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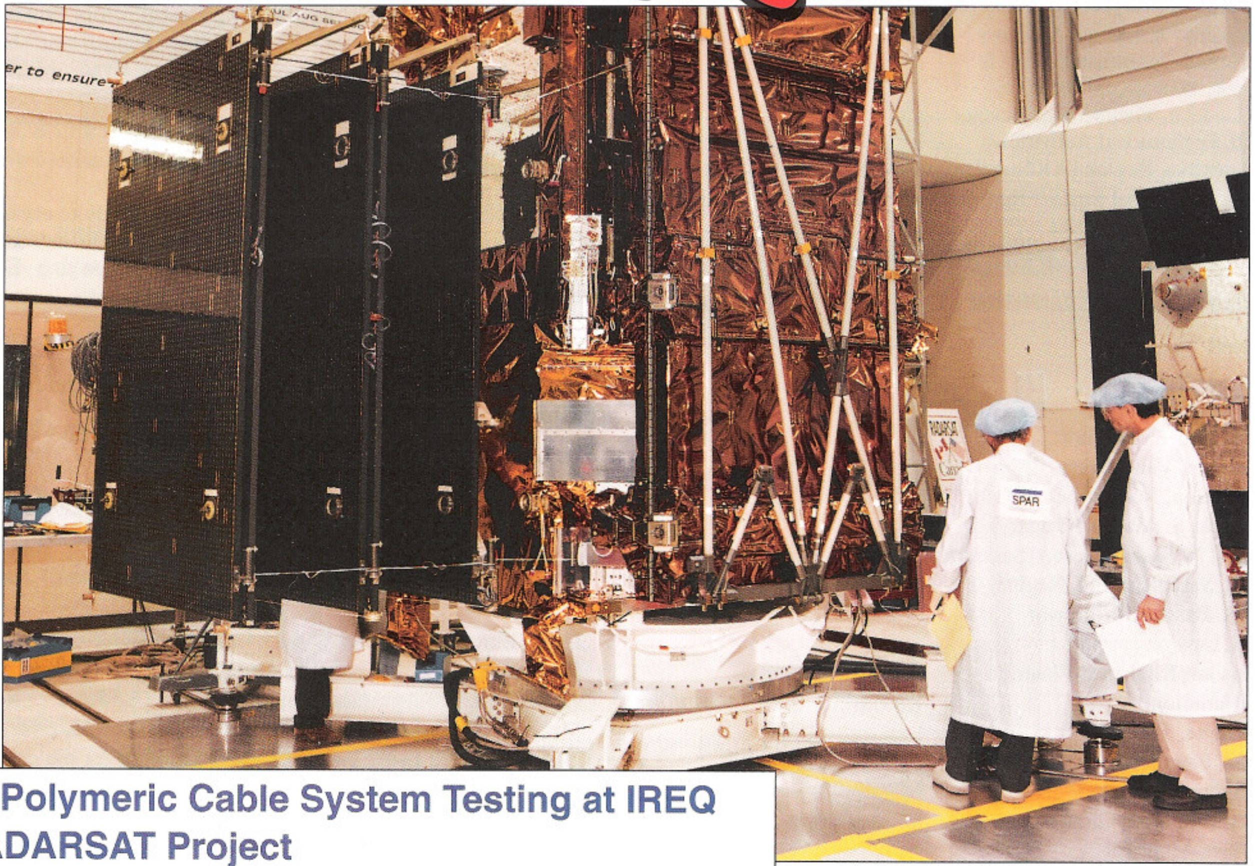

345-kv Polymeric Cable System Testing at IREQ

The RADARSAT Project

The Integrated Rural Delivery Network

IEEE

The Institute of Electrical and Electronics Engineers Inc.

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(ii) Canadian members of the profession and community who are non-members of IEEE;
(iii) the associated academic (i.e. universities, colleges, secondary schools), government and business communities in Canada.

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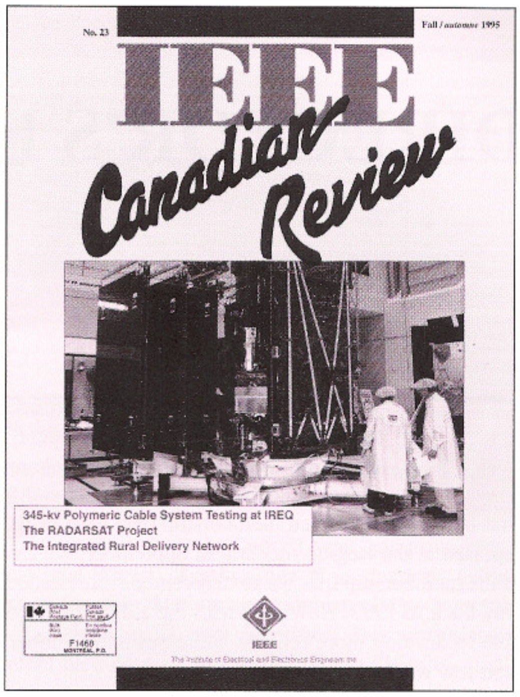
Cover picture

Overall view of the RADARSAT satellite under test with partially deployed solar array.

Photo couverture

Gros plan du satellite RADARSAT,sous test à SPAR, avec déploiement partiel du panneau solaire .



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DIRECTOR'S REPORT

My term as your Director and as President of IEEE Canada is nearing an end. Your next President, Linda Weaver, will be taking over the office as of January 1, 1996. She has already undertaken to rectify some difficult problems, the first being the corrupted membership data base in IEEE Canada. As she reported at the Region meeting in September, we have little faith in any of the membership lists we have received from headquarters, going all the way back to 1993. However, with the aid of the Sections, we hope to be able to develop more reliable addresses and member profiles within the next few weeks.

We have also become aware that many of our transfer members from CSECE have been incorrectly recorded. We are working to iron out those bugs as quickly as possible. Our new Manager of the Regional Activities Department, Cecelia Jankowski, attended the Region meeting in September and promised her assistance to help solve the problems. I have known and worked with Cecelia for several years: she was a dedicated and capable volunteer for many years before joining the staff. With her help, the problems are resolvable.

One of the services we hope to develop even further during Linda's term is the IEEE Canada computing system, which now offers IEEE Canada Member Services, a member hotline - member.services@ieee.ca, Email aliases, WWW site and facilities, and an IEEE Canada FAX server.

We should be able to provide our members with other services, too. For example, through IEEE we can provide automobile and home insurance, life insurance (term and universal), overnight express (airborne), moving services (NAVL), discounted copying (Kinko's), car rental discount, and IEEE travel services. Plans are underway to offer the following services to IEEE Canada members: off-shore mutual funds (late 1995), international credit card (late 1995), Canadian Credit card (early 1996), small business insurance (1996), computer discounts (1996), and phone assistance (early 1996). To find out more, or to take advantage of any of these services, contact Robin Morton at "r.morton@ieee.org".

To give you the best services, we need to know what you want. If you have specific needs, please let either Linda or I know what they are.

IEEE has been going through some growing pains: the leadership feels that it is time to implement an alternative Board structure. The June issue of "The Institute" outlined three possible scenarios and asked for feedback.

It is very important that every member give the requisite feedback. I have some grave concerns about all three scenarios, principally because: (1) the oversight of staff activities may well be lost in all of them, and (2) the international nature of IEEE will be compromised by all three proposed Board structures. I believe we should evolve from our current position gradually to correct problems as they are identified. Radical change may well destroy what we have. Every member should respond to the Organizational Improvement Committee to voice an opinion as to what our structure should be. Henry Shein is collecting the information for the committee. Let him know what you think (h.shein@ieee.org).

The first merged society IEEE Canada CCECE conference was held in

by Ray Findlay
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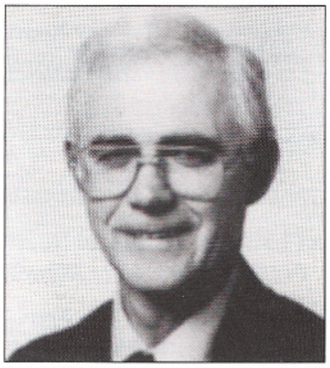


Montréal in the first week of September. Renato Basisio, the General Conference Chair, did a superb job of organizing. There were over 400 people in attendance at the conference. However, we can do better still. The next conference will be in Calgary in May under the General Chair, Om Malik. Please plan to attend, to present a paper and to support the conference.

Cathie Lowell, our Region Administrator, will continue to serve you, to answer your questions and to respond on behalf of Linda during Linda's term. You can find out what you need to know by contacting her at "c.lowell@ieee.org ".

Finally, I know that I leave IEEE Canada in good hands. Your Region Committee will continue to operate on your behalf. They did wonderful things on your behalf over the past two years - I owe them greatly for their dedicated service. Although I don't have room to mention everyone, there are a few I would like to thank publicly: Jacek Chrostowski, whose dedicated efforts resulted in our electronic communication system and the development of our IEEE Canada server in Ottawa; Ibrahim Gedeon, whose tireless membership development has received international attention; Adam Skorek, whose work to develop an educational program for Canadian members has attracted attention far beyond our borders; Paul Freedman, who has selflessly devoted much of his spare time to producing this magazine, and in the process, producing something our members say they want, namely more applications-oriented articles; Michel Lecours, who single handedly reduced the costs of our Journal to affordable proportions; and Louis-André Poulin, our treasurer, who has kept us on track, invested our reserves wisely, and kept us well in the black.

Oh, sure, I could remark on the great student programs developed by Tim Chia and Peter Smith, the plans for a new professional program Ken Butt has developed, or the new awards program Mo El-Hawary put together, but I don't have room. Then there are the countless Section and Council executive members who put in long hours in developing local programs for their members. I thank them all for their help, their wisdom and their dedication. They are what makes IEEE Canada the most rewarding region to serve in all of IEEE.

RAPPORT DU DIRECTEUR

Mon mandat à titre de directeur et président d'IEEE Canada tire à sa fin. Linda Weaver, votre prochaine présidente, entrera en fonction le 1er janvier 1996. Elle a déjà commencé à s'attaquer à quelques problèmes difficiles, le premier étant la base de données peu précise des membres d'IEEE Canada. Comme elle l'a déjà signalé au cours de la réunion régionale en septembre, nous accordons peu de confiance à toutes les listes des membres que nous avons reçues du bureau chef, et ce depuis 1993. Toutefois, avec l'aide de nos sections, nous espérons être en mesure de mettre à jour, d'ici quelques semaines, une liste plus fiable des adresses et profils de nos membres.

