normal way, based on an assumed lead time 22 hours. The calculations are shown in e #2 and indicated that we could anticipate rvice availability in the order of 99.88% year. Our experience, after a years operation, at four stations of this type of substantially at variance with the projected availability, as will be seen by perusing Figure #9.

Table #2

Redundant Northern Ontario Stations

EQUIPMENT	MTBF	MTTR	Availability LEAD TIME	AVAILABILITY	
Antenna & Feed	110,000	10	22	0.999709	
LNA (2.4 dB)	35,000	0.5	22	0.999358	Rx Chain Redundant 0.999999
Downconverter	25,000	2.0	22	0.999040	
Freq. Std. Tx/Rx Upconverter	25,000	2.0	22	0.999040	Tx Chain Redundant 0.999999
HPA 35W Varian HVPS	20,800	2.0	22	0.998847	
Interface Unit	60,000	1.0	22	0.999617	Redundant 0.999996
Channel Unit Tx/Rx	12,057	2.0	22	0.998016	
Sw. Gear & Cables				0.999990	
Power Conditioning + 4 HR Battery Reserve	50,000	3.0	22	0.999500	

Station Availability = 0.998810

= 10.42 Hours Outage Per Year

Equipment infant mortality is, of course, a major contribution to reduced availability but other factors had significant impact, a few of which are listed below as examples.

a) Commercial Power/Ambient Temperature

A relatively continuous source of electrical power had been assumed. During the first year, however, numerous and prolonged power outages took place. Shelter temperature during the winter dropped to 45°C (≅ 50°F) below zero. As might be expected at such temperatures, when power was reapplied a number of component failures resulted, particularly in power supplies.

To restore this type of problem shelters have been modified to retain their heat for longer periods and modifications to the technical power systems to prevent the application of power at low ambient temperatures have been installed or will be installed early in 1978. In addition, procurement specifications have been changed to reflect the need for equipment to survive under such circumstances.

b) Equipment Packaging

The TWT transmitters were arranged in their rack in such a manner that overheating of the second transmitter occurred. This resulted in premature transmitter failure. Rack blowers have been added to reduce the heating effect and rack modifications are under consideration.

c) First-Line Maintenance

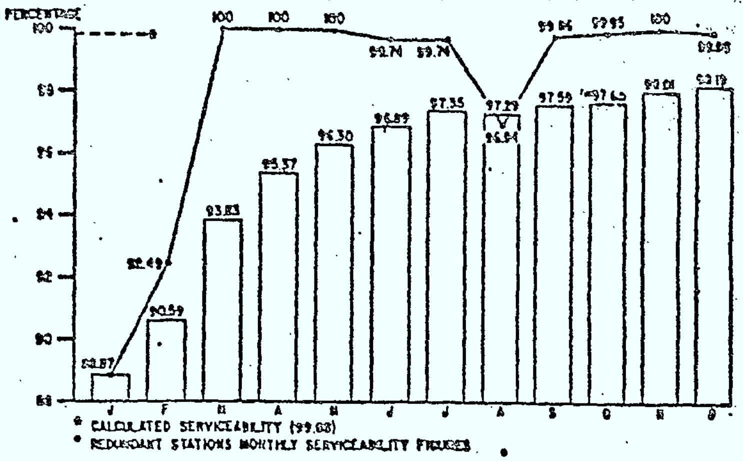
First-line maintenance task was assumed by the customer who operated with a limited technical staff in the area. Restoration of Telesat facilities was, as a result, occasionally delayed as the customer staff responded to situations which they considered as having a higher priority. Efforts were made to arrive at a formula which would properly recognize the priorities of both the customer and Telesat.

d) Transportation

The areas serviced by Telesat earth stations in Northern Ontario do not possess the transportation structures we take for granted throughout most of Canada. Road or rail access is non-existent and air travel remains at the bush pilot level of development. The only air-strips are lakes or the occasional short strip cut out of the wilderness. Under these conditions, travel is restricted to good weather only and the condition of the lakes.

1977 ACCUMULATED SERVICEABILITY
NORTHERN ONTARIO REDUNDANT STATIONS

FIGURE 9



Aircraft and staff have been stranded for days by winter storms with the duration of service outages being appropriately extended. Additional flexibility is being built into the maintenance structure by locating critical spares in customer sub-depots and by encouraging increased utilization of local agents.

As each problem area was encountered, the station availability improved apace.

It is early in the life of the stations to project their eventual 5 year term availability, but one can reasonably assume that 99.8% will be an attainable objective.

