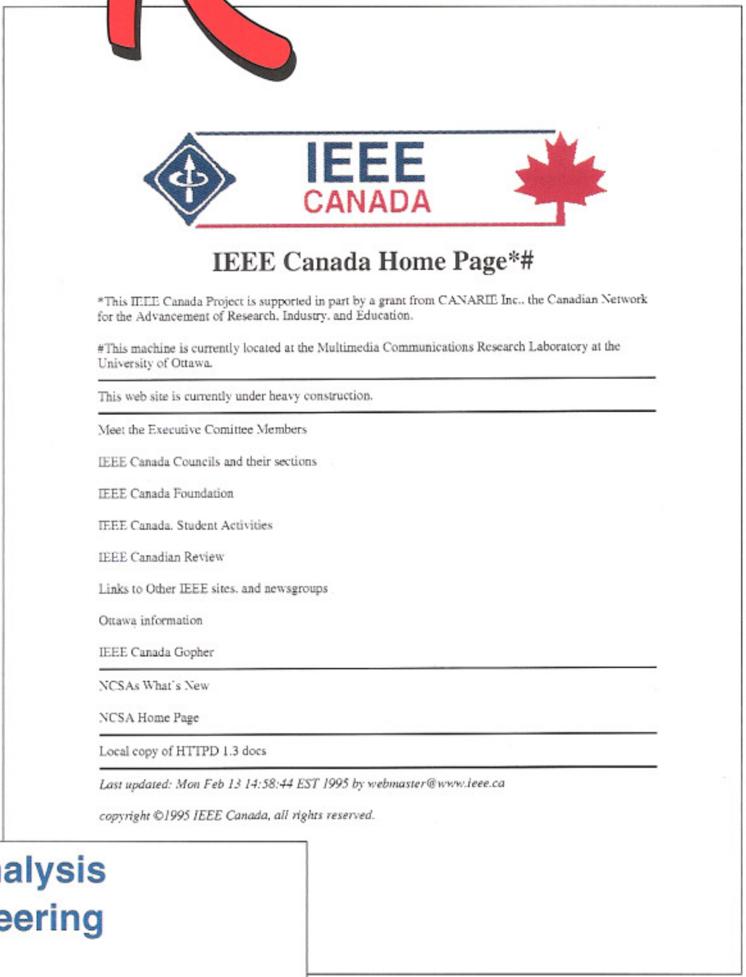
No 21

Winter
hiver 1995

IEEE Canadian Review


IEEE CANADA

IEEE Canada Home Page*#

*This IEEE Canada Project is supported in part by a grant from CANARIE Inc., the Canadian Network for the Advancement of Research, Industry, and Education.

#This machine is currently located at the Multimedia Communications Research Laboratory at the University of Ottawa.

This web site is currently under heavy construction.

Meet the Executive Comittee Members

IEEE Canada Councils and their sections

IEEE Canada Foundation

IEEE Canada. Student Activities

IEEE Canadian Review

Links to Other IEEE sites. and newsgroups

Ottawa information

IEEE Canada Gopher

NCSAs What's New

NCSA Home Page

Local copy of HTTPD 1.3 docs

Last updated: Mon Feb 13 14:58:44 EST 1995 by webmaster@www.ieee.ca

copyright ©1995 IEEE Canada, all rights reserved.

Canada Post / Postes Canada
Postage Paid / Port payé
Bulk third class / En nombre troisième classe
F1468
MONTRÉAL, P.Q.

IEEE

The Institute of Electrical and Electronics Engineers Inc.

IEEE Canada

IEEE Canadian Review General Information

The ***IEEE Canadian Review*** is published three times per year as follows: Winter (to appear in March); Spring/Summer (to appear in July); Fall (to appear in November).The ***IEEE Canadian Review's*** principal objective is to project an **image** of the Canadian electrical, electronics, communications and computer engineering professions and their associated academic and business communities to :

(i) Canadian members of IEEE;
(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.

To ensure that the ***IEEE Canadian Review*** has the desired breadth and depth, Associate Editors are responsible for identifying issues and screening articles submitted to the ***IEEE Canadian Review*** according to the following general themes :

1- National Affairs
2- International Affairs
3- Industry
4- Education
5- Power
6- Communications
7- Computers

Now IEEE related events and news of a topical nature may be published in the IEEE Canada E-mail/Fax newletter. Submissions should be E-mailed to the IEEE Newsletter Editor, Dr. Chris Barnard, at barnard@iit.nrc.ca.

Advertising Policy

It is the policy of the ***IEEE Canadian Review*** to invite organizations to place corporate advertising in the review. For information regarding rates and copy requirements, please contact the Managing Editor, Paul Freedman at the address shown below.

Circulation

The circulation of the ***IEEE Canadian Review*** is the entire membership of IEEE in Canada, representing over 12,000 readers.

Information for Authors

Authors are invited to contribute to the ***IEEE Canadian Review***. Submissions in electronic form are especially welcomed. Please contact one of the Associate Editors or the Managing Editor.

IEEE Canadian Review is published three times per year by IEEE Canada. IEEE Canada is the Canadian Region of the Institute of Electrical and Electronics Engineers, Inc. **Address:** CRIM, 1801 McGill College Avenue, Montréal, Qc H3A 2N4. Tel.: (514) 398-1234. Fax.: (514) 398-1244. Responsibility for the contents rests upon the authors and not the IEEE, or its members. **Annual Subscription Price**: free of charge to all IEEE members in Canada. For IEEE members outside Canada: $15 per year. Price for non-members: $24 per year. Corporations and libraries: $30 per year. Additional copies may be ordered at the cost of $5.00 each from the managing editor. **Change of address**: please send change of address directly to IEEE Service Center, 445 Hoes Lane, Box 1331, Piscataway (New Jersey) 0885. **Reprint Permission**: abstracting is permitted with credit to the source. Libraries are permitted to photocopy for private use of patrons. Instructors are permitted to photocopy isolated articles for non-commercial classroom use without fee. For other copying, reprint or republication, please write to the Managing Editor. Printed in Canada. Postage paid at Montréal, (Québec).

IEEE Canadian Review

Managing Editor
Rédacteur en chef

Paul Freedman
CRIM
(514) 398-1234
Montréal, Québec
freedman@crim.ca

Chairman, Advisory Board
Président du comité-conseil

Tony Eastham
Queen's University
Kingston, Ontario
Anthony.R.Eastham@QueensU.ca

Chairman, Editorial Board
Président du comité éditorial

Vijay Bhargava
Dept. of Electrical, Computer and Engineering
University of Victoria
Victoria, British Columbia
bhargava@sirius.UVic.ca

Associate Editors
Adjoints à la rédaction

Gerard Dunphy
Newfondland and Labrador Hydro
St. John's, Newfoundland
(709) 737-1323
gdunphy@engr.mun.ca

Vijay Sood
Institut de recherche d'Hydro-Québec (IREQ)
Varennes, Québec
(514) 652-8089
sood@ireq-sim.hydro.qc.ca

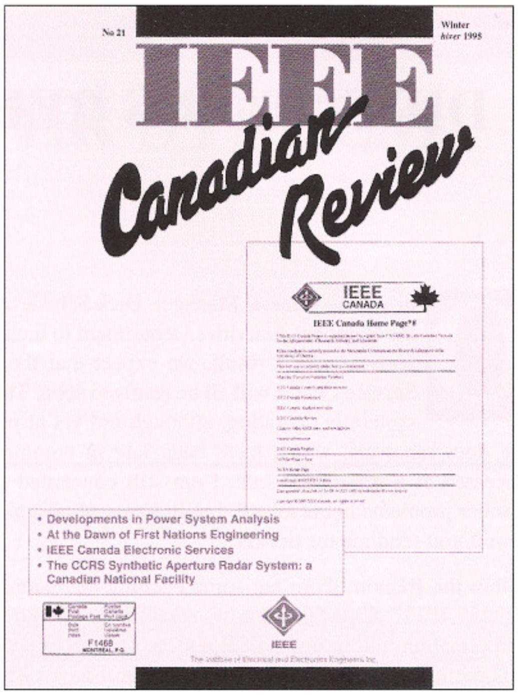
Ray Lowry
Intera Information Technologies (Canada) Ltd.
Calgary, Alberta
(403) 266-0900
rlowry@ims.calgary.intera.ca

Cover picture

This is the picture of the IEEE Canada "home page", the "front door" for news about IEEE Canada and its activities, accessible from the information highway "Internet".

Tableau couverture

Ceci est une représentation de «home page» d'IEEE Canada la «porte d'entrée» vers des renseignements sur IEEE Canada et ses activités qui sont accessibles par le biais de l'autoroute électronique «Internet».