Nous nous sommes aussi rendus compte que le transfert des données d'un nombre important de nos membres provenant de la Société canadienne de génie électrique et informatique (SCGEI) n'a pas été enregistré correctement. Nous nous efforçons de rectifier ces erreurs le plus rapidement possible. Cecilia Weaver, notre nouveau chef du département des activités régionales, a assisté à la réunion régionale de septembre et s'engage à nous aider. Je connais Cecilia depuis longtemps, ayant beaucoup travaillé avec elle, et je puis vous dire qu'elle a été une bénévole dévouée et efficace pendant de nombreuses années avant de devenir membre du personnel.

L'un des services que nous espérons pouvoir développer davantage pendant le mandat de Linda est le système électronique d'IEEE qui offre maintenant certains services aux membres canadiens tels que des adresses internet (member.services@ieee.ca), des sites WWW offrant divers services et un serveur de fax.

Nous devrions être aussi en mesure d'offrir aux membres d'autres services au Canada. Par exemple, par l'intérmédiaire d'IEEE nous pourrons leur proposer de l'assurance automobile et habitation, de l'assurance vie (temporaire et universelle), un service de messagerie par avion, des services de déménagement (NAVL), des prix réduits sur des services de copies (Kinko's), un service de location de voiture à rabais et enfin un service d'agence de voyage. On compte offrir les services suivants : des fonds mutuels outre-mer (fin 95), une carte de crédit internationale (fin 95), une carte de crédit canadienne (début 96), de l'assurance pour les petites entreprises (96), des réductions sur achat d'ordinateurs (96) et de l'assistance téléphonique (début 96). Pour mieux connaître ou profiter de ces services, vous pouvez contacter Ron Morton à l'adresse suivante : "r.morton@ieee.org". Pour vous offrir les meilleurs services possibles, nous devons connaître vos besoins, si vous avez des demandes particulières, faites le savoir à Linda ou à moi-même.

Certaines difficultés se sont accentuées ces dernières années et la direction d'IEEE pense que le moment est venu de restructurer le Conseil. Dans le numéro de juin du newsletter "The Institute", nous avons résumé les trois scénarios possibles et nous vous avons demandé de nous faire connaître votre point de vue.

Il est très important que chaque membre donne son avis sur ces questions. J'ai quelques inquiétudes sérieuses à propos des trois scénarios, essentiellement pour les raisons suivantes :

1) dans les trois cas, nous risquons de ne plus pouvoir assurer le suivi des activités du personnel.

2) les trois structures proposées par le Conseil vont compromettre le caractère international d'IEEE. J'estime que nous devrions évoluer progressivement en fonction de notre situation actuelle pour rectifier les problèmes à mesure qu'ils sont identifiés. Des changements radicaux pourraient bien détruire nos acquis. Henri Shein reccueille actuellement ces renseignements pour le Comité. Faites lui savoir ce que vous en pensez (h.shein@ieee.org).

La première conférence de la société conjointe IEEE Canada/SCGEI s'est tenue à Montréal en septembre. Renato Basisio, président de la conférence est à féliciter pour son travail. Plus de 400 personnes y ont assisté. Toutefois, nous pouvons faire encore mieux. La prochaine conférence se tiendra à Calgary en mai prochain, sous la présidence générale d'Om Malik. Je vous prie de bien vouloir y assister, de soumettre un article et de l'appuyer.

Cathie Lowell, notre administratrice régionale, continuera à vous servir, à répondre à vos questions, au nom de Linda pendant la durée de son mandat. Pour obtenir tous les renseignements nécessaires, vous pouvez la contacter à l'adresse : "lowell@ieee.org".

Pour conclure, je suis convaincu que je laisse en partant IEEE Canada entre bonnes mains. Votre comité régional continuera à représenter vos intérêts. Depuis deux ans, il a fait en votre nom des choses remarquables et je lui dois beaucoup pour ses loyaux services. Même si je ne peux ici mentionner tout le monde, je voudrais en remercier quelques-uns publiquement : Jacek Chrostowski, qui a mis en place notre système de communication électronique et installé le serveur d'IEEE Canada à Ottawa; Ibrahim Gedeon, qui n'a pas ménagé ses efforts pour attirer de nouveaux membres, ce qui lui a valu une reconnaissance internationale; Adam Skorek, qui a mis en place un programme de formation pour nos membres canadiens qui a suscité l'intérêt bien au-delà des frontières; Paul Freedman qui n'a pas ménagé son temps pour que soit publié à chaque trimestre "IEEE Canadian Review", tout en insistant davantage sur des articles liés aux applications; Michel Lecours, qui a su réduire les coûts de notre journal à des proportions raisonnables; et Louis-André Poulin, notre trésorier, qui nous a permis de rester sur la bonne voie, d'investir nos réserves avec sagesse et de garder notre bonne santé financière.

Il est certain que je pourrais vous parler des excellents programmes destinés aux étudiants mis au point par Tim Chia et Peter Smith; des projets d'un nouveau programme destiné aux spécialistes mis au point par Ken Butt; ou du nouveau programme de concours conçus par Mo El-Hawary, mais l'espace me manque. Il y a aussi les membres des sections et du comité exécutif qui ont consacré de longues heures à élaborer des programmes locaux pour leurs membres. Je les remercie tous de leur aide, leur sagesse et leur dévouement.

345-kv Polymeric Cable System Testing at IREQ

Hydro-Québec's underground transmission network, mostly installed in downtown Montréal (Québec), is mainly composed of 120-kV circuits (27) but also includes two at 315 kV. Until 1989, all of Hydro-Québec's high-voltage underground cables were self-contained oil-filled (OF) type. The OF paper-insulated cable and accessories have proven that they provide excellent reliability at the highest system voltage and current ratings. Although biodegradable cable oil is now standard, a perceived disadvantage of OF cables is the possibility of fluid leakage into the environment. The primary cause of oil leaks in modern cable systems is third party damage during construction work.

Extruded polymeric cables and accessories are an alternative to OF cables for underground high voltage cable systems 120-kV and above. Extruded crosslinked polyethylene (XLPE) insulated cables have the advantage that they are unpressurised and do not require monitoring equipment. XLPE insulation has a distinct advantage over OF insulation when the fire performance of the cable is an important consideration. Other advantages can also be outlined in favor of XLPE insulation such as: factory testing of components, ease and speed of installation, flexible splicing schedule, improved electrical performances (dielectric losses and capacitance) and its ability to outperform the 85°C continuous operating temperature of OF cable. XLPE cables and accessories technology offers 90°C condition operating temperature. Moreover, a comparative cost evaluation made in 1989 by Hydro-Québec between 120-kV XLPE and OF cable systems showed a 10-15% savings on the installation and maintenance costs in favor of polymeric insulated cable systems.

Since 1989, 120-kV XLPE insulated cables and accessories have been installed for three major circuits in Montréal (Québec). In view of the increasing electrical demand in downtown Montréal, new underground 315-kV circuits are planned to be installed in the years to come. However, at the present time there are no XLPE cable systems in service anywhere in the world using prefabricated (premolded) joints above 275 kV. The design of prefabricated joints at 315 kV (or 345 kV) required to operate at high stress levels still present the greatest technical challenge toward achieving repeatable performance and acceptable assembly times. Since the reliability of the cable and accessories is required to be at least on par with that of paper-oil insulated cables, and since there is no service experience worldwide at that voltage level for XLPE cables with premolded joints installed in manholes, there was definitely a need for a prequalification program for these materials.

This paper describes the program of the prequalification tests of 345-kV XLPE cables and accessories under way at Hydro-Québec's Research Institute (IREQ) in partnership with three cable manufacturers, Alcatel, Fujikura and Pirelli.

THE SCOPE

The main objectives of the prequalification testing program are:

- to assess the long-term reliability of the cable systems and in particular the premolded joints
- to ensure that the cable, premolded joint design and installation techniques are compatible with standard Hydro-Québec duct and manhole dimensions

by J.-L. Parpal. R. Awad and M. Choquette.
IREQ

Extruded insulation is an attractive technology for cables and premolded joints if utilities are interested in eliminating their dependency on pressure-monitoring systems. No premoulded joints for voltages over 275 kV are in service anywhere in the world and since all underground cables must be installed in duct banks and manholes in Montréal, Hydro-Québec has decided to proceed with a prequalification test program to assess the reliability of the cable materials and verify the cable and accessories installation methods to be used.

L'isolation extrudée représente une technologie intéressante pour les câbles et jonctions prémoulées si l'on veut éliminer le besoin de systèmes de surveillance de la pression d'huile. Comme il n'existe aucune jonction de type prémoulée, de niveau de tension supérieure à 275 kV en service à travers le monde et parce que tout les câbles souterrains doivent être installés en canalisation multitubulaire et chambre de jonctions à Montréal, Hydro-Québec a donc décidé de réaliser des essais de préqualification pour évaluer la fiabilité des matériels de câbles et de vérifier les méthodes d'installations de câbles et jonctions dans les chambres de jonctions.

Although the voltage level of the Hydro-Québec system is 315 kV, the test program is designed for 345 kV, which is the standard operating voltage for many electrical utilities in North America. Thus the long-term test, which is the first part of the test program, is being performed at 345 kV (phase-to-ground) so that these cables and accessories will be qualified for the North-American market. This implies that all type test voltages were those required for 345-kV cables and accessories. The type tests (based on Hydro-Québec technical specification SN-49.1 for 120 kV, 230 kV and 315 kV) on the cable, joints and terminations were performed by the cable manufacturers prior to the installation of the materials for the long-term testing.

THE TEST PROGRAM

The tests selected for this program are based on Conférence Internationale des Grands Réseaux Électriques (CIGRE) standards (Working Group 21.03), in which the aging conditions are designed to verify the life expectancy of the cable system and reveal any signs of degradation. The more severe conditions in the Hydro-Québec program are aimed at obtaining accelerated aging, which will provide useful data on the long-term dielectric performance of the various components and, also on the thermomechanical behavior of the entire cable system.