As can be seen from the foregoing, within Telesat, the Operations and Engineering groups are involved in a continuous process of improvement of both maintenance procedures and equipment design.

Conclusion

Major growth in the Telesat network, in the 1980's will take place in the 14/12 GHz band. The majority of earth stations associated with this larger network will be in Canada's southern climes, and in all probability located at the customers premises. This will present a new and different series of problems - not so much how to maintain the equipment but how to control the much larger network.

However, demand for more and improve services in the Arctic will continue, and the problems associated with that environment will still have to be resolved. New problems will arise and new solutions to old problems will have to be found.

Acknowledgements

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SYSTEM ASPECTS OF THE INITIAL TELESAT THIN ROUTE SATELLITE COMMUNICATION SYSTEM

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SUMMARY

On February 1, 1973, the Thin Route satellite communications system commenced commercial service via the Canadian Domestic Satellite. The service provided by Telesat to Bell Canada is designed to extend high quality, reliable telephone communications to small remote communities in Northern Canada. The system employs single channel per carrier, delta modulation, 2-phase coherent phase shift keying, and frequency division multiple access techniques (SC/C, DM, 2Ø-CPSK FDMA). This paper describes the initial Thin Route system and indicates the proposed system expansion over the next two years.

INTRODUCTION

Existing telephone communications to many small communities in northern Canada relies on HF radio links and features several user disadvantages including time varying noise performance, significant outage time due to propagation conditions, and press-to-talk operation.

The Thin Route service is designed to overcome these problems and to provide high quality, reliable telephone communications to remote communities which have a requirement for a small number of voice circuits --typically between two and eight.

The initial Thin Route system, installed in 1972-73, serves the settlements of Igloolik and Pangnirtung in the Northwest Territories. Two pre-assigned satellite voice circuits are provided between each settlement and Allan Park Earth Station in southern Ontario. From Allan Park the circuits are back-hauled by Bell Canada terrestrial microwave radio to Ottawa where interconnections are made with the telephone network.

Expansion of the Thin Route System is already under way. At the present time Telesat plans to install Thin Route earth station facilities in a further seven communities in 1973 and an additional eight in 1974. The design of these new thin route stations is based on a station G/T of 22 dB/°K as compared with 26 dB/°K in the existing Igloolik and Pangnirtung stations.

Eventual system capacity is in excess of 120 simplex (60 duplex) voice circuits based on a homogeneous system model of non tracking ground stations with a G/T of 22 dB/°K.

Ultimately the number of circuits may be increased well beyond 120 by using voice activation techniques. Demand assignment and circuit sharing are currently under study with a view to increasing the efficiency and flexibility of the system in the future.

VOICE CIRCUIT PERFORMANCE REQUIREMENTS

The conventional means of specifying the noise performance of a voice circuit in dBrnc0 is inadequate to fully define the grade of service for a delta modulation system since both idle circuit noise and quantization noise must be accounted for.

At low bit error rate (BER≤10-4) the idle channel is extremely quiet and typically measures 20 dBrnc0. However, during periods of speech, quantization noise is produced in the delta codec (encoder/decoder). This means that circuit noise is essentially speech activated. Thus the concept of superposition for signal and noise is not valid for delta modulation as far as speech is concerned.

It is pertinent to note however that listener annoyance is related to idle circuit or intersyllabic noise and that the human ear tends to suppress noise during speech activity. In this respect, the characteristics of delta modulation may be said to be "matched" to the hearing process.

The voice performance requirements adopted (Table I) provide for a single grade of service to the north and to the south. Noise performance is specified jointly in terms of idle circuit noise and signal to quantizing noise (S/Q).

SYSTEM DESCRIPTION AND PERFORMANCE

The decision to employ single channel per carrier, variable slope delta modulation, 2Ø CPSK, FDMA techniques was taken after considerable trade-off studies[1] had been made.

Digital transmission techniques are attractive in that they exhibit:

- Low C/N for threshold performance
- Immunity from intelligible interference
- Compatibility with growing requirement for transmission of digital information
- Compatibility with demand assignment and circuit sharing techniques.

Delta Codec

One of the most distinctive features of the Telesat Thin Route system is the utilization of variable slope delta modulation at 40 kbps for the encoding of the voice baseband. For a sampling rate of 40 kbps, excellent voice quality is achieved at low bit error rates (BER), i.e., 10^{-4} or less. Good intelligibility is maintained down to 10^{-2} BER. Below 10^{-2} BER, voice quality degrades rapidly.

The system design objective is for operation below a 10^{-3} BER for 99.9% of the time.

The major objective parameters of the delta codec are summarized in Table I.