CONTENTS / *SOMMAIRE*

DIRECTOR'S REPORT/*RAPPORT DU DIRECTEUR*

Ray Findlay

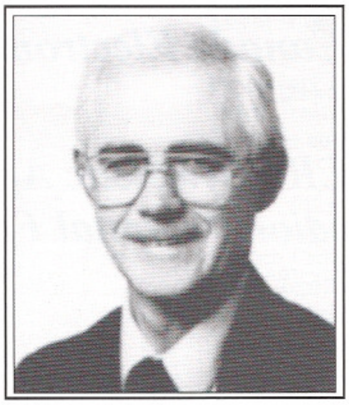
Our Acting General Manager, Dick Schwartz, has reorganized the Regional Activities Department to include most member services. As a result, we expect that the problems of the Service Center will all be resolved soon. The new computing system is operating, although not yet at peak performance. The dues renewals, which have been late in coming, are now being processed at a reasonable rate. I am still concerned lest there be any member problems not resolved. I will do my utmost to help you resolve them if you send me the details.

Within the Region, there are some exciting developments: the merged society, IEEE Canada, is now essentially operating as one, with representation within both IEEE and as a member society of EIC. The bank accounts for CSECE and IEEE Region 7 have been merged, and the regional committee is representative of both founding organizations. As your Director, I would like to interject a personal note of thanks to all the volunteers who have been serving in two capacities this past year operating on behalf of both societies and doing an outstanding job of both. The second warm note is that as a result of their efforts, our Region's bank account is very healthy.

IEEE Canada now has a fully regional and national conference of international stature, the Canadian Conference on Electrical and Computer Engineering. The conference will be held in Montréal September 5-8, followed immediately by the Region meeting on September 9 and 10. Please plan to attend the conference, and, if within your purview, to present a paper. I remind you that all region meetings of IEEE Canada are open and that any member may observe the governance process. So if you are attending the conference, I invite you to stay over the Saturday night and spend a few hours observing, and perhaps giving your opinion on the issues in our region.

As a matter of report, I had the honor to be invited to attend the Newfoundland/Labrador Section meeting on December 7, by video conference. While I was seated in a comfortable studio in Toronto, the Section members were gathered in a like studio in St. John's, all arranged by the Section so that I might participate.

Finally, many of you have told me that me must open an office to serve Canadian members. I am in full accord with this sentiment. I have worked out the preliminary details with Frank Moore, the Staff Executive for Member Activities at Headquarters. My objective is to have an IEEE office in Ottawa to handle IEEE business for members in Canada. This office will be operated and funded by IEEE. In addition, I intend that there will be staff dedicated to the needs of IEEE Canada funded by the Region. Frank and I are working on a business plan to present the case for this to the Board of Directors. If all goes well, we will have the office in place by the end of the year. In the meantime, if you have special needs, please call either me or our Region Administrative assistant, Cathie Lowell. Cathie is at c.lowell@ieee.org, and her office telephone number is (905) 628- 9554.



Afin de regrouper la plupart des services aux membres, notre directeur général des activités, Dick Schwartz, a réorganisé le département des activités régionales. Nous espérons, par cette démarche, que les problèmes du centre de services seront résolus bientôt. Le nouveau système informatique est maintenant opérationnel, mais pas encore à 100%. Les réabonnements qui accusaient un certain retard sont présentement traités à un rythme raisonnable. Avec les informations nécessaires, je ferai mon possible pour résoudre les quelques derniers litiges pouvant encore exister avec nos membres.

Au niveau de la Région, il y a des développements intéressants : la fusion CSECE/ IEEE Canada est presque complétée avec une participation dans IEEE et comme société membre d'EIC. Les comptes bancaires de CSECE et IEEE région 7 ont été fusionnés et le comité régional est représentatif des deux organisations fondatrices. En tant que votre directeur, j'aimerais remercier personnellement tous les bénévoles qui ont oeuvré au sein de ces deux sociétés dans la dernière année. Grâce à leurs efforts, la situation financière de la Région est très enviable.

IEEE Canada a maintenant son congrès de calibre international : le Congrès canadien en génie électrique et informatique (CCECE). Ce congrès se tiendra à Montréal, du 5 au 8 septembre prochain et sera immédiatement suivi par le congrès régional les 9 et 10 septembre. Planifiez dès maintenant votre participation et soumettez vos communications s'il y a lieu. Je vous rappelle que les membres sont bienvenus à tous les congrès régionaux. Donc, si vous prévoyez assister au CCECE, je vous invite à venir assister et peut-être même donner votre point de vue sur les affaires régionales.

Le 7 décembre dernier, j'ai eu l'honneur d'assister à la réunion de la section Terre-Neuve-Labrador par vidéo-conférence. Tout avait été organisé afin que je puisse y participer, assis bien confortablement dans un studio de Toronto pendant qu'eux faisaient de même à Saint-Jean.

Et pour finir, plusieurs d'entre vous croient qu'il doit y avoir un bureau pour les membres d'IEEE Canada. Je suis pleinement d'accord avec cette idée. J'ai commencé à consolider les détails préliminaires avec Frank Moore, le directeur du personnel des activités aux membres au bureau chef. Mon but est d'établir un bureau d'IEEE à Ottawa qui se chargerait des affaires d'IEEE Canada. Ce bureau serait mis sur pied et financé par IEEE. De plus, je souhaite que ce bureau réponde aux besoins d'IEEE Canada qui sont particuliers à notre région. Frank et moi travaillons à l'élaboration d'un plan d'affaires en ce sens à présenter au conseil d'administration. Si tout va bien, le bureau devrait être fonctionnel avant la fin de l'année courante. Entre-temps, si vous avez des problèmes, je vous invite à me contacter ou encore à contacter notre assistante administrative régionale, Cathie Lowell (e-mail : c.lowell@ieee.org. Téléphone : (905) 628-9554).

ECE Dept., McMaster University, Hamilton (Ontario) L8S 4K1

e-mail: rfindlay@ieee.org - Phone no: (905) 515-9140 ext. 24874 (off.) - (905) 648-4431 (home) - Fax no.: (905) 525-1276

DEVELOPMENTS IN POWER SYSTEM ANALYSIS

by Prabha Kundur, Kip Morison
Powertech Labs Inc.

This paper presents research and development efforts by a joint BC Hydro -Electric Power Research Institute (EPRI) team for programs for the analysis of problems related to the planning and operation of modern power systems.

Cet article présente les efforts en R-D réalisés conjointement par BC Hydro et Electric Power Research Institute (EPRI) et portant sur les logiciels d'analyse de problèmes reliés à la planification et à l'opération du réseau électrique d'aujourd'hui.

Today's utility engineers face new and increasingly complex problems associated with planning and operating power systems. Several factors are bringing about profound changes in the requirements for power system analysis. One factor is the limited facility expansion experienced by most utilities. The inability to add transmission facilities due to continuing economic restrictions and environmental constraints, has resulted in new dynamic phenomena such as small-signal instability and voltage instability. These have been observed on many actual systems and must be taken as integral considerations in the routine assessment of system security.

Another complicating factor is the changing supply strategies resulting from increasing penetration of dispersed generation. These are small generation sources which can be sited on distribution networks throughout the system. Not only does this represent a divergence from conventional system design of a few large generation sources located remotely from the loads, but many dispersed generation sources are new technologies such as photovoltaic, compressed gas, or magnetic storage devices. The dynamic characteristics, performance, and impact on distribution and transmission systems are not well understood, but are becoming of paramount importance in many utility systems. And finally, this myriad of new problems places additional burdens on engineers, at a time when many utilities are reducing staff levels. This has increased the demand for faster, easier to use, more sophisticated tools for planning and operating. Advances in computer hardware have increased expectations of software users and many off-line tools and techniques are being migrated to an on-line environment to improve system security and reduce the volume of off-line studies.

All of the above evolutionary changes point to the need for a new generation of analytical tools that can fulfil the changing requirements of utility engineers. BC Hydro (BCH) has recognized this need and is in the process of forming a strategic alliance with the Electric Power Research Institute (EPRI). Together they have initiated several ambitious research and development efforts to address the present and future power system analysis requirements for both the off-line and on-line environments. Most of the R&D work is being conducted by a joint team from BC Hydro and Powertech Labs Inc. (PLI), the research and technology subsidiary of BC Hydro. Since 1974, PLI has provided technical support and testing to BC Hydro, Canada's third largest utility. Today, PLI is a stand-alone subsidiary with its own commercial mandate. It's $50 million facilities in Greater Vancouver British Columbia, are central to the western North American market place and the Pacific Rim. Over 100 technical and scientific staff provide chemical, civil, electrical, environmental, metallurgical, and materials science expertise. The Power system Studies group at PLI work closely with BC Hydro staff to provide a wide range of R&D and consulting services in system analysis, design, and operating.