A test loop comprising cables and accessories in ducts as well as a joint in a manhole (rigid clamping point or free-expansion) has been set up at the Hydro-Québec's research facility in Varennes (Québec) as a replica of the utility's standard installations (Figure 1-3). This cable testing facility is unique in Canada and was specially designed to test cables rated from 120 kV up to 1200 kV AC or DC. Lengths of cables of 100-200 meters with joints can be tested in conditions similar to those in service, with thermal cycling, over periods of months. Experienced research personnel have successfully performed the delicate testing of the 500-kV DC (1989-90) and 800-kV AC (1992-93) paper-oil insulated cables.

Current transformers are used to heat the cable and thermocouples, placed along the surface of the cable, monitor the temperature. The conductor temperature is extrapolated every minute from the measured surface temperatures along the cable loop.

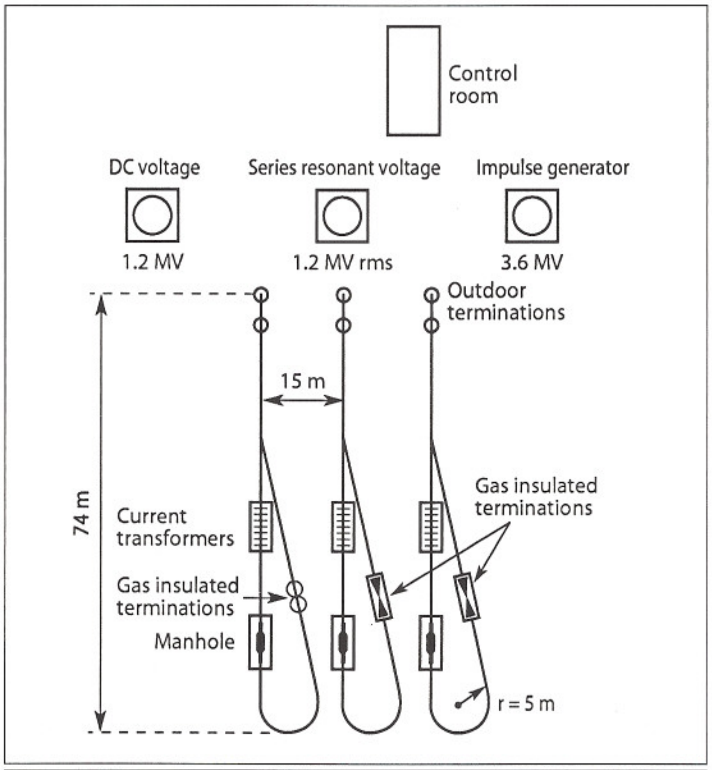


Figure 1: Installation scheme of the cable test loops

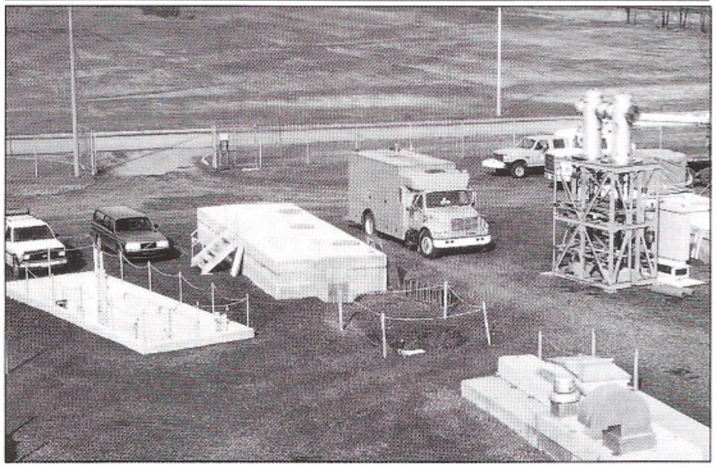


Figure 2: Current transformers, joint and SF_6 termination manholes

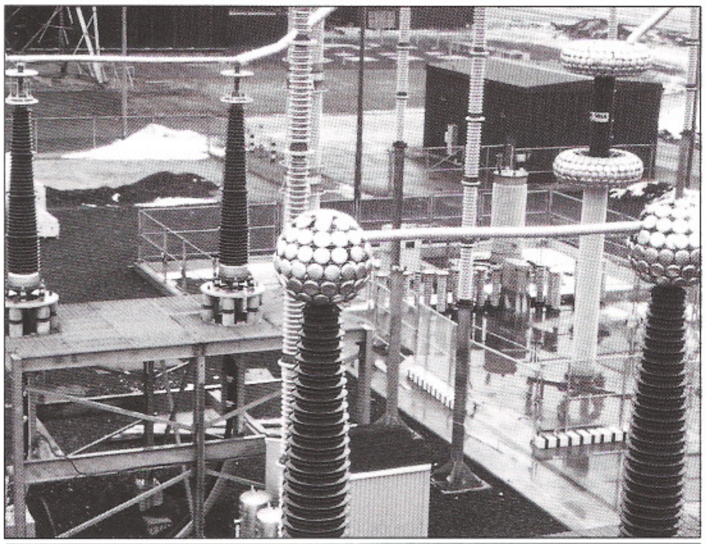


Figure 3: Outdoor terminations

Type Tests

The type tests (for description of tests see the Association of Edison Illuminating Companies standard, AEIC CS7-93) on the cable, joint and terminations are performed by the cable manufacturers before beginning of the long-term testing. The type tests are performed according to Hydro-Québec specification SN-49.1 in general, to International Electrotechnical Commission (IEC) 885-2 for partial discharges and IEC 230 for impulse testing.

Electrical Tests After Installation

Once the cables and accessories are completely installed at IREQ, an AC voltage is applied to the cable assembly. A 400 kV voltage (phase-to-ground) between the conductor and the metallic shield of an extruded cable for 15 min and the dielectric losses are measured.

Long-Term Test

The long-term test in the prequalification program is considered to be the best means of gaining some indication of the reliability of the proposed cable system. The accelerated aging resulting from more severe test conditions not only provides information on the dielectric performance of the different cable components but on the thermomechanical behavior of the cable system as well. Upon successful completion of the 400-kV test, each cable loop is subjected to voltage for the long-term test under the temperature and duration conditions listed in Table 1.

Table 1 : Long-term and limited type test conditions

Voltage	345 kV (phase-to-ground)
Duration	6000 h
Thermal cycling	8 h heating (95° C max.) 16 h cooling
tg δ	400 kV at 95°C
Lightning impulse test	1300 kV +10 and -10 at 95°C
Switching impulse tests	900 kV +10
AC test	450 kV 1h

Limited Type Tests

Following the long-term test, the cable and accessories assembly will be subjected to lightning and switching impulses and AC voltage (Table 1). These tests are intended to give some indication of any degradation in the insulating materials that could result from the long-term test.

Engineering Tests

Upon satisfactory completion of the limited type tests, the cable assembly will be subjected to a 60-Hz voltage breakdown test: the voltage will be raised in steps of 100 kV for 15 minutes until either failure of the insulation or flashover of the external terminations occurs.

THE MATERIAL TESTED

The respective characteristics of the Alcatel, Fujikura and Pirelli cables and accessories are summarized in Table 2. The cables were pulled in 200 mm diameter Epoxy Reinforced fiber glass (FRE) ducts. The joints were installed in manhole with the following dimensions: 11 m long, 3 m wide and 3 m high. Two types of prefabricated joints (sectionalised) are tested: an Ethylene-Propylene-Diene-terpolymer (EPDM) rubber monoblock slip-on type and a combination of premolded EPDM rubber, a compression device and an epoxy unit. The cable and joint installation in the manhole allows for the expansion and thrust of the cable as a result of the conductor temperature rise due to the load current. Two types of installation are presently tested:

- rigid clamping mode (joint and cable rigidly clamped)
- free expansion loop (cable laid on supports, forming an expansion loop on each side of the joint)

The manufacturers provided the SF_6 enclosures together with the SF_6 terminations and two types of configurations are tested:

- side-by-side (vertical)
- back-to-back (horizontal)

THE R&D PROGRAM

The test program also includes an R&D section co-funded by the Electrical Power Research Institute (EPRI) of the USA, which comprises thermomechanical measurements and calculations as well as a microphysical characterization. For the thermomechanical research, displacement and force sensors have been installed at the anchoring points in the manhole to record the stresses imposed during the tests. Since the manhole dimensions and cable-joint comply to Hydro-Québec's standard installations, it is planned to take a number of thermomechanical measurements during the long-term test to validate the behavior of the 345-kV test loop under the thermal conditions typical of cable operating in duct and, also, to compare the theoretical results with values measured during the thermal cycling. IREQ's thermomechanical model could then be used for future cable installations design without any new tests being required.

The microphysical measurements will be performed on samples from the laboratory-aged cable section and compared to unaged samples. The diagnostic methods to be investigated will include Fourier Transform Infrared (FTIR) and Ultraviolet (UV) spectroscopy, Differential Scanning Calorimetry (DSC), density, Time Domain Spectroscopy (TDS) and impurity measurements such as Proton Induced X-rays Emission (PIXE) and Neutron Activation Analysis (NAA). The goal is to develop a diagnostic method to evaluate any electrical aging of polymeric insulation that is not related to manufacturing defects.

SUCCESS CRITERIA

The long-term and limited type tests should be completed by the end of December 1995, and the thermomechanical calculations and

Table 2 : Summary of cable and accessories characteristics

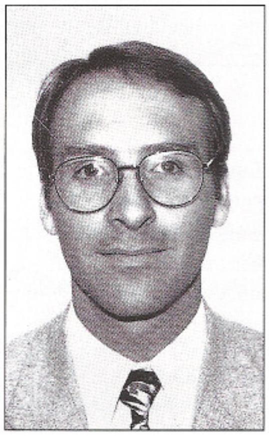
Component	ALCATEL	FUJIKURA	PIRELLI
Cable Section	Cu 1600 mm^2	Cu 1000 mm^2	Cu 1600 mm^2
XLPE insulation	26.6 mm	27 mm	25 mm
Metallic sheath	Lead alloy	Corrugated Aluminum	Lead alloy
Outer jacket	PE	PE	PE
Overall diameter	130 mm	140 mm	130 mm
Prefabricated joint	slip-on type	compression type	slip-on type
Outdoor terminations	EPDM stress cone in SF_6	Condenser-cone (paper/aluminum) in silicone oil	EPDM stress cone in silicone oil
SF_6 terminations	DPDM stress cone-in SF_6/SF_6	Condenser-cone (paper/aluminum) in silicone oil/SF_6	EPDM stress cone in silicone oil/ SF_6

microphysical characterization by the end of November 1996. The cable system must have completed the 6000 h (or equivalent) time test and passed the limited type tests without any electrical failure in order to be prequalified.