PARAMETERS	SPECIFICATION VALUE	
...ng Rate	40	kbps
...ircuit Noise	<37.5	dBrnc0
Dynamic Range (for S/Q ≥25 dB measured at 1 kHz)	≥30	dB
Maximum S/Q (measured at 1 kHz)	≥30	dB
Frequency response (measured at -10 dBm0, referred to 1 kHz)		
300 - 3400 Hz	+1,-10	dB
300 - 3000 Hz	+1,- 6	dB
600 - 2400 Hz	+1,- 3	dB

Table I - Major Parameters of Initial Thin Route Delta Codec (Low BER)

Figure I shows measured output signal to noise ratio (S/N) as a function of level and BER for a 1000 Hz input signal.

At zero BER the noise is wholly quantizing noise. As BER increases the output noise is composed of quantizing noise together with error induced noise until, at high BER, error induced noise becomes the dominant effect.

The curves also show the two distinct regions of codec operation - low signal levels where "granular" noi... occur and high signal levels where the codec is d...ed by slope overload noise.

For a sinusoid slope is proportional to both amplitude and frequency. Thus slope overload will occur at lower signal levels for high frequency test tones. This is shown in the S/Q curve for 2600 Hz.

PSK Modem

The selection of CPSK modulation is predicated on the fact that 2Ø and 4Ø CPSK provide the lowest theoretical system BER for a given received energy per bit to noise power density ratio (E_b/N_o). Two phase modulation is preferred over four phase:

(a) because the modem is simpler and not subject to quadrature channel crosstalk impairments and,

(b) the Thin Route System is space segment power limited rather than bandwidth limited.

Differential encoding of the codec bit stream is employed in the transmit channel unit in order to preserve speech intelligibility at high bit error rates. This technique eliminates the effect of the π-phase ambiguity in the demodulator recovered carrier for a small penalty in E_b/N_o e.g. 0.6 dB at 10^{-3} BER.

Figure II shows measured link BER performance as a function of E_b/N_o.

Single Channel per Carrier FDMA

...e access technique, SC/C FDMA, was chosen to pe...elatively simple and economical earth station des... while retaining a flexible networking capability by means of channel select frequency synthesizers.

INITIAL THIN ROUTE GROUND STATION EQUIPMENT

(a) Ground Station Configuration

Table II summarizes the primary parameters of both the northern earth stations and the Allan Park Park earth station.

PARAMETER	IGLOOLIK & PANGNIRTUNG	ALLAN PARK
Transmit Frequency	5985 ±18 MHz	5985 ±18 MHz
Receive Frequency	3760 ±18 MHz	3760 ±18 MHz
ANTENNA	26 ft. Dia. (Non tracking)	97 ft. Dia. (Tracking)
Tx Gain (dB)	50.5	62
Rx Gain (dB)	48.5	59
G/T (dB/°K)	26	37
LNA Noise Temp.(°K)	100	100
TRANSMITTER	2 x 35 W TWT Hybrid Combined at O/P	1.5 KW KLYSTRON (Redundant Multicarrier)
POWER - MAIN	Commercial AC	Commercial AC
BACK-UP	4 hr-lead acid battery	Diesel/Battery
STAFFING	Unmanned	Manned - 24 hrs.

Table II - Earth Station Primary Parameters

In the northern stations the electronics equipment is housed in a 18 ft. x 7½ ft. x 8½ ft. fibreglass shelter. Outside ambient temperatures may range from -50°F to 80°F over the year so that active thermal control is necessary to maintain the inside ambient temperatures at 70°F±20 F.

Automatic de-icing is provided for the antenna feed horn window and sub-reflector by means of infra-red lamps. No de-icing provisions are made for the main reflector.

(b) Channel Units and Common IF Equipment

Of particular interest are the channel units and common IF equipment in the initial Thin Route system, see Figure III. Each station is equipped with one (redundant) set of common IF equipment and two channel units. The expansion philosophy is such that additional voice circuits up to a maximum of eight can be provided at a northern station by simply plugging in the additional channel units, the existing common IF equipment being shared. Expansion beyond four circuits may require a higher power transmitter. Note, with reference to Figure III, the present configuration at Igloolik and Pangnirtung bypasses the multiport combiner and is arranged so that each modulator output feeds a separate transmitter chain.

Selection of channel frequencies is performed respectively by the transmit and receive frequency synthesizers. These are programmable to select any of 600 frequencies spaced at 60 kHz intervals across the 36 MHz IF band.