OFF-LINE ANALYSIS

Power System Analysis Package (PSAPAC)

Many commercially available off-line power system analysis packages lack capabilities to adequately assess key aspects of system performance. In particular, the assessment of small-signal stability and voltage stability is generally neglected by utilities due to the lack of suitable tools. For example, many utility base cases examined by eigenanalysis display undamped modes of oscillations that have gone unnoticed because the disturbances that could excite the modes have not been studied. In other cases, unnecessary reactive compensation devices have been planned because the root cause of voltage instability could not be identified. EPRI recognized these types of problems in the mid 1980's and the development of the Power System Analysis Package (PSAPAC). The structure of the package as it exists today is shown in Figure 1 was the result. This package, developed largely by staff now at PLI, provides tools for comprehensive system analysis of system steady-state and dynamic performance. All tools use leading-edge analytical techniques to provide users with extensive analysis capabilities and unmatched speed. The Extended Transient/Midterm Stability Program (ETMSP) [1] for example, incorporates implicit numerical integration for optimum solution speed. Modelling includes detailed flexible AC transmission systems (FACTS) devices, HVdc, under-load tap changing transformers, and a myriad of special models as well as user-defined modelling capability. In addition to "bread and butter" tools such as powerflow and time-domain transient stability simulation, included in PSAPAC are sophisticated eigenanalysis methods for small-signal analysis. These have proven essential for such problems as the study of low frequency oscillations and control design. The voltage stability assessment program VSTAB determines stability margins and employs modal analysis for identifying modes of voltage instability essential for designing remedial measures. Other features of the package include load model synthesis capability and a coherency based dynamic reduction program. To facilitate program use, all programs read most of the commonly available data formats and are available on a number of computer platforms. A full-service user support centre is operated at PLI to maintain the software and to assist users.

Recognizing the growing dependency of engineers on such tools and their expectations for software performance, PLI together with BCH is developing a new generation of PSAPAC software that will incorporate a study manager, an advanced graphical user interface, and distributed computing capabilities. The objective is to deliver high-performance power system analysis software that uses the latest in man-machine interface techniques. This development work is underway and is scheduled over a 24 month window with a first release of the time-domain simulation program expected in early 1996.

Validation and Application to Special Stability Analysis Problems

Several applications of PSAPAC have involved validation of the software and the solving of special problems. A major study by a Northeast Power Coordinating Council (NPCC) Working Group [2], was aimed at reconstructing and analyzing several system events occurring over the last few years. One event, the loss of a 1200 MW generating unit in Indiana, resulted in lightly damped oscillations throughout the eastern interconnected system. Recordings were compared with simulations and a methodology was developed for analysis of such oscillations. Using very large system models, the procedure included time-domain simulations, small-signal analysis, dynamic reductions, and Prony analysis. Another recent application of the PSAPAC software was in a project sponsored by the Canadian Electrical Association (CEA) to investigate low frequency inter-area oscillations [3]. This study examined the fundamental nature of this phenomenon, and focused on control design for system stabilization including the design of controllers for HVdc modulation and power system stabilizers. Control design methods such as pole placement, phase and gain margin, and H infinity were examined and demonstrated. The PSAPAC software combined with the techniques and experience gained from these studies has lead to procedures suitable for complete assessment of large systems and the design of protections and controls to enhance stability [4].

Addressing Reactive Power Planning Needs

The inability to add new transmission facilities has created voltage stability and control problems for many utilities and has motivated aggressive reactive compensation strategies. It is clear that there exists a great need in industry for better reactive power planning tools that can assist in designing the most cost-effective compensation plans. Existing planning tools, such as the optimal powerflow (OPF) address only voltage decline constraints and ignore voltage stability issues completely. Voltage stability assessment tools, such as EPRI s VSTAB [5,6] program that uses modal analysis to identify voltage collapse areas, can assist in siting, sizing, and selecting the type of compensation needed, but do not include minimization of an objective function (ie there is no optimization). BCH and PLI are working with EPRI on project RP3578- 1 to evaluate existing reactive planning tools and identify their individual strengths and weaknesses in dealing with voltage stability. The objective is to determine if existing tools can be used in a complementary way to meet industry needs or if new tools and techniques are needed. The project also includes field measurements to establish better load models for use in voltage stability analyses. The results of the project will be used to form the specification for new R&D initiatives. The project has been underway for one year and is scheduled for completion in mid 1995.

ON-LINE ANALYSIS

In addition to the considerable research and development efforts aimed at off-line software, significant advances are being made in on-line software for power system security assessment. These have been brought about by several motivating factors:

- Economic savings from reduced off-line studies: with manpower at a premium in most utilities, and the dimension of study problems constantly increasing, there is a strong desire to migrate off-line studies, which require analysis of all possible conditions, to on-line which analyze only the current condition.
- Economic benefits derived from knowing the security condition more precisely. Traditional methods use off-line studies of all possible conditions from which results are loaded into look-up tables for on-line use. Actual conditions are then matched to the closest condition studied off-line to determine suitable limits and remedial actions. Computing limits on-line using the exact system condition allows the system state to be accurately evaluated to determine how close the system is to thermal limits, voltage decline limits and stability limits. This may allow higher transfers or more economic dispatching. At the very least it permits more secure maneuvering of the system.
- Computer hardware has reached the cost/performance point at which many off-line analyses can be conducted on-line with acceptable speed. If required, applications can be distributed on low-cost high2-MIPS CPUs to achieve the required performance.

Transient Stability Assessment (TSA)

BC Hydro was the first utility to develop and implement an on-line transient stability analysis package. The package utilizes a time-domain simulation engine, and a number of peripheral techniques to achieve speed and a high degree of automation [6]. Rule based approaches are used for contingency selection to determine the outages that must be fully simulated. Additional intelligence was added in the expert system to take advantage of the relationship between contingencies thereby reducing the number of cases for which full simulations must be conducted. In fact, expert system technology is embedded throughout the package to expedite the analysis wherever possible. Special transient energy function (TEF) methods are employed to provide early termination of simulations (to stop simulations as soon as possible once the outcome is known) and to provide information about the proximity to instability. This information is essential for efficiently finding the stability limits using iterative time-domain simulations. After each time-domain simulation run, the stability margin calculated is used to predict the necessary increase in critical parameter to reach the stability limit. In addition, the package determines arming of generation rejection required to ensure stability for contingencies that cannot be made stable without post contingency control actions. It is expected that additional performance enhancement can be made by replacing the existing time-domain simulation engine with a modified version of ETMSP, which, because of advanced sparsity methods and the use of implicit numerical integration, has proven to be three to four times faster than the program currently used in the TSA package. For many conditions in the BC Hydro system, voltage stability rather than transient stability is the limiting factor. The successful development of the TSA package, therefore, motivated the development of a similar package for voltage stability assessment as described below.

Voltage Stability Assessment (VSA)

Until recently, the phenomenon of voltage instability was not well understood, and methods were not available for it's analysis. However,