About the author

Dr Jean-Luc Parpal is a research scientist in the department of Cables and Insulation at the Hydro-Québec Institute of Research (IREQ). Dr Parpal received a BSc (1973) and MSc (1974) degree in Physics from University of Montréal (Québec) and a PhD (1982) degree in Engineering Physics from École Polytechnique of Montréal. Before joining the Cable and Insulation department in 1987, he was with the Internal Insulation department since 1982. He is currently involved in the study of the degradation mechanisms and electrical diagnostics of polyethylene insulation under electrical and mechanical stresses. He is the project leader of the prequalification testing program for 345-kV XLPE cables and accessories.

Ray Awad obtained his B. Sc. in Electrical Engineering from Cairo University in 1966. After immigrating to Canada in 1968, he completed his Masters Degree in Electrical Engineering in 1973 at Concordia University in Montreal (Québec). He joined Pirelli Cables Inc. in 1969 as a cable engineer. When he left Pirelli in 1979, he was Manager the of Cable Design Group. At Hydro-Québec, he is a section head responsible for overhead and underground transmission line design.



Martin Choquette obtained his B. Sc. in Electrical Engineering from École Polytechnique in Montreal (Québec) in 1986 and completed a Masters of Engineering at McGill University in Montreal. He joined Pirelli Cables Inc. in 1986 as a high voltage cable design engineer. Since 1990, he works in the department of overhead and underground transmission at Hydro-Québec as a Project Engineer in high voltage underground and overhead lines.

What CONAC Can Do For You

There are a significant number of technical meetings held each year under the auspices of the IEEE. These meetings, whether large or small, entail a great deal of effort on the part of the organizing team of the conference or symposium. Some technical meetings are annual affairs with a long-standing organizational history, others are infrequent or one-time events that have no pre-established structure or routine to fall back on.

Most organizing committees, involved in either long-standing or infrequent conferences, consist of new people who may be inexperienced and may require some information, guidelines or tips for running a successful conference. The IEEE Canada Conference Advisory Committee (CONAC) provides such a service to its membership (Sections and Chapters). CONAC is an Operating Committee of the IEEE, reporting to the IEEE Canada Board of Directors, with a specific mandate to facilitate conference organization.

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THE RADARSAT PROJECT

by Anthony Luscombe. SPAR and Shabeer Ahmed, CSA

Canada's advanced developments in airborne imaging radar have been described in a series of articles in previous issues of this magazine. This final article describes the most ambitious Canadian development so far, the synthetic aperture radar (SAR) system on the RADARSAT satellite. RADARSAT is Canada's first remote sensing satellite, and the radar is the most advanced operational civilian satellite sensor of its type. The radar is capable of operating in many different modes to provide images covering large ranges of resolution, area coverage and angle. The satellite is scheduled for launch in Autumn 1995 with a design life of five years.

Les progrès du Canada dans le domaine de l'imagerie radar aéroportée ont été décrits dans une série d'articles parus au cours de la dernière année dans cette revue. L'article final décrit le projet canadien le plus ambitieux à ce jour, le radar à synthèse d'ouverture (RSO) équipant le satellite RADARSAT. RADARSAT est le premier satellite de télédétection canadien, et le radar qui le caractérise est le détecteur satellitaire civil opérationnel le plus perfectionné du genre. Le radar peut fonctionner dans plusieurs modes différents afin de fournir des images offrant une gamme étendue de résolutions, de couvertures et d'angles. Le satellite doit être lancé à l'automne 1995 et sa durée de vie calculée est de cinq ans.

Over the last two decades, considerable Synthetic Aperture Radar (SAR) expertise has been built up in Canada through development and operation of the airborne SAR systems described in previous articles in this magazine, and through use of the image data in many land, sea and ice applications. This article describes Canada's most ambitious SAR development so far, the system on the RADARSAT satellite launched in Autumn 1995. (At the time of writing the precise date was not known due to launch vehicle uncertainties.) The fine resolution, large scale, all-weather imaging provided by spaceborne SAR is particularly valuable for Canada, with its vast land area, geographic location and extensive coastline. RADARSAT is Canada's first remote sensing satellite, the world's first non-military operational satellite SAR, and the first capable of truly global coverage. The SAR is highly versatile in its operations, capable of producing many different types of images to meet the needs of diverse applications. The project is a Canadian/U.S. collaboration, with the launch as the U.S. contribution. The satellite has been funded largely by Canadian federal and provincial governments through the Canadian Space Agency (CSA), and Canadian industry has been responsible for the design and implementation of both the satellite and the SAR sensor. Canadian companies also developed the ground segments of the system which control satellite operations, and receive, process, analyse, calibrate and distribute the image data. The satellite has been designed to operate for five years, with plans for follow-on satellites ensuring a supply of data well into the next century.

Although the same essential synthetic aperture technique applies for satellite and aircraft sensors, there are significant differences--both advantages and disadvantages--to be taken into account when designing a spaceborne system. These aspects are discussed in the first section, which is followed by a section describing important features of the RADARSAT SAR designed to take advantage of the opportunities of imaging from space. The third main section provides a picture of the overall RADARSAT system, covering elements such as the Mission Control, the Ground Reception and Processing Facilities, and the distribution network, as well as the space segment. All elements are important in an efficient operational system which converts data requests into imaging operations, and processes the resulting data into quality images delivered on time, to users. The final two sections cover important Canadian applications, and plans for future RADARSAT missions providing both continuity and enhanced capabilities.

Satellite SARs

Descriptions of the basic synthetic aperture imaging technique given in the previous articles on aircraft systems apply equally well to a satellite SAR. The main differences for a spaceborne system arise from the greatly increased distance from the ground, and the satellite flight characteristics. The potential resolution is virtually independent of altitude, but to achieve this fine resolution, a satellite SAR must fly much further to form the synthetic aperture than an equivalent airborne sensor. The greater demands on the satellite system are therefore in the coherent processing task, and in the increased power that must be transmitted.

A major potential benefit of the satellite altitude is the increased area of the Earth's surface accessible for imaging. SAR sensors always image areas to one side of the flight path, and from an aircraft, coverage is limited by the horizon. From the RADARSAT altitude of 800km, however, a region of several thousand kilometres is potentially within line of sight. Unlike the SAR systems currently flying on ERS-1, ERS-2 (ESA) and JERS-1 (Japan), where the swath is at a fixed angle and is limited to 100km or less, the RADARSAT SAR sensor is designed to exploit the potential large field-of-view to give wide and selectable coverage, as explained below.

Because a satellite sensor is inaccessible after launch, it must operate reliably for several years without any opportunity for manual control, adjustment, maintenance or repair. Wherever possible, therefore, redundant components and subsystems are included to cover failure in the primary units, with switching and command structures designed to cover all contingencies. Benefits of having the SAR permanently orbiting the Earth, however, are its longterm continuous deployment, rapid geographical mobility, and regular and systematic flight pattern. The satellite cannot be redirected to cover a specific area, but any area of the Earth will be in view within very few days: a maximum of three days at Canadian latitudes, for example, or five at the equator. Regular repeat coverage can also be provided over the five year design life to detect changes or track developments. Having designed reliability into the system, and having placed it in orbit, it will reliably provide consistent images without uncertainties caused by the logistical problems, local weather conditions and pilot idiosyncracies of airborne systems.

RADARSAT SAR Design and Modes

The RADARSAT SAR operates at a C-band frequency of 5.3GHz with horizontal polarisation. The principal innovation of this system is its versatility of operation, with imaging modes to provide a wide variety of types of data. Very few satellite SARs have been launched, and all three systems active in 1995 are limited to imaging with fixed values for the main parameters: swath width, resolution and incidence angle. By contrast, the RADARSAT modes illustrated in Figure 1 allow imaging of

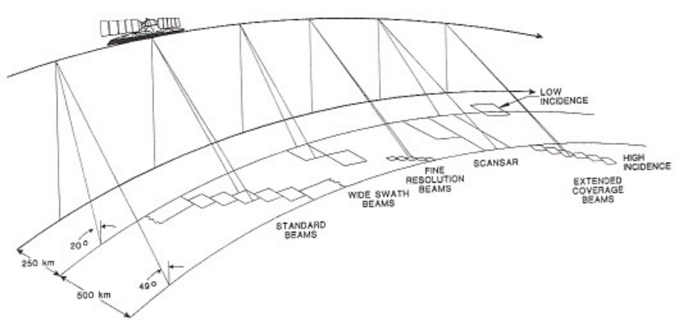


Figure 1: RADARSAT SAR Imaging Modes

swath widths from 50km to 500km, at resolutions from 8m to 100m, and at incidence angles from 20° to 50° (extended to 10° to 60° with experimental modes).

Two of the principal design features which provide this versatility are the antenna's length and its elevation beamforming capability. The antenna is a rectangular array, 15m in length and 1.5m in width. The length, 50% greater than ERS-1, is important because it produces a narrower beam in azimuth, and therefore restricts the Doppler bandwidth of the signals returned from the ground. This, in turn, allows the system to operate with a lower pulse repetition frequency (PRF) without undersampling the signal, and therefore leaves larger gaps between pulse transmissions for reception of the returns from a wider swath. This is particularly significant in allowing imaging at higher angles because the duration of the return from a given swath width increases rapidly with angle.