For demodulation the channel unit uses an I-Q Channel (Costas Loop[2]) coherent demodulator operating at a fixed carrier input frequency (40.02 MHz) and post detection filtering. The pull in range of the demodulator is in excess of $\pm$2.5 kHz.

Bit timing recovery is achieved by hard limiting the video output of the demodulator I channel and extracting the timing component by means of a phase lock loop. From the PLL output narrow pulses are produced to mid bit sample the hard limited video and produce a minimum-error replica of the transmitted digital bit stream.

The station common IF equipment consists of a multiport combining network for summing the transmit IF carriers, a multiport divider for providing each channel unit with a receive spectrum replica, station frequency references and an AFC system.

The use of an AFC or spectrum centering scheme is necessitated by the limited acquisition range of the demodulator, and the significant long term frequency drift of oscillators in the common part of the transmission channel - notably the spacecraft transponder L.O. and the RF portion of the main station down-converter. A stable pilot tone at an IF frequency of 69.96 MHz is transmitted from Allan Park with an absolute uplink stability of $\pm$200 Hz and is phase locked in the AFC of each receiver to a locally generated stable 97.98 MHz tone thereby centering the Thin Route carrier spectrum and nullifying the effect of spacecraft L.O. and receiver frequency drift (up to $\pm$40 kHz). However, a stringent frequency stability requirement still exists for the non-common parts of the transmission channel, particularly the main up-converter local oscillators. The long term frequency stability of these latter oscillators is specified as 1 part in 10^{-7} per month which gives an interval of some four months before retuning is required.

Future Thin Route stations will be equipped with up-converter local oscillators at least one order of magnitude more stable in order to extend the retuning interval to one year.

CONCLUSIONS

This paper has introduced the Initial Thin Route system which is presently in commercial service with Bell Canada. The system has greatly improved telephone communications to the communities of Igloolik and Pangnirtung in Canada's Northwest Territories. The service is being extended to a further fifteen northern communities during 1973-74.

Additional classes of traffic including data, facsimile and teletype are currently under examination to establish suitability for transmission over the Thin Route. Data, in particular, using voice band data modems appears promising. Higher data rates up to 40 kbps are possible if direct interfacing with the PSK modem is performed.

Finally, voice activation, demand assignment, and circuit sharing techniques are being explored with a view to increasing the system flexibility and effective channel capacity in the future.

ACKNOWLEDGEMENTS

The author wishes to acknowledge the support and significant achievements of the staff of the prime contractors to Telesat Canada in the Thin Route Program:

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(Channel Equipment)

Raytheon Canada Ltd., Waterloo, Ontario, Canada
(Northern Stations)

RCA Canada Ltd., Montreal, P.Q. Canada
(Allan Park Station)

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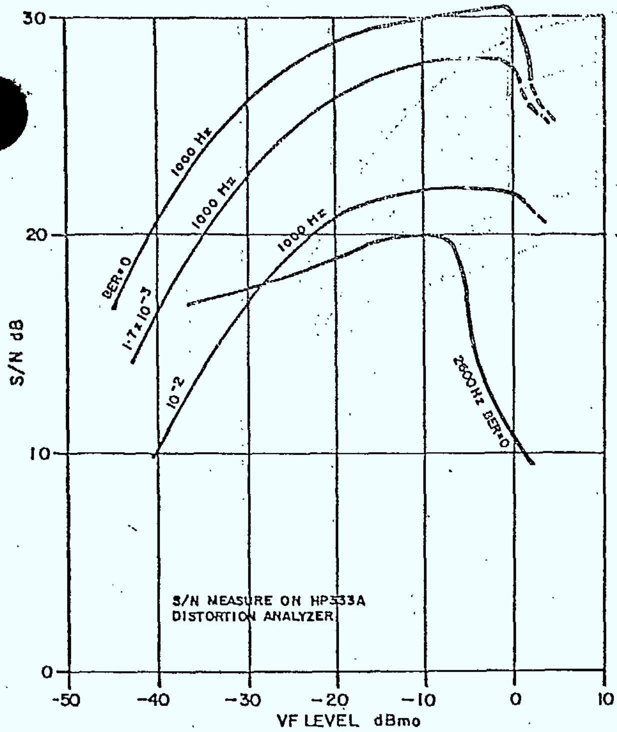