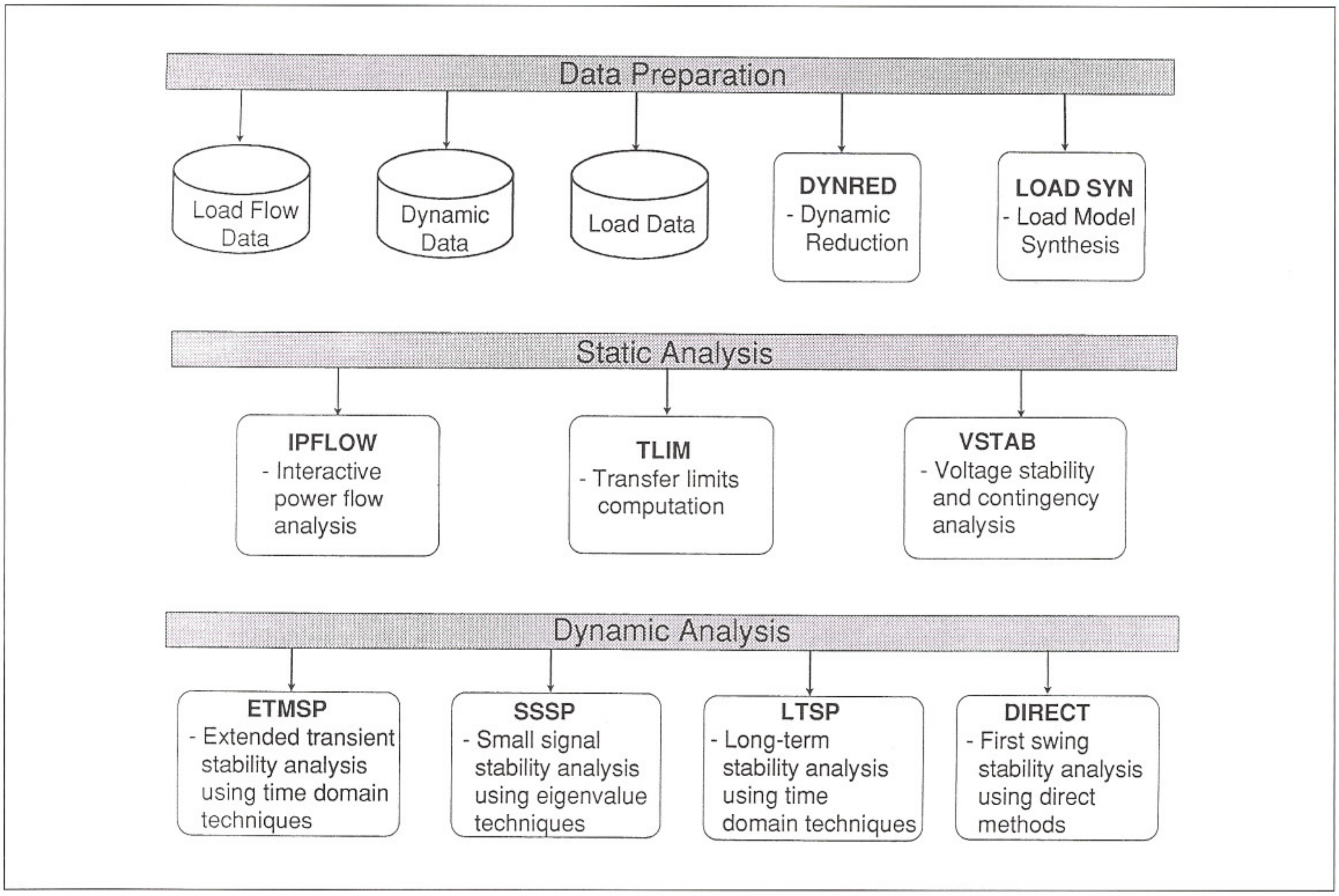


Figure 1: Power System Analysis Package (PSAPAC)

significant research efforts throughout the industry have clarified the causes and mechanisms of instability, and tools and techniques have been developed for off-line assessment [7]. Tools such as the VSTAB program, which uses enhanced powerflow methods and modal analysis, and ETMSP which uses extended time-domain techniques, can be used to determine the potential for instability, its causes, and necessary remedial actions. Both these programs have been used by a number of utilities in planning studies. While most research has been devoted to developing tools for off-line analysis of voltage stability, the problem of on-line assessment has not been adequately addressed and most utilities have no on-line assessment capability. BC Hydro currently conducts off-line studies using Q-V curve techniques to determine voltage stability margins and required generation rejection armings. The study results are loaded in to look-up tables for on-line use. However, the required number of such studies is enormous. Establishing of the lookup tables requires finding m x n limits (some with remedial measures), where n is the number of possible system states and m is the number of contingencies. The total number of limits needed (m x n) may run into the thousands. To add to the complexity, each limit may require a series of PV or QV curves or, if remedial measures are needed, may involve several time-domain simulations. The system states considered must include different loads levels, transfer conditions, topologies, and equipment status. The contingency list must include all credible contingencies established from experience.

If the studies can be performed on-line, the actual system state is known and the equivalent of only one column of the m x n limit matrix need be computed (one state for m contingencies). This represents a tremendous savings of effort and will produce more accurate results because all studies are carried out using the actual system state.

As part of the BC Hydro/EPRI alliance, PLI and BC Hydro have begun development of key components for the engine of a full-function VSA package. The engine will be used for on-line analysis of the current system state as well as for analysis of conditions specified by the operator (test mode). The overall package structure is shown in Figure 2. Much of the system shown in the Figure will differ from utility to utility depending on existing facilities and integration considerations. The computational engine identified in the figure is designed to be generic to all installations, with built on flexibility to provide margins computed in a variety of ways (to allow adherence to various criteria). The functions of the individual engine components are as follows:

Contingency Screening and Ranking Module. It is impractical and unnecessary to analyze in detail the impact of every conceivable system contingency. Generally, only a limited number of contingencies will be of immediate concern although these might be quite different from the contingencies critical for transient stability, thermal overload, or voltage decline. It is desirable therefore to be able to screen the contingencies such that a list of those most likely to cause problems can be assessed in detail. These should also be ranked according to their expected impact.

Secure Region Module. Operators need to know how far the system is from instability in terms of key system parameters (such as load, transfers, or dispatch patterns) when subjected to all the selected contingencies. This module computes the region in which the system remains secure. In the case of simple systems this could be a simple two dimensional area

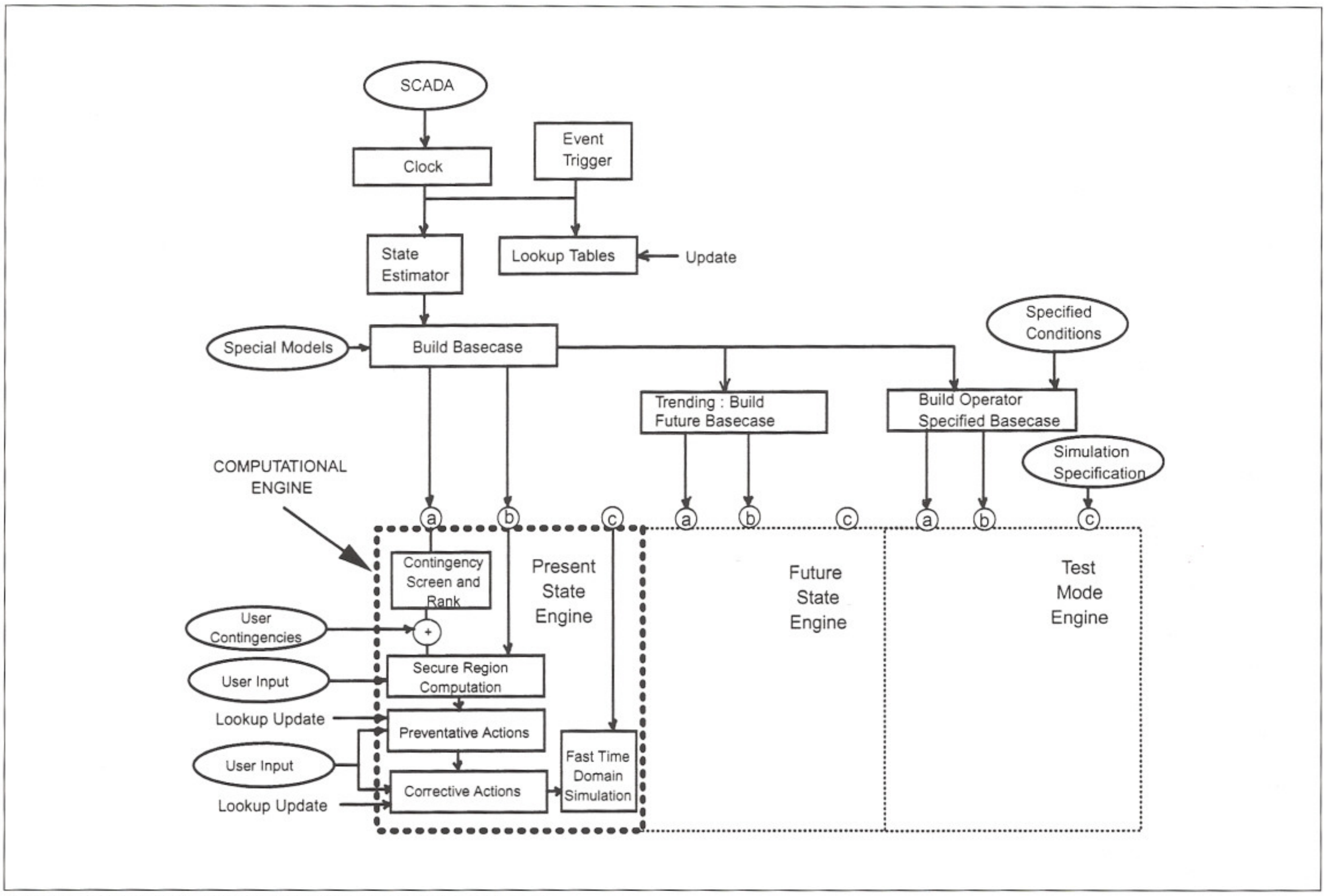


Figure 2: Functional representation of VSA package

with axes corresponding to key parameters. In complex systems the region could be a volume bounded by a hypersurface corresponding to the transition from stability to instability. If insufficient margin is detected (ie the operating point is not sufficiently far into the secure region), control actions are required to move to a more secure posture, or to arm controls that will be invoked following the troublesome contingencies. Because accurately determining a stability limit when only one parameter is varied can in itself involve significant computation, generating the secure region when several parameters are varied and when many contingencies are involved presents a formidable challenge for on-line assessment.