The elevation beamforming is achieved by phase control across the antenna aperture, allowing the beam width, shape and direction to be adjusted to give coverage of the required region broadside to the satellite. For conventional SAR imaging, a single beam is used to image along a swath parallel to the flight track. Each of the set of seven Standard Beams, for example, images a 100km swath, but at incidence angles which vary from 20° for Beam 1 to nearly 50° for Beam 7. With the appropriate choice of beam, therefore, RADARSAT can image anywhere within a region of over 500km (over 900km including Extended Coverage Beams). Unlike previous systems, RADARSAT uses the satellite's large potential field-of- view to considerably improve imaging access and repeat frequency, but also to allow imaging at incidence angles optimum for each application.

The RADARSAT antenna is inherently capable of switching between beams in a few microseconds. This capability is not required for conventional SAR imaging, but has been exploited in a special 'ScanSAR' mode which images swath widths of up to 500km by combining the coverage of two to four separate beams. The radar transmits and receives a burst of pulses with one beam, before switching to another beam for the next burst, and so on around the set of beams. The segment of the swath imaged with each burst is much longer than the distance moved by the satellite in collecting the signal, and so continuous coverage is maintained with all beams. Because the radar operations are shared between beams, the potential resolution in this mode is correspondingly coarser. RADARSAT is again the first system with this capability.

In the trade-off between resolution and swath width, the Fine Resolution mode does the reverse of ScanSAR, providing resolutions of 8-10m across swaths of about 50km. This mode adds minimal complexity to the system since the narrower beams and finer resolution pulse are just extensions to sets already required. With the full set of modes, the system thereby provides options covering a full order of magnitude in both swath width and resolution, with the Standard Beams providing a compromise option, but over a large choice of angles. Performance for these modes is summarised in Table 1.

All modes produce data at a consistent rate of around 100 Mbps, compatible with the capacity of the X-band data downlink. To avoid limiting imaging to times when the satellite is in contact with a ground receiving station (as with ERS-1), the payload includes high data rate tape recorders which can store data for over 10 minutes of operation. The subsequent playback transmission to the ground is on a second downlink channel, and can be simultaneous with another imaging operation. Any point on the Earth's surface which falls within the accessible angles to the right side of the satellite can therefore be imaged. At the RADARSAT orbit altitude of about 800km, and inclination of 98.6°, this includes the entire globe except a circular region of 10° latitude around Antarctica. To fill this gap, the spacecraft will be rotated 180° to face to the left for two periods during the mission. This will make RADARSAT the first satellite SAR to image the region, and the first remote sensing satellite to provide truly global coverage.

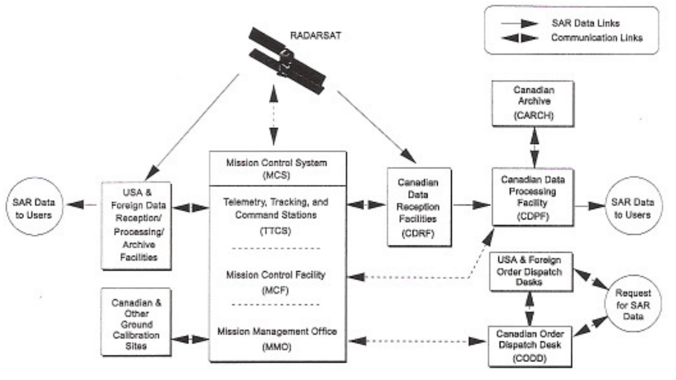


Figure 2: The RADARSAT System

Table 1 : RADARSAT Performance Summary

MODE	RESOLUTION RANGE AZIMUTH	NUMBER OF LOOKS	SWATH WIDTH	INCIDENCE ANGLES
STANDARD BEAMS (7)	24m X 2 m	4	105 km	20° - 49°
WIDE SWATH BEAMS (2)	32m x 26m	4	158 km	20° - 39°
FINE RESOLUTION (5)	9m x 8 m	1	49 km	37° - 48°
EXTENDED COVERAGE BEAMS				
Low Incidence (1)	43m x 26m	4	170 km	10° - 23°
High Incidence (6)	19m x 26m	4	75 km	49° - 59°
SCAN SAR				
2-Beam	35m x 30m	1	310 km	20° - 39°
	100m x 100m	14		
4- Beam	34 m x 52 m	1	520 km	20° - 49°

Values are averaged performance figures across a given set of beams.
Two alternative forms of image are listed for each ScanSAR option.

The RADARSAT Operational System

An essential requirement for RADARSAT is that it be an operational system, reliably providing quality SAR data in response to users' orders. The space segment is only one element of the overall system needed to achieve this (Figure 2). The main chain of events starts at the bottom right of the figure with reception of requests for SAR data products at the order desks. If the archives contain no suitable data, the request is forwarded to the mission planners for inclusion in the acquisition schedule. The Mission Control System (MCS) generates a file of time-tagged commands for each day's operations for uplink to the satellite. Commands for 24 hours of autonomous operation can be stored on-board, and as each command is executed, the data are either recorded for subsequent downlink to Canadian ground stations or transmitted directly to stations in Canada or abroad. The raw SAR data are then transferred to processing facilities, and from there the desired product is sent to the customer.

A new company RADARSAT International (RSI) was established to provide an efficient interface between the system and users. RSI accepts domestic and foreign orders for data and distributes the products globally, and the company is also responsible for negotiating agreements with foreign stations for direct reception of RADARSAT data. RSI provides one part of the Canadian Order and Dispatch Desk (CODD), which is a distributed subsystem with work stations serving the various partners and user groups. Each station collates requests from its own user constituency, and the RSI station connects to client "feeder terminals" outside Canada and the USA. In addition to taking requests for data, work stations can help customers to plan data requests, search the catalogue, examine acquisition plans and track the progress of requests through the system.

All system functions and transactions are controlled by the three parts of the MCS: the Mission Management Office (MMO), the Mission Control Facility (MCF) and the Telemetry, Tracking and Command Stations (TTCS). The MMO is responsible for implementing the operations plan, for optimizing system performance and use within the technical constraints, and for minimizing operational risks. The MMO approves schedules for spacecraft maintenance and data acquisition, and monitors and reports system performance. This requires coordination of orbit manoeuvres and "housekeeping" activities, as well as SAR on-times and mode selections, tape recorder usage, receiving station availability, processing priorities, and calibration activities.

The MCF controls and manages spacecraft operations, including orbit maintenance and spacecraft health, by generating commands and monitoring their execution. The MCF is responsible for the acquisition of the spacecraft after launch, for deployment of solar arrays and SAR antenna, and for all subsequent check-out and commissioning sequences. The MCF is linked to two TTCS, in St.-Hubert, Quebec and in Saskatoon, Saskatchewan, which track the spacecraft, and exchange commands and telemetry with it. In addition, NASA's Deep Space Network can be used for launch and early orbits and subsequently in emergencies or special manoeuvres.

Existing Canadian receiving stations at Gatineau, Quebec and Prince Albert, Saskatchewan have been modified to allow simultaneous reception of both SAR data downlink channels, and NASA receives data at its Fairbanks station in Alaska. A network transfers data from both Canadian stations to the Canadian Data Processing Facility (CDPF) at Gatineau for processing. This facility has sufficient speed and throughput capacity to meet the requirements currently identified, with provision for upgrades as demand increases during the five-year operational phase.

The overall system has been built by companies from across Canada. The satellite and SAR sensor prime contractor is Spar Aerospace in Sainte-Anne-de-Bellevue, Quebec, with hardware supplied by CAL Corporation in Ottawa, ComDev in Cambridge, Ontario and SED in Saskatoon, Saskatchewan. In the ground segment, MDA in Richmond, B.C. developed the MCS and CDPF, Array Systems in Toronto have built a SAR processor and supplied data analysis workstations for the MCS and CDPF, and MPB Technologies in Dorval, Quebec built the precision transponders for the calibration sites. RSI, which operates order desks and distributes products, is based in Richmond and Ottawa. There are also many companies and organisations across the country developing techniques and software tools for assorted data applications such as ice mapping, and forest and agriculture monitoring.

Applications for RADARSAT Data

The airborne systems have provided considerable experience in various SAR data applications in Canada. Although the data generated by RADARSAT is applicable in many of the same areas, the data characteristics and acquisition patterns are not the same. Characteristics of RADARSAT which make it a valuable new source of data are the regularity, consistency and longevity of its supply, its large scale coverage and global access, and the choice of angles and resolutions. RADARSAT therefore extends the possible applications of remote sensing data both by supplementing the range of data and complementing existing sources. A few of the most important applications anticipated for RADARSAT data are described briefly here. (For detailed information, see reference.)

Ice monitoring has always been seen as one of the principal operational applications for RADARSAT. The system is capable of imaging any area of sea around Canada at least once every three days, and the more northerly regions daily. Rapid data processing and transfer allow the Canadian Ice Centre in Ottawa to maintain updated information for ship routing, principally on ice concentrations and on the location of the ice edge, but also classifying ice types and identifying potentially dangerous features such as ice ridges. RADARSAT can also provide valuable data for cryospheric science, for example in understanding longer term climatological developments.

Options across the full range of RADARSAT modes are required for different ocean applications. Fine resolution modes are needed for measurement of finer scale wave structures. The wide RADARSAT coverage will be valuable to image large scale features like surface wind and internal wave patterns, and to perform large area monitoring of the sea, for example for oil discharges. All ocean features are expected to be clearer for imaging at steeper angles, but the relative weakness of the ocean reflectivity at shallower angles will enhance detection of vessels.

Important land applications for RADARSAT images include agriculture, hydrology and forestry. The satellite will provide map data over large areas with information, for example, on land use, on the vegetation coverage and crop condition. As input to a hydrological data base, SAR images show clearly the extent of snow cover and open water, and provide information more generally on water content in the soil. With a regular supply of a consistent form of data from RADARSAT, techniques demonstrated using limited amounts of data can become part of standard monitoring procedures.

All applications outlined so far require regular supplies of data for routine monitoring operations, with repeat coverage varying from days for oceans and ice, to months or years for forest mapping. The long term availability and regular orbit pattern of a satellite ensure that all can be served. Completely different demands of other applications can also be fulfilled, however. For geological studies, for example, comprehensive fine resolution coverage of a particular area could be obtained with a systematic imaging schedule over a limited period. At the other extreme are the imaging requests which arise in emergencies, to map flooding in a remote area, for example, or to determine the extent of damage from a violent storm. In these situations, imaging may not be possible immediately, but is guaranteed within a short period by RADARSAT's wide field-of-view.