FIG I CODEC SIGNAL TO NOISE RATIO AS FUNCTION OF VF TONE LEVEL AND BER

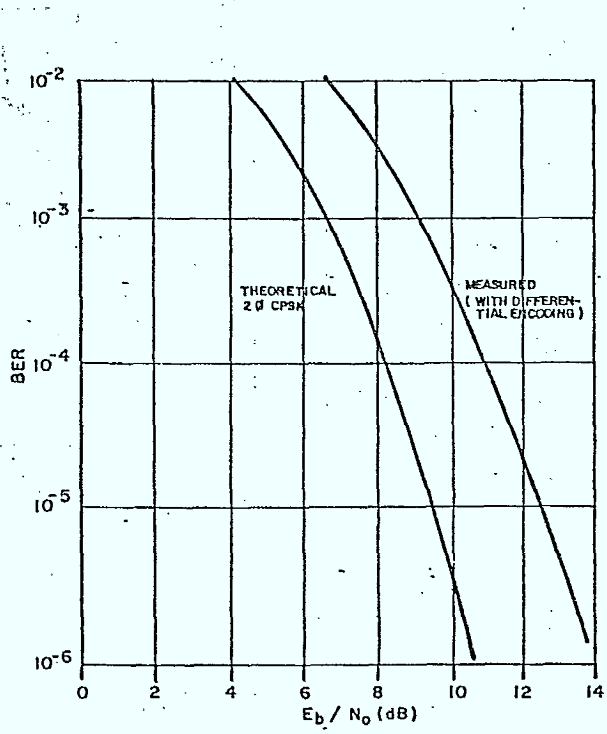

FIG II LINK BIT ERROR RATE PERFORMANCE

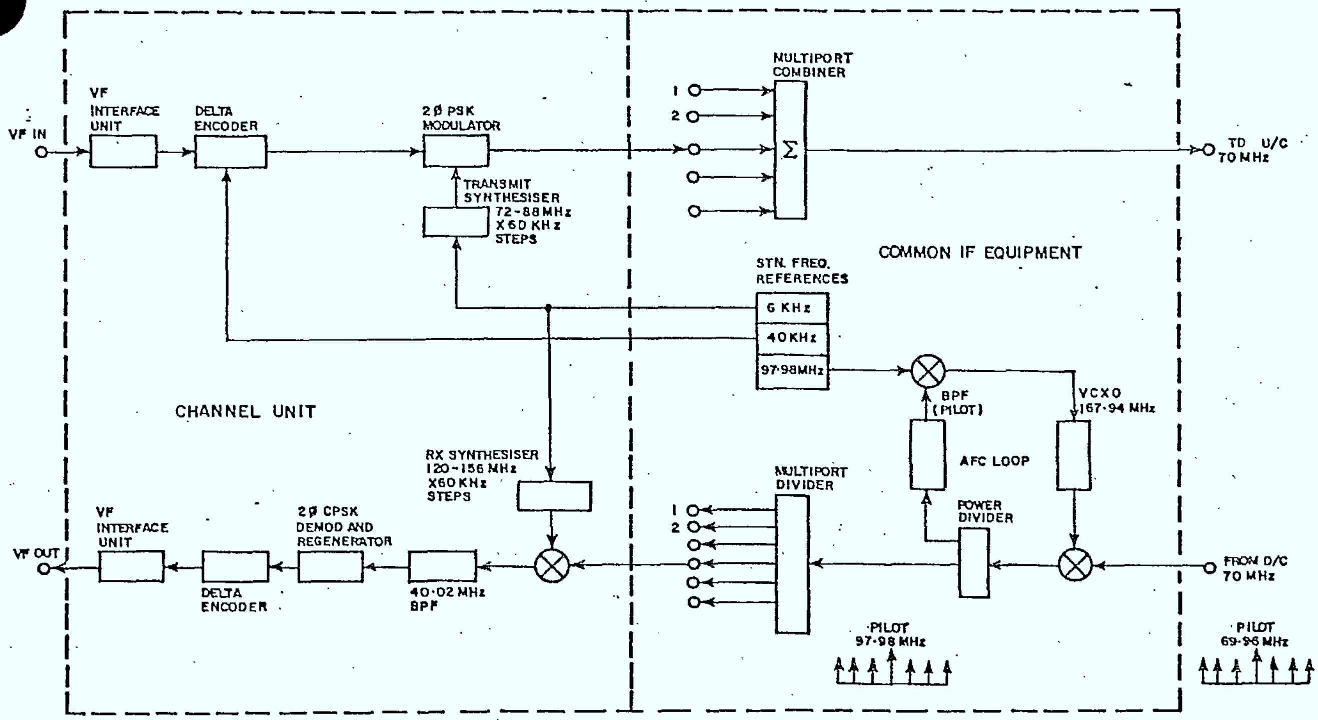

FIG III CHANNEL UNIT AND COMMON IF EQUIPMENT — INITIAL THIN ROUTE SYSTEM