Preventative Control Action Module. If it is found that the system has insufficient margin for any contingency, actions must be determined to move the system state in such a way as to create sufficient margin. These consist of pre-contingency measures. Even if the system is found to have sufficient stability margin in, it is generally possible at any time to move the system state to increase the security margin. This may result in economic benefits by permitting changes in generation dispatch or the increase in transfers (import/export). The VSA package should provide information regarding the change in secure operating region with changes in various parameters, and strategies for increasing security for any given condition.

Corrective Control Action Module: In the event of multiple (or severe) contingencies, special corrective control actions may be necessary to prevent voltage instability. These are generally impactive on customers (interruption or degradation of power quality) and therefore are reserved for use in response to very severe system disturbances. The most common control action of this type is load shedding. The VSA package must be able to determine the best location and minimum amount required. Other control schemes such as blocking of transformer under-load tap-changers, or capacitor/reactor switching are also possible.

Time-Domain Simulation Module: This module will be used to validate corrective actions (such as load shedding) and will also be used to run specific detailed simulations in Test Mode). Whenever detailed chronology of events is important, this module is used. Conventionally formulated time-domain simulation programs are much to slow for on-line use and therefore a highly specialized method is required. The program must run extremely fast and be capable of capturing dynamics and timings important for voltage stability.

The development of the engine components described above is expected to be completed in 1997, and will be extensively tested in simulated on-line environments by four host utilities to be selected at a later date. As this is designed to be a portable engine, the development phase will be followed by an integration stage in which the engine is installed in selected utility EMS environments.

Closing

As the environment in which power systems are planned and operated evolves, it is clear that utilities must take a more aggressive approach to system analysis if they are to meet requirements of secure and economic operation. This paper has described how Powertech Labs Inc, together with BC Hydro and other partners, is meeting the challenges facing today's utilities through advanced research and development initiatives.

REFERENCES

[1] EPRI Research Project RP1208-9, "Extended Transient Midterm Stability Program", Final Report prepared by Ontario Hydro, June 1992.

[2] NPCC Working Group on Review of Reliability of Inter-Area Operation (COSS-2) Final Report, 1994.

[3] CEA Project 294 T 622 Final Report, Investigation of Low Frequency Inter-Area Oscillation Problems in Large Interconnected Power Systems", prepared by Ontario Hydro, 1994.

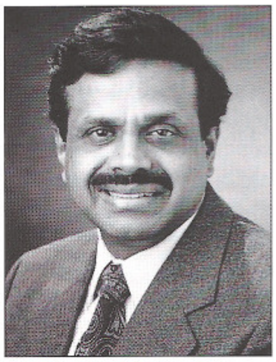
[4] P. Kundur, G.K. Morison, N.J. Balu, "A Comprehensive Approach to Power System Analysis", A paper presented at the 1994 CIGRE Meeting, Paris, 1994.

[5] EPRI Research Project RP3040-1, "Voltage Stability / Security Analysis and On-Line Control", Final Report prepared by Ontario Hydro, November 1992.

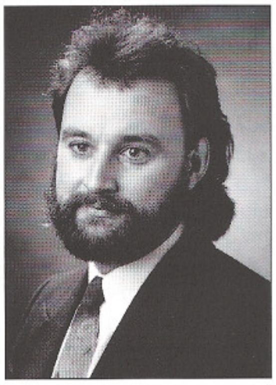
[6] Y. Mansour, E. Vaahedi, A. Chang, B.R.Corns, B.W. Garret, K. Demaree, T. Athay, K. Cheung, "Online Transient Stability Assessment for BC Hydro", Model Development, Analysis and Post-processing, A paper presented at the IEEE Winter Meeting, February, 1994.

[7] K. Demaree, T. Athay, K. Cheung. Y. Mansour, E. Vaahedi, A. Chang, BR. Corns, B.W. Garret, "Online Transient Stability Assessment for BC Hydro Implementation", A paper presented at the IEEE Winter Meeting, February, 1994.

About the authors



Prabha Kundur received M.A.Sc. and Ph.D. degrees from the University of Toronto, Canada, in 1965 and 1967 respectively. He taught at Mysore and Bangalore Universities during 1967-1969. In 1969 he joined Ontario Hydro where he became Manager of the Analytical Methods & Specialized Studies Department. In 1993 he moved to Powertech Labs Inc, the research and technology subsidiary of BC Hydro where he is currently Vice President of Power Engineering. He also holds the positions of adjunct professor at the University of Toronto as well as the University of British Columbia. He is author of the book Power System Stability and Control, McGraw-Hill Inc, 1994.



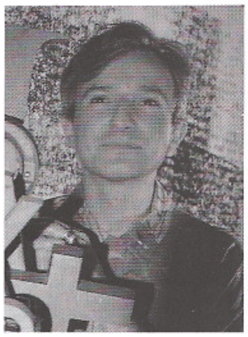
Kip Morison joined the Power System Planning Division of Ontario Hydro in 1981 and received his M.A.Sc. degree for the University of Toronto in 1985. At Ontario Hydro he became Senior Engineer in the Analytical & Specialized Studies Department involved in special stability and control problems. In 1993 he moved to Powertech Labs Inc. where he is currently a Senior Research Engineer in the Power System Studies Group.

Perspective / *Perspectives*

A few words from the Managing Editor

By Paul Freedman
Managing Editor

Lead Researcher / *chercheur principal*
CRIM
1801, ave McGill College, Suite 800
Montréal (Québec)
H3A 2N4
Téléphone: (514) 398-1645
Télécopieur: (514) 398-1244
e-mail: freedman@crim.ca



As the cover picture of this issue makes clear, IEEE Canada is quickly establishing an electronic presence and PostScript versions of previous magazine articles will soon be archived. Please note that articles may be reproduced without charge so long as proper credit is given to IEEE Canada.

And once again, many thanks are due to Associate Editors Ray Lowry and Vijay Sood for their continuing help with articles about SAR and Power Systems developments in Canada. Unfortunately, this issue is going to press a few weeks late due to problems with the preparation of the Call for Papers for the upcoming CCECE '95 conference.

Still, we ultimately depend upon you, our readers, to help us continue to make the magazine something worthwhile. So if you'd like to share some thoughts about previous articles or better still, propose some ideas for future articles, please don't hesitate to get in touch with me or one of the Associate Editors.

Indeed, this is exactly what one reader, V.C. MacDonald, did in some recent electronic correspondence. He suggests that readers interested in standards associated with high-speed networking of the kind described in the article in our last issue, The HPC High Performance Computing Centre, should contact the secretariat of the Information Highway Working Group (IHWG) of the Telecommunications Standards Advisory Council (TSACC). The contact person is: Tom Hughes, Industry and Science Canada, Ottawa, Ontario K1A 0C8.

Finally, as noted in my previous column, advertising remains a problem. I have finally identified a suitable agency and with just a little luck, there will be some advertising starting in the next issue to help offset our printing costs.

Voilà. Encore un autre numéro qui tire à sa fin. J'aimerais bien rappeler aux lecteurs que c'est le contenu (et non la langue) qui compte : des articles à caractère technique et canadien, faisant partie de l'actualité.