Conclusion

RADARSAT is the first Canadian remote sensing satellite. The satellite is the first operational spaceborne SAR system, and its radar is the most advanced civilian SAR system to be flown, allowing imaging in a number of different modes, covering a wide variety of angles, resolutions and swath widths. The system has been designed to operate for a five year mission, and planning is already underway for RADARSAT II and its successors. The series must ensure a continuous supply of consistent data to meet the ongoing needs of established users, but additional imaging capabilities are also under consideration for future satellites. Some of these enhanced capabilities, such as multi-frequency, multi-polarisation and Spotlight imaging, have been developed from the experimental stage into established techniques with Canadian airborne systems described in previous articles. This therefore continues the process seen in the first RADARSAT mission whereby pioneering Canadian work in SAR techniques feeds into an operational system. With RADARSAT and the complementary operational airborne SAR capabilities of systems like STAR-1 and its successors, Canada is well-placed to maintain its position as a leading international supplier of commercial SAR data.

Reference

RADARSAT, Canadian Journal of Remote Sensing, Special Issue, Vol. 19, No. 4, Nov-Dec 1993.

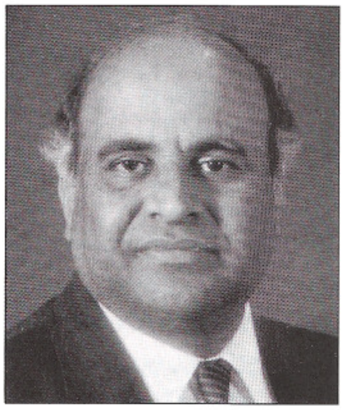
About the authors

Anthony Luscombe has worked in synthetic aperture radar design and analysis ever since leaving university to join Marconi Research Centre in Great Baddow, England in 1977. His educational background is in mathematics, with B.A. and M.A. degrees from St. John's College, Cambridge in England. After working on the concept and feasibility stages of the European Space Agency's ERS-1 SAR, he joined the RADARSAT team at Spar Aerospace in Ste.-Anne-de-Bellevue, Québec in 1984. During his period at Spar, he has been responsible for the conceptual design of the SAR, and for aspects such as mode definition, performance assessment and image calibration.

Shabeer Ahmed holds a Ph.D from the University of Waterloo in mechanical engineering. He began his career in spacecraft technology in 1969 at SPAR Aerospace in Toronto as a research and development engineer on spacecraft mechanisms for spectrometers and lunar sounder antennas for the Apollo 15, 16, and 17 missions, and the World's first Flexible Roll-Up Solar Array (FRUSA). Later, he participated in the design and development of the solar array, attitude control, structure and thermal subsystems for the CTS-Hermes project and helped initiate the technology development effort on the Shuttle Remote Manipulator System (CANADARM). In 1982, he joined the RADARSAT Program to develop its space segment. Since 1989, he has led the end-to-end RADARSAT System Implementation team and is presently the Canadian Space Agency's Mission Director for the launch and commissioning phases of RADARSAT.

1995 McNaughton Medalist / *Médaillé McNaughton 1995*

Vijay K. Bhargava



Vijay K. Bhargava was born in Beawar, India in 1948. In 1966, he came to Canada and by 1974 had obtained the B. Sc., M. Sc. and Ph.D. degrees from Queen's University in Kingston, Ontario. He has held positions with the Indian Institute of Science, University of Waterloo, Concordia University, École Polytechnique de Montréal, UNIDO and NTT Wireless Communications Labs. Currently he is a Professor at the University of Victoria and a Fellow of the British Columbia Advanced Systems Institute.

Dr. Bhargava is the Founder and President of Binary Communications Inc. (established 1983), which has successfully developed in VLSI, a rate programmable Reed Solomon CODEC for applications in wireless communications and computing. He has provided consulting services to BNR, MPR Teltech Ltd., Mobile Data International, GE-Ericsson and to Departments of National Defence, Communications, Transportation and to Revenue Canada. His contributions and leadership in the development of error control coding devices have resulted in their commercial application for a large number of wireless communications systems.

Dr. Bhargava's professional life revolves around teaching, research and writing. He has developed a number of training courses for the practising engineer in the areas of personal communications systems, secure communications, mobile and satellite communications and error control coding techniques. In 1984 he developed the graduate program of the newly established Department of Electrical Engineering at the University of Victoria. He has supervised over 30 graduate students, several of whom now hold important positions in industry and academia. He is a co-author of Digital Communications by Satellite (New York: Wiley 1981) and a coeditor of Reed Solomon Codes and their Applications (IEEE Press 1994). He is Editor-in Chief of Wireless Personal Communications (Norwell, MA: Kluwer) and is on the Editorial Board of two other journals.

Dr. Bhargava has contributed significantly to learned societies. He revived the bilingual Canadian Journal of Electrical and Computer Engineering. He founded the Canadian Conference on Electrical and Computer Engineering and the IEEE Pacific Rim Conference on Communications, Computers and Signal Processing. The former has become a major national conference, while the latter has become a premier regularly scheduled IEEE Conference in the Pacific North-west. He has held numerous offices in the IEEE and is currently the Vice President of Regional Activities. A Fellow of the IEEE and the Engineering Institute of Canada (EIC), Dr. Bhargava has been honored many times by his colleagues. Amongst these awards are the IEEE Centennial Medal (1984), EIC Centennial Medal (1987), A. F. Bulgin Premium of IEE, U.K. (1987), EIC John B. Stirling Medal (1991), and the Applied Science and Engineering Gold Medal from the Science Council of British Columbia (1993). Vijay Bhargava is married to Yolande Henri of Warwick, Québec. They have two children, Alexandre (17 years) and Maude (14 years).

Vijay K. Bhargava est né a Beawar, en Inde, en 1948. Il est arrivé au Canada en 1966 et a obtenu en 1974 un baccalauréat, une maîtrise et un doctorat de Queen's University à Kingston, en Ontario.

Il a occupé différents postes à l'Institut indien des sciences, à l'University of Waterloo, à l'Université Concordia, à l'École Polytechnique de Montréal, à l'ONUDI et au NTT Wireless Communications Labs. Il est actuellement professeur à l'University of Victoria et membre associé du British Columbia Advanced Systems Institute.

Le Dr Bhargava est fondateur et président de Binary Communications Inc. (une société créée en 1983), qui a développé avec succès un CODEC Reed Solomon à intégration à très grande échelle et à vitesse programmable pour les applications informatiques et de communication sans fil. Il a fourni des services de consultation à BNR, à MPR Teltech Ltd., à Mobile Data International, à GE-Ericsson, aux ministères de la Défense nationale, des Communications, des Transports, ainsi qu'à Revenu Canada. Ses contributions et ses qualités de chef liées au développement de dispositifs de codage de contrôle d'erreur ont mené à l'application commerciale d'un grand nombre de systèmes de communication sans fil.

La vie professionnelle du Dr Bhargava est axée sur l'enseignement, la recherche et la rédaction. Il a élaboré de nombreux cours de formation à l'intention de l'ingénieur praticien dans les secteurs des systèmes de communications personnelles, des communications de sécurité, des communications mobiles et par satellite, et des techniques de codage de contrôle d'erreur. En 1984, il a conçu le programme de deuxième et de troisième cycles du nouveau Département de génie électrique de l'University of Victoria. Il a supervisé plus de 30 étudiants de 2e et 3e cycles dont plusieurs occupent maintenant des postes importants au sein de l'industrie et d'académies. Il est coauteur de Digital Communications by Satellite (New York: Wiley 1981) et rédacteur adjoint de Reed Solomon Codes and their Applications (IEEE Press 1994). Il est également rédacteur en chef de Wireless Personal Communications (Norwell, MA: Kluwer) et fait partie du comité de rédaction de deux autres revues.

Le Dr Bhargava a grandement contribué aux sociétés savantes. Il a fait renaître la revue bilingue canadienne de génie électrique et informatique. Il a fondé le congrès canadien en génie électrique et informatique et le congrès IEEE de la région du Pacifique sur les communications, les ordinateurs et le traitement des signaux. Le premier est devenu un important congrès national, tandis que le deuxième est devenu l'un des congrès les plus populaires de la Côte nord-ouest du Pacifique. Il a occupé de nombreux postes au sein de l'IEEE et est actuellement vice-président des activités régionales.

Fellow de l'IEEE et de l'Institut canadien des ingénieurs, le Dr Bhargava a été honoré à maintes reprises par ses collègues. Parmi ces prix, mentionnons la médaille du Centenaire de l'IEEE (1984), la médaille du Centenaire de l'Institut canadien des ingénieurs (1987), la médaille John B. Stirling de l'Institut canadien des ingénieurs (1991), et la médaille d'or des sciences appliquées et du génie du Science Council of British Columbia (1993), Vijay Bhargava est marié à Yolande Henri, de Warwick, au Québec. Ils ont deux enfants, Alexandre (17 ans) et Maude (14 ans).

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Call for Associate Editors

The ***IEEE Canadian Review*** has a large and well educated readership of over 13,000 people occupying important positions in industry, governement, and the research community in Canada. The publication of the Review represents a challenging experience. The incoming Managing Editor is now seeking volunteers to take on the responsibilities of Associate Editor. Volunteers should be particularly familiar with at least two of the seven areas of interest listed on the inside front cover, and be prepared to suggest four or five topics for future articles, seek out possible authors, and work with them to prepare manuscripts for submission to the Managing Editor. Appointments are for two year terms. Candidates are asked to submit their curriculum vitae to the new Managing Editor, Vijay Sood, at:

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Appel pour rédacteurs adjoints

La rédaction du ***IEEE Canadian Review*** pose de nombreux défis car les 13,000 lecteurs ont une formation technique avancée et se trouvent en industrie, au gouvernement et dans la communauté de recherche au Canada. Le nouveau rédacteur en chef est présentement à la recherche de bénévoles au poste d'adjoint à la rédaction. Les candidats doivent posséder une grande connaissance d'au moins deux des sept domaines d'intérêt affichés à l'endos de la page couverture. De plus, ils seront censés proposer quatre ou cinq sujets pour des articles futurs, identifier des auteurs potentiels et travailler sur la préparation des manuscripts à soumettre par la suite au rédacteur en chef. Les engagements sont d'une durée de deux ans. Les personnes intéressées sont invitées à faire parvenir leur curriculum vitae au nouveau rédacteur en chef, Vijay Sood, à l'adresse suivante :

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The Integrated Rural Delivery Network

A Collaborative Project to Provide Enhanced Electronic Access to Non-Urban Residents

by Steven M. Millan and Willis P. Martin
TeleCommunications in Health and Learning Inc.