1995 Canadian Conference on Electrical and Computer Engineering

Congrès canadien en génie électrique et informatique 1995

September 5-8, 1995 / 5 au 8 septembre 1995

Le Centre Sheraton - 1201, boul. René-Lévesque ouest, Montréal (Québec) Canada

sponsored by / parrainé par

IEEE Canada

CALL FOR PAPERS / APPEL DE COMMUNICATIONS

THEME:

ENGINEERING IN THE GLOBAL VILLAGE / LE GÉNIE DANS LA CITÉ GLOBALE

This conference provides a forum for the presentation of electrical and computer engineering research in Canada and other countries. Papers written in English or French on any of the following topics are invited:

- Communications
- Computers
- Very Large Scale Integration (VLSI)
- Energy and the Environment
- Techniques for Information Technology
- Artificial Intelligence and Neural Networks
- Parallel Processing
- Signal and Image Processing
- Control and Robotics
- Power Systems and Power Electronics
- Electromagnetics
- Industrial Materials and Processes
- Electronic Systems in Transportation
- Biomedical Engineering

Submit three copies of a 400-500 word summary by May 9, 1995, to the Technical Program Chairperson. Indicate the topic of your paper. Notification of acceptance will be sent by June 16, 1995. If your paper is accepted, a camera-ready version must be received by the Technical Program Chair no later than June 30, 1995. For conference information, please contact the Conference Chairperson.

Ce congrès constitue un forum de présentation des travaux de recherche en génie électrique et informatique, mené au Canada, ou dans d'autres pays. On sollicite des communications en anglais ou en français sur les thèmes suivants :

- Communications
- Informatique
- Intégration à très grande échelle (ITGE)
- Énergie et environnement
- Techniques pour la technologie de l'information
- Intelligence artificielle et réseaux de neurones
- Traitement parallèle
- Systèmes de traitement du signal et de l'image
- Commande et robotique
- Électronique de puissance et systèmes de puissance
- Électromagnétisme
- Matériaux et traitements industriels
- Systèmes électroniques en transport
- Génie biomédical

Veuillez soumettre, en trois exemplaires, votre résumé de 400 à 500 mots avant le 9 mai 1995 au président du programme technique. Indiquez le thème de votre communication. Vous serez avisé de l'acceptation de votre communication au plus tard le 16 juin 1995. Dans le cas où votre communication est acceptée, un exemplaire prêt pour la reproduction devra être envoyé au président du programme technique avant le 30 juin 1995. Pour recevoir de plus amples renseignements sur le Congrès, veuillez écrire au président du Congrès.

Technical Program Chairperson / Président du programme technique

Professeur Louis-A. Dessaint
École de technologie supérieure
Département de génie électrique
Groupe de recherche en électronique de puissance
et commande industrielle (GRÉPCI)
4750, avenue Henri-Julien
Montréal (Québec) CANADA H2T 2C8
Tél.: (514) 289-8872
FAX: (514) 289-1711
email: dessaint@ele.etsmtl.ca

Conference Chairperson / Président du Congrès

Professeur Renato G. Bosisio
École Polytechnique de Montréal
Département de génie électrique et génie informatique
Centre de recherches Poly-Grames
3333, chemin Queen Mary - suite R222
Montréal (Québec) CANADA H3V 1A2
Tél.: (514) 340-4654
FAX: (514) 340-5892
email: rbosisio@grmes.polymtl.ca

AT THE DAWN OF FIRST NATIONS ENGINEERING

Order of Engineers of Québec and Concordia University combine efforts to assist First Nations breaking into engineering

by Jorge Campos
Chief Electrical Engineer, City of Westmount

As First Nations communities struggle to improve the quality of life in the reserves, the need for science and technical oriented people increases. Native engineers will have a prominent, if not fundamental, role in the development of their communities. Yet, due to social and historical factors, an effective First Nations engineering work force is mostly a dream which is overdue to bloom into reality. Sensitive to a new spirit amongst native leaders, the Order of Engineers of Québec and Concordia University initiated serious efforts to promote native access to engineering.

À l'heure où les autochtones se démènent pour améliorer la qualité de vie dans les réserves, leurs besoins, en ce qui concerne la science et la technologie, s'accroient. Les ingénieurs autochtones auront un rôle déterminant, voire même fondamental, dans le développement de leurs communautés. Jusqu'à présent, à cause de facteurs sociaux et historiques, former un groupe de travail d'ingénieurs compétents à l'intérieur des communautés autochtones était un rêve, mais qui est en voie de devenir réalité. Sensible à ce nouvel état d'esprit parmi les leaders autochtones, l'Ordre des Ingénieurs du Québec en collaboration avec l'Université Concordia ont initié un effort sérieux afin de promouvoir l'accès à l'ingénierie pour les communautés.

The predisposition to move towards brighter horizons is nowhere so evident as in the First Nations leaders' determination to direct their youth to higher studies in science and engineering. With lawyers successfully settling more and more land claims, the need for technical people to develop the native administrated territories becomes a pressing priority. Municipal infrastructures, bridges and roads, health services, natural resources optimization and geographic management are just some of the fields requiring immediate attention.

The new commitment has not gone unnoticed. It has enjoyed substantial coverage in the Canadian press, even occasionally making front page headlines. Many universities and the provincial engineering associations did not ignore it either. Recent articles in Plan and in Engineering Dimensions, respectively the publications of the Order of Engineers of Québec (OEQ) and of the Association of Professional Engineers of Ontario, have shed light into the difficulties experienced by natives in their struggle for technical emancipation.

Faced with a promising situation which seems to linger, the OEQ and Concordia University took in late 1993 a rather bold step. They combined efforts to create the Joint Working Force on Native Access to Engineering. The OEQ counted with a strong knowledge on minority issues, accumulated from such programs as Women in Engineering. On the other hand, Concordia University has for years welcomed native students. With an estimated two hundred North American aboriginal students in a population of 25,000, the university had the concern to assure the services of some native teachers. Since 1992, it also runs a Native Student Center. The center acts as a relay for information and experience exchange, counselling and in-house tutorial clinics.

Joining the working group, the Canadian Aboriginal Science and Engineering Association (CASEA) brought a valid native perspective to the proceedings. CASEA is an association of engineers and science oriented aboriginals dedicated to leadership training, promotion and diffusion of applied science programs among native communities. It follows on the footsteps of its powerful american counterpart, the American Indian Science and Engineering Society from Boulder, Colorado.

The mandate of the OEQ-Concordia University working group is to promote the integration of First Nations students in engineering. In a more specific way, it aims at helping create the conditions which would channel native students to engineering faculties and provide the necessary support to keep them there until they finish a degree.

The hurdles are many and not easy to overcome. They start with a lack of motivation due to the absence of role models. Just a few decades ago, Indians could not go to university. They had to give up their status and leave their communities if they wanted an university education. In Québec, in 1987, only 2.2 per cent of registered Indians held university diplomas, versus a 7.1 per cent for non-natives (more recent statistics are difficult to obtain, due to non-discriminatory laws governing surveys). From those, only a handful are engineers. It is a factor that has had a devastating effect in career choices. A study made in Kahnawake, an indian community in the outskirts of Montréal, showed that roughly 70 per cent of students coming out of a native school will go to Cegep (pre-university institutions); only 10 per cent of those graduating will move on to university.

Then, there is a certain pernicious conformism. The old ways of living and thinking are deeply entrenched. The advantages of breaking way from them are not always obvious. Many times the reward at the end of the trail does not seem worth the effort. It is not uncommon that the students are discouraged by family and friends to leave their communities. Those who persist in the ideal of higher education can find themselves labelled as giving in to the white man's pressure.

Not less devastating are the difficulties students experience once they enter university. They clash with different traditions, different perspectives on life, different needs. They find the university life intimidating, the complex bureaucracy oppressing. They have to adapt to culturally alien ways of learning and interacting. Many will be studying in a second language, and the advanced technical jargon of the classroom challenges their writing and reading skills. Frustration and despair settle in. A great number will not even complete the first year.

In the past, authorities and universities have tried to deal with the issue focusing on remedial measures directed to the students already in university. Half a dozen universities across Canada maintain Native Student Centers to assist their First Nations students. Typically, the centers offer social and tutorial activities to different levels of effectiveness.

The native access programs in engineering tried to go farther. The concept was pioneered twenty five years ago, by the University of Manitoba with its Native Engineering Access Program (ENGAP). The program established a bridging year for natives wanting to pursue their studies in engineering. Every second year, fifteen students enter a pre-admission program which offers up-grading courses in mathematics and science, while attending some engineering courses. The program has been highly successful in attracting applicants and the students have shown same levels of academic proficiency as the general student population. Today, Lakehead University in Thunder Bay, Ontario, maintains a similar initiative, the Native Engineering Access Program (NAPE). University of British Columbia is hoping to follow soon with its own program.

The efforts of the OEQ-Concordia University working group can eventually lead to a native access program. However, independent of how commendable these programs are, they have not succeeded in engaging younger generations to the opportunities laying ahead and the advantages of a degree in engineering. For a significant increase in the number of native engineering graduates, not only the native drop-out rate in the faculties must fall, but we need more students entering university. It is there where the OEQ-Concordia University working group seems to be breaking new ground.