Access to the electronic "Information Highway" is seen as a key enabling factor for economic development and community well-being in the rapidly developing knowledge-based economy. The Integrated Rural Delivery Network (IRDN) was developed by a public-private consortium in the Province of Newfoundland to address the electronic access needs of people who live outside large urban centres where the communications infrastructure is limited.

À l'heure actuelle, miser sur les connaissances fait en sorte que l'accès à l'autoroute électronique est perçu comme une des clefs à réussir le développement économique et bien-être communautaire. Le «Réseau intégré en milieu rural» est le fruit d'une concertation privé-publique en Terre Neuve destinée à fournir un tel accès aux gens qui habitent en dehors des grands centres urbains en tenant compte de l'infrastructure de télécommunications limitée.

Canada's communications world is undergoing rapid change in response to increasing demands, the development of new technologies and an evolving social, economic, political and business environment. Important trends affecting communications include the following:

- The growing importance of information as one of the key factors in the "new" economy.
- The globalization of the economy with its implications for borders that are open to competition.
- Industrial de-regulation (including the communications industry) and a greater reliance on market-driven mechanisms for the delivery of many services which were previously the preserve of governments.
- Constraints on government spending due to the magnitude of public debt, requiring continuou improvement in the cost-effectiveness of such services as education and healthcare.
- The rapid development of electronic technologies such as computing, communications and television accompanied by convergence among the various technologies and their applications.

With its advanced but relatively small economy, Canada is highly dependent on access to leading-edge communications. This dependency is further exacerbated by the geographic size of the country and the clustering of its population along the Canada-US border. In response to these dependencies and needs, Canada is among the world leaders in the development of advanced communications systems.

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The Province of Newfoundland is a leader in Canada in pioneering the use of communication technology for the provision of services and information to rural communities. Specialized facilities are widely distributed throughout the Province and the Telemedicine/TETRA network, for example, now reaches 225 sites in more than 152 communities. This operation, which has grown steadily over the past 16 years, delivers an extensive array of on-line distance education and telemedicine services throughout Newfoundland and Labrador and currently supplies in excess of 8000 hours of services per year.

The leadership role of Newfoundland in rural electronic access is not fortuitous but the result of a deliberate response to servicing the needs of a small population distributed widely over a large area. With a land mass more than three times the size of New Brunswick, Nova Scotia, and Prince Edward Island combined, Newfoundland and Labrador's population is just over half a million people, many of whom live in small communities.

While the benefits of electronic access are well recognized and there is general support among policy makers for the goal of universal access, financing the access system is a key issue which is especially critical in areas with small populations and low volumes of usage. By improving the cost-effectiveness of the delivery system, the Integrated Rural Delivery Network (IRDN) aims at improving rural electronic access in Newfoundland and elsewhere in Canada and the world where similar conditions exist.

The IRDN project was proposed in early 1994 and implemented at a cost of $600,000 by a broadly based consortium of private and public sector bodies operating in the Province of Newfoundland. CANARIE Inc. and the Atlantic Canada Opportunities Agency each provided one third of the funding with the remaining one third provided by the consortium. The members of the IRDN consortium are:

- Telecommunications in Health and Learning Inc., a private sector communications applications company owned by Newfoundland Telephone and Memorial University of Newfoundland;
- Newfoundland Telephone Company Limited, a major publicly traded communications provider in Newfoundland and Labrador;
- Compusult Limited, an independent private sector firm providing software development, computer consulting, system integration, internet access and value added reseller services.
- Enterprise Network Inc., a Provincial Crown Corporation which operates a value-added network for the provision of on-line economic development information for small business and

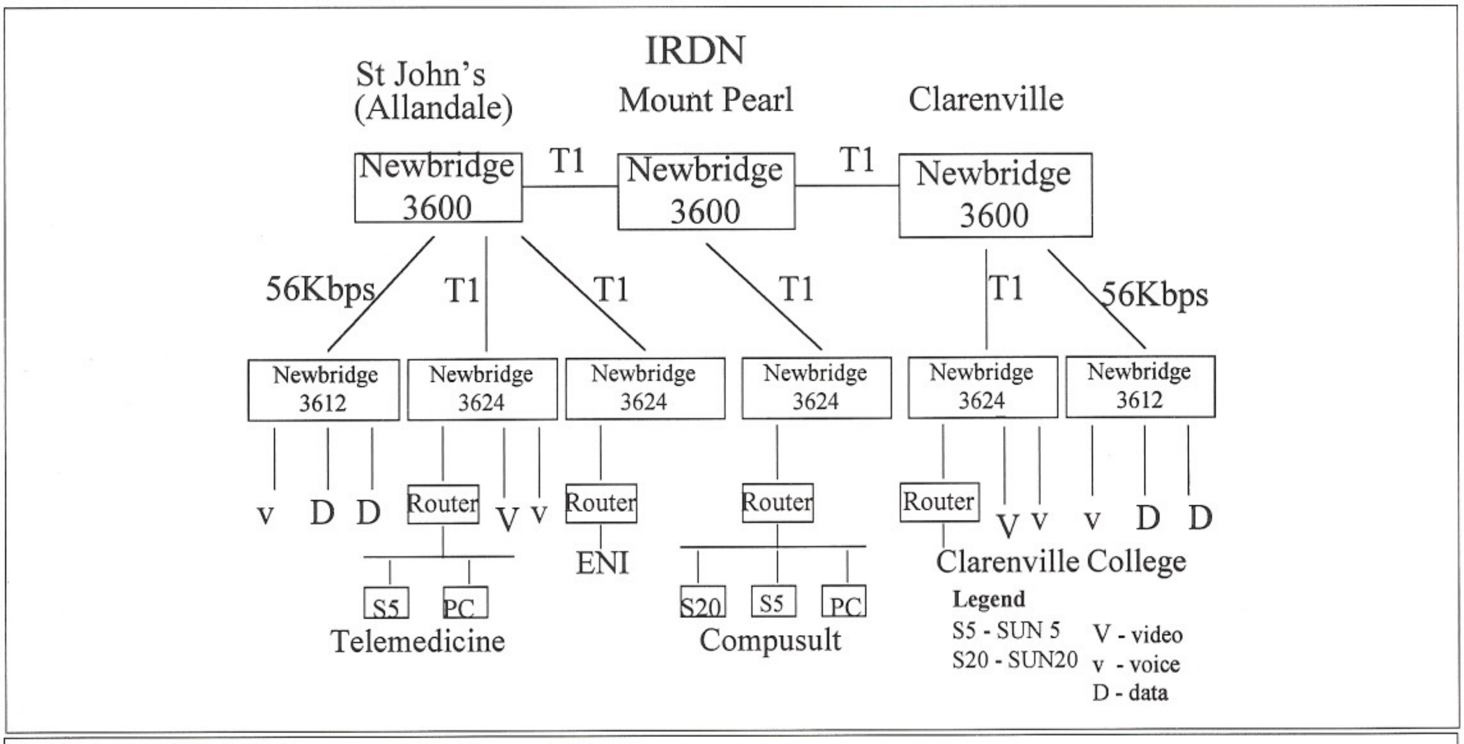


Figure 1: IRDN Layout

community development.

- Telemedicine/TETRA, a specialized facility of Memorial University of Newfoundland for the delivery of an extensive array of on-line distance education and telemedicine services throughout Newfoundland and Labrador.

The key problem addressed by the IRDN is the need for a cost-effective means of bringing the benefits of modern electronic access to rural communities. Such access enables the sharing of information and resources between urban centres and non- urban communities and the delivery of multiple services such as telemedicine, distance education, electronic commerce, telework and internet access.

The design philosophy of the IRDN is to produce efficiencies and cost-effectiveness through the sharing of facilities. This philosophy is embodied in two main system features: a common user interface and dynamic bandwidth sharing. Additional general design objectives include the following:

the system should be operable over a variety of existing communication systems from high end digital fibre to low end twisted pair copper lines; as a direct consequence of the previous objective, the system should provide broad access for rural users on existing communications infrastructure; the system should be migratable to improved communication facilities as these become available in the future.

The IRDN consortium has a continuum of interests from sservice providers, to technology developers, to product commercializers. The primary role of the end users in the consortium was in the production of detailed System Design Specifications based on their current and anticipated near-term needs. A related and equally important role was to determine if their design requirements had been met by the new IRDN technology.

While the user needs were specifically defined, the overall requirement was for a flexible communications system capable of carrying data, voice, images and compressed video. Transmission quality standards were set by the experience and operating needs of the consortium members who currently operate networks.

Project Description

Figure 1 depicts the overall layout of the IRDN test network. The backbone network consists of Newbridge 3600s Bandwidth Managers located at the Newfoundland Telephone central offices at St. John's, Mount Pearl, and Clarenville interconnected by T1 facilities. As shown in Figure 2 Clarenville is located approximately 200 km west of the twin cities of St. John's and Mount Pearl and serves as a regional communications and commercial hub. The network's associated Newbridge 4602 Network Manager is resident on the SUN SPARCstation 20 at Compusult. T1 access facilities and Newbridge access technology connect the backbone network to the three service providers (Compusult, ENI, and TETRA) and a client location (Clarenville Community College), also shown in Figure 1. The sizing of the backbone network is limited only by the capacity of Newbridge

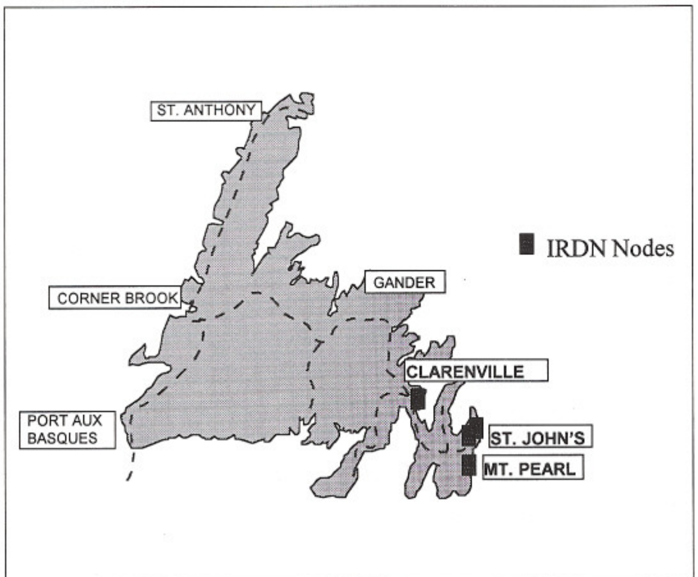


Figure 2: Map of IRDN Locations

3600s and the access facility is scalable up to T1.