The working group has been concentrating its attention on a strategy that pretends to reach potential engineering students early in their studies. By raising in them a healthy appreciation for engineering and surrounding them with a supportive environment, it is expected that more of these youngsters will opt for professional careers.

The Engineering Exploration Summer Camp for Aboriginal Students, held during the week starting July 25, 1994, in downtown Montréal, resulted from such strategy (see figures 1, 2). It was the first of its kind to be organized in Québec. A group of twenty students was exposed for five days to the many facets of the profession, while learning how engineering can affect their own communities. The interaction with veteran engineers, such as Dr. Richard Guy and Dr. Claude Bédard, proved to be enriching. The importance of role models also was not disregarded. The youngsters had the opportunity to learn first hand, from native engineers, about the benefits of a professional career in engineering. Amongst the invited guests were high profile native professionals and CASEA administrators, such as Joe Deon, Marc Paré and Marc Lalande.

The initiative received enthusiastic support and was highly praised, either by native authorities or by the participants. The untold expectation was always that one or more of those youngsters will grow up to become like Daron Ahhaitty, a native American engineer of Rockwell International, with a leading role on the Space Shuttle Program. The success of the Engineering Exploration Summer Camp prompted its repetition for 1995.

Problem awareness workshops directed to native educators and cooperation agreements with Cegeps traditionally frequented by First Nations students are two aspects being explored to create the supportive environment that students require. The goal is to prepare the youngsters, psychologically and academically, for a smooth transition to university. Instead of waiting that they reach university to help them deal with the harsh environment, they could start being progressively prepared and encouraged during the last years of Cegep for the upcoming difficulties.

Of course, the basic infrastructures for a supportive environment inside the university are also being laid out. As mentioned above, the present work may lead to a redesigned native engineering access program at Concordia University. The approach will undoubtedly be innovative. Instead of waiting for the students, the OEQ-Concordia University working group is going to them.

Figure 1: The construction of a rocket was one of the activities the students enjoyed during the Engineering Exploration Summer Camp. A group of participants attends to the launching. The first workshop will take place in early 1995 and negotiations are under way for the cooperation agreements.

The proceedings of the OEQ-Concordia University working group have raised certain expectations in Québec. Other universities observe the progress with a prudent but genuine interest. For instance, in a coordinated effort with the group, the University of Québec, in Chicoutimi, is considering to initiate this year a Science and Engineering Summer Camp for Native Students. It would be fantastic if the example could be followed by other universities and provincial engineering associations all across Canada.

However, one thing should be clearly understood. In the long run, the success of the efforts of clear minded organizations, such as the Order of Engineers of Québec and Concordia University, depends on the support they receive. Native science and engineering associations, such as CASEA, must be nurtured. Government funding and private sponsoring are corner stones to assure the longevity of the project. Not less important is the support of each one of us, privately or professionally. A simple word of encouragement, an open door for an organized visit of an industrial facility, a warm though in the attribution of sponsoring funds, can make all the difference for hundreds of potential native engineers.

Are we indeed living in the epoch of renewed hope for the aboriginal communities? Are we at the dawn of a new generation of First Nations

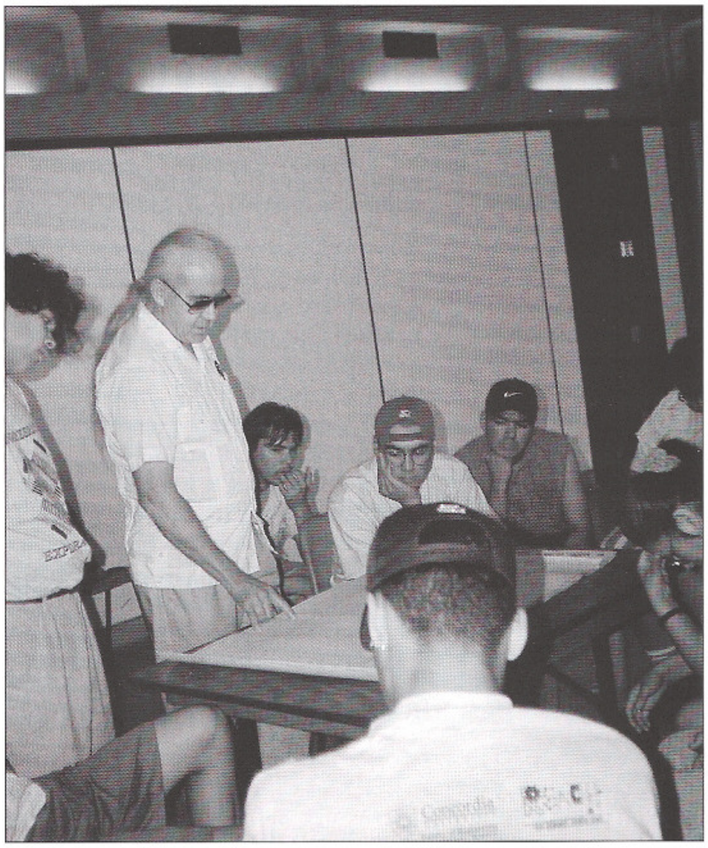


Figure 2: The importance of role models was not disregarded in the Summer Camp. The youngsters had the opportunity to learn first hand, from native engineers, about the benefits of a professional career in engineering.

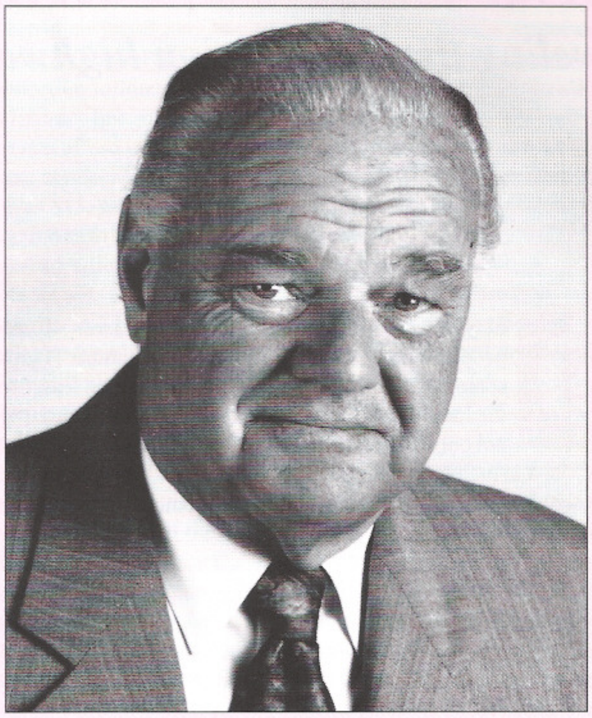
engineers, who would address the needs of their people in the context of their culture and values? I sincerely hope that we can duplicate the success story that has been the integration of women in engineering! Canadians have a historical responsibility to put an end to the sad state of affairs in the reserves. But if an altruistic motive is not sufficient for some, the opportunities created from developing some of the most forgotten communities in the country may help rekindle the whole economy. In the end, everyone would win.

About the authors

Jorge Campos was a founding member of the OEQ-Concordia University Joint Working Force on Native Access to Engineering, where he keeps favouring native interests. He holds a Master's degree in Business Administration from McGill University. In his M.B.A. he has a double concentration in "International Business Management" and in "Policy Management".

From 1991 to 1994, he sat in the board of directors of the Order of Engineers of Québec. He is also a member of the CSA Montréal Consumers Advisory Board and of the CSA Committee on Industrial Products. A senior member of IEEE, he cooperated at several occasions with the IEEE Canadian Review. From 1990 to 1992, he held the position of Production Manager for the magazine.

ELECTION RESULTS



IEEE MEMBERS CHOOSE WALLACE S.READ AS 1995 PRESIDENT-ELECT

Mr. Read, president of the Canadian Electrical Association in Montréal and a former electric utilities executive in Newfoundland, has been elected 1995 president-elect of The ***Institute of Electrical and Electronics Engineers Inc***. (IEEE). Dr. Read will begin serving as IEEE president on January 1, 1996. He is currently a member of the IEEE Board of Directors, now serving as vice-president, Standards Activities.

This is the second time in the IEEE's history that a Canadian has been elected president. The first Canadian to hold the office was Robert H. Tanner of Ottawa, who served in 1972.

Dr. Read joined the Institute in 1952 and has been an active member. He served as a member of the Board of Directors from 1984-1985, 1988-1990 and 1993-1994; and as a Director for Region 7 from 1984 to 1985. He is a Fellow of both the IEEE and the Engineering Institute of Canada.