A v.35 connection was provided on the Newbridge 3624 T1 Multiplexers for frame relay. For channel switching another v.35 connection was provided for video and two E&M cards for voice applications. Frame Relay accesses a maximum of 16 DS- 0s, video up to 6 DS-0s, and two DS-0s were allocated for voice. The Newbridge 3612 Narrow Band Multiplexers were equipped for one compressed voice (operating at 16 kbps) and two data circuits (one at 14.4kbps and the other at 9.6kbps) over 56kbps links.

ACC Danube routers were provided to derive a LAN connection to the Frame Relay channel at the four locations and the SUN SPARCstation 5 servers connect to this LAN for client access.

A Web browser is used to provide the user-friendly client software interface and the Newbridge Mainstreet technology is used to derive the network functionality. Server software developed on thgis project resides in SUN SPARCstations which controll and monitor the entire network. Use of a Web browser for client access provides for a familiar environment while system communication between the SPARCstation 5 servers and the SPARCstation 20 provides for dynamic application setup and takedown of channel switched services.

The Netscape Web browser displays the IRDN home page at the login screen. The browser offers a familiar screen to those who use the Internet and is very easy for the novice to learn. After appropriate login the user can select the service provider and from there the service of interest. A click of the mouse brings up the application and, in the background, dynamically establishes the network configuration required for the selected service.

From the IRDN Administration screen a number of functions are available for the administration of the network. These functions include:

- changes to account information,
- additions/changes to service applications,
- scheduling of services,
- recording of session data.

Applications Tested

The IRDN test network is fully functional, with frame relay and channel switching capability. Several applications related to the delivery of services to rural areas have been deployed and tested to the end of June 1995. A great deal of testing of the network components and the associated software modules took place as the system was developed, however, comprehensive testing by each of the service providers was carried out during the later stages of the project to determine compliance with the System Requirements Specification agreed to at the beginning of the project in mid-1994.

Telemedicine/TETRA

The Telemedicine/TETRA objective for IRDN was to run its provincial health and education programmes while sharing bandwidth on the network as far out to remote sites along the coast of Newfoundland and Labrador as is feasible.

Telemedicine/TETRA has an extensive telecommunications network which provided the opportunity to test the following applications:

- Audiographic teleconferencing (two-way voice and graphics);
- Video conferencing;
- Remote transmission of real time EEG signals, Ultrasound and Nuclear Medicine files.

Test results show that audiographic teleconferencing applications which combine voice and telewriter data (300bps) can be established on the IRDN by selecting the application on the client access terminal. The telewriter is an electronic whiteboard which permits two way transmission of handwriten text or graphics. Performance is at least equivalent to that realized on the existing configuration over the public network. With connection to the network via the Newbridge 3612 the combined voice and data signal can be compressed to the 16kbps level before corruption of the data prohibits use of the telewriter. At this sampling rate the voice is considered acceptable for teleconferencing. The setup and takedown capability of IRDN permits the rescheduling of the same bandwith for other teleconferences or other applications once the current teleconference is complete.

Testing of one voice and two data circuits over a 56kbps line using the Newbridge 3612 demonstrates an effective means of further bandwidth sharing to rural users that have digital access. (Digital switching and digital transmission facilities serves approximately 90% of the telephone subscribers in the Province of Newfoundland and Labrador). Allocation of bandwidth between the three services can vary with the application assuming that the voice channel is acceptable in the compression mode. This offers another level of potential cost reduction in the implementation of a complete network design. Dial access onto the IRDN from a location that does not have a digital connection operates the same as on the public network and was used for several tests.

The use of Frame Relay is a more effective method of transferring data across the network than the posting of a full time connection. A plan to do this by transferring Nuclear Medicine files to the Nuclear Specialist at the Health Sciences Complex from clinics in outlying areas was prepared in June 1995 and basic tests completed. Beta testing with the Nuclear Specialist will be carried out later in the year. This solution is also applicable for Ultrasound transmissions. Real time EEG transmissions were successfully demonstrated between the Clarenville hospital and the Health Sciences complex over a full time voice channel.

Assignment of channel switched bandwidth is not restricted to voice; video conferencing at 384 Kbps between Clarenville College and the Telemedicine Centre was also successfully demonstrated. Dynamic bandwidth setup was accomplished at the client software which can easily be programmed to assign the same backbone facilities to other user locations or to assign more or less bandwidth depending on the requirements and capacity of the network.

Enterprise Network Inc. (ENI)

The ENI objective for IRDN was to provide equitable, cost- effective access to the network throughout the province through the sharing of bandwidth and facilities with other organizations. The Enterprise Network provides access to business and economic information to enterprises throughout Newfoundland and Labrador, fostering regional development through a number of Telecentres. These Telecentres offer walk- in access to the ENI network.

ENI applications were tested successfully with the exception of applications based on DOS. The testing included shared use of the Newbridge 3612 with Telemedicine: ENI ran applications on one of the data ports while Telemedicine ran a voice and a data application on the other ports. Not only can ENI share bandwidth on the backbone network over Frame Relay but also to rural areas over a 56kbps line. Dial access onto the IRDN to run ENI applications was also demonstrated.

The use of DOS applications is fading in favour of Windows so the development of server software for ENI's DOS applications was given a low priority and time did not permit the completion of this work.

Compusult Ltd.

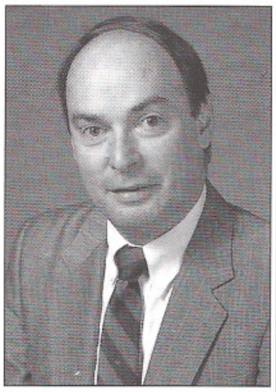
Compusult's IRDN objectives were to allow the company to provide an improved client software user interface to access Compusult Integrated Data Access System (CIDAS) for Environment Canada data and the company's Internet services, and to offer new client/server software and related consulting services to Canadian and International Markets. As described above the Web browser provides a user interface that meets the access objectives. By selecting the appropriate application the user is connected to the Compusult LAN from which access to CIDAS and Internet services are available. Access to these services over the full Frame Relay bandwidth will enhance the delivery of these services and thereby broaden their potential market.

Conclusions

The IRDN Project has produced a unique networking capability that has a wide range of applications in both the rural and urban marketplaces. The dynamic network setup and takedown capability for channel switched services in conjunction with the frame relay capability provides for maximum utilization of the network resources. The administration modules ensure that usage management is available to meet the operational needs of service providers.

A Marketing Plan has been developed which positions IRDN as a cost-effective network solution for rural and remote locations, where the availability and viability of ISDN and ATM technologies will be limited. The plan sets down marketing objectives and an action plan for commercialization of the IRDN as a product by early 1996.

About the authors



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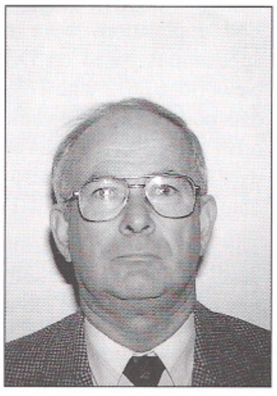

Willis P. Martin, P. Eng. is an Engineer with TeleCommunications in Health and Learning Inc. (THL) and has responsibilities for IRDN project management. Willis joined THL in 1993 after retiring from Newfoundland Telephone where he was responsible for planning and design of the provincial telecommunications network. His B. Eng. (Hons) was obtained from the Technical University of Nova Scotia and his M.A. Sc. from the University of British Columbia.

A few words from the Managing Editor

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It's with some sadness (and some relief) that I type these words as my two year mandate as Managing Editor of the IEEE Canadian Review draws to a close with this issue. More than anything else, I have tried to encourage a more technical slant to the magazine articles and a more balanced thematic distribution of topics, to better reflect the distribution of IEEE membership interests. As a result, the magazine has become, I hope, a showcase for technical articles about Canadian success stories such as IMAX and RADARSAT to name just two.

I'm proud of the new emphases I have brought to the Review and I'd like to think that by promoting such articles, we are reminded that there is technical and commercial excellence in Canada that we can and should be proud of. Note too that as of the Fall '94 issue, the articles which have appeared are available electronically (in compressed PostScipt format) at the IEEE Canada world wide web site (http://www.ieee.ca).

J'ai également instauré la traduction du rapport du directeur afin de rappeler aux lecteurs francophones que la société IEEE Canada s'adresse à tous les membres IEEE au Canada, peu importe leur langue maternelle.

Fully electronic destop publishing has helped to reduce magazine layout time and magazine preparation costs. And thanks to the Internet access provided by CRIM, my employer, I was able to work with my Associate Editors, authors of articles, etc. across the country in an efficient way.

But even in the most technological of disciplines, I believe that people still count more than products and bringing the right kind of stories to your mailbox is a collective effort. Once again, I gratefully acknowledge the help I have received from Vijay Sood, Ray Lowry, and Gerard Dunphy, and from my assistant Francine Riel here at CRIM. I hope that Vijay, in his new capacity as the next Managing Editor, will be lucky enough to find himself at the heart of similar team. For this reason, I call your attention to the «Call for Associate Editors» appearing in this issue of the magazine. The future success of the Review deserves and requires your continued support. And at just over 1$ per copy per issue, it seems like good value indeed for the money.