Also from Canada, Vijay K. Bhargava has been re-elected vice-president, regional activities, by the IEEE Assembly, while Linda E. Weaver has been selected as the 1995 Director-Elect for Region 7 (IEEE Canada) by canadian members.

The results of the other Office elections are: Director Division II, Pierre A. Thollot; Director Division IV, Rolf H. Jansen; Director Division VI, Stephen H. Unger; Director Division X, Tzyh-Jong (T.J.) Tarn. They will all assume office on January 1, 1995.

Taking office on January 1, 1996 will be the following candidates selected as Director-Elect Division V, Michael C. Mulder; Region 1, Arthur W. Winston; Region 5, John R. Reinert; Region 6, John B. Damonte; and Region 7, Linda E. Weaver.

IEEE CANADA ELECTRONIC SERVICES

Traveling the information highway

by Jacek Chrostowski
IEEE Canada Section - Chapter Technical Support Chair

In this article, we review some of the latest Internet-related activities conducted by IEEE Canada. In addition, we reprint two articles about the Internet itself and how to obtain Internet access using a PC or Macintosh and modem.

Dans cet article, on passe en revue les derniers développements liés à l'Internet mis sur pied par IEEE Canada. De plus, on reprend deux articles qui ont paru ailleurs au sujet de l'Internet et comment se connecter à partir d'une machine PC ou Macintosh avec modem.

Did you know that currently there are over 40 million people using the Internet and that this number is growing some 10% per month? Did you know that at least 50% of the Internet traffic is commercial - selling/advertizing and not only related to software? Did you know that over 80% of IEEE Canada members have access to the Internet? If you did not know this, probably you haven't noticed the electronic mail addresses on television appearing at the end of the programs asking for your comments. In fact, one of the new cable TV channels, Discovery, devotes a large segment at 7 pm to a program about the Internet. This is a good news. However, working with IEEE volunteers, I have noticed that a lot of members have very mundane problems, e.g. how to connect to the information superhighway, do not understand the new language used by the converted (hypertext, Web, Mosaic etc.). I have recently met several top managers in high-tech companies who are completely unfamiliar with the Mosaic type programs for searching on the Internet and are too embarrassed to acknowledge this to their staff. There is also a fear of the large cost of connecting, as the agenda up to now was dominated by corporate users and the research community. This is not true anymore on both accounts. The number of computers sold to homes last year was larger than that sold for businesses. If you have a PC with Windows and a modem, or a Macintosh and modem, you can connect through the local dial-up Internet provider in most of the cities in Canada for $20-30 per month. IEEE is, not surprisingly, very active in electronic publishing and communication and we are at the forefront of these new developments. (We remind our readers that this very page was formatted using electronic desktop publishing tools.) Both IEEE HQ and IEEE Canada now have "World Wide Web" WWW sites with a wealth of information about technical activities, conferences, and connections to the IEEE staff. This is the first year when we are going to be providing IEEE publications on a large scale. To bring you closer to this new technology which will dominate the way in which we communicate, we will describe a couple of examples of current activities about the IEEE Canada part of the Internet.

Wide World Web site of IEEE Canada

IEEE Canada has the Internet domain and server with the name "ieee.ca" thanks to the CANARIE organization (The Canadian Network for Advancement of Research, Industry and Education, WWW site: www.canarie.ca), which last year contributed substantial funding for enhancing electronic services to our members. The server is connected to the Internet via a 64 kB ISDN line. You can find us by typing http://www.ieee.ca in your Mosaic or Netscape Internet access application program. The current version of the "home page" is on the front cover of this magazine. It is being continuously rebuilt as we add new elements to the site. It provides information about the IEEE officers, volunteers, and connections to other IEEE sites. Very shortly we will introduce three elements:

1) Canadian Showcase - featuring small/medium Canadian companies, affiliates of IEEE Canada. If your company would like to have a presence there without too much cost and trouble, please contact Hanna Chrostowski, IEEE Canada Server Administrator by phone/fax 613-834-0052 or E-mail: hchrost@hpb.hwc.ca.
2) As part of the CANARIE project, we are building a database of our members and their profiles. It will be accessible only to IEEE Canada members, as an extra service to members. More information about the content can be obtained from Les Chan, IEEE-Canarie project engineer at chan@mpp.ps.iit.nrc.ca.
3) Uniform, easy to remember, electronic addresses for every member of IEEE Canada in the following format j.chrostowski@ieee.ca. By using such an address "alias" which we will create for you, when you change your computer, location or company, you won't have to inform everyone about the changes, just one location, the IEEE Canada. Student members are particularly welcome. To subscribe, send your request to mail-admin@ieee.ca with your IEEE number.

Fax from Internet

IEEE Ottawa Section (and shortly other sections in Canada) provides a service to the community by offering the fax service directly from Internet. You can fax information to the Ottawa-Hull calling area (telephone area codes 613, 819) from anywhere in the world if you know a fax number of the person you want to reach. To do so, instead of the regular Electronic Address, put the name/fax number in the following format - reversing the digits (Sorry for this, it is the format chosen by the people who first implemented it, so we did not change it here, to be compatible with other locations in the world) "remote_printer/Address_name@1.1.1.1.1.1.1.3.1.6.1.tpc.int". The program is very successful, a lot of people use it, as it saves the operator time for local transmissions (if you do not have a fax on your computer), not to mention the cost savings of the long distance telephone calls. Several other

Canadian sections implementing this service will have their local logos. There is also place for commercials from the local sponsors, who are very welcome. Look for the information "what's new on the Web" when the new additions become active.

IEEE Canada Newsletter and gopher site

IEEE Canada publishes a monthly electronic newsletter which is archived at the gopher site providing the text only information.This service does not require Internet access software. To subscribe, send an E-mail message to listserv@mpp.ps.iit.nrc.ca. The first line of the message should be SUBSCRIBE IEEE-CANADA-NEWSLETTER "Your-name", without quotes. You will receive an automatic confirmation and you can expect to receive each newsletter as it is posted. To unsubscribe, send the message UNSUBSCRIBE IEEE-CANADA-NEWSLETTER. If you do not have E-mail but have access to a fax machine, send your name/ company and your fax number to Chris Barnard at 613-952-0215. Three versions of the newsletter are available. A short abstract is sent to all subscribers. You can also access our gopher site on mpp.ps.iit.nrc.ca. Finally, you can get (via E-mail or fax) full documents from the listserv database by sending E-mail to listserv@mpp.ps.iit.nrc.ca with only the word INDEX in the body of the message. You will receive (by return E-mail or fax) information on how to retrieve files from the long-term index of IEEE Canada. You are invited to submit information about the local or national events to the IEEE Canada Newsletter Editor, Chris Barnard, fax: 613-952-0215 E-mail: barnard@iit.nrc.ca. The gopher site, which can also be reached from the WWW site, carries the previous issues of the newsletter, abstracts from The Canadian Journal of Electrical and Electronic Engineering, and other information.

IEEE Lectures broadcast on CANARIE broadband network.

Last October marked the first IEEE Lecture broadcast via a fibre optic ATM network across the country. The talk was given at the National Research Council (NRC) by Dr. Allistair Glass from AT&T Bell Laboratories. In November 1994, the IEEE workshop at NRC devoted to medical applications demonstrated connections between Ottawa, Vancouver, Chicago, Toronto, Boulder and New Brunswick (by satellite) and caught the news with the transmission of the 3D human body across the continent. This technology is in the early stages of applications. The IEEE Communication Society is very aggressively promoting networking to deliver conferences and lectures, both for members and for the public. The next event in this arena is the joint workshop between Ottawa and Rio de Janeiro using ATM about applications on broadband fibre optic networks. This first of a kind experimental multi-site meeting, and the fourth in the series "Photonic networks, components and applications" will take place on September 12 to 15, 1995. More information is available from the author.

We now reprint two articles which previously appeared in other publications to provide the reader with complementary information about the Internet.

AT HOME WITH INTERNET

This is an abridged version of an article by Bob Jopson from the November 1994 issue of Optics & Photonics News.

Mosaic (and other WWW browsers) provides a point-and-click connection to computer systems throughout the world. With a 10-cm movement of your mouse and a click of a button, you can jump from Australia to Europe in less time than it takes to read this paragraph. However, unless you work for a large corporation or university, the joys of armchair travel may not be yours. For, buried in a recent column on Mosaic (June OPN, p. 48), is the fine print: You must have a direct connection to Internet if you wish to use Mosaic. Who can afford to run an Internet line directly to a home or small business? The answer is that you can afford it. There are many companies that will provide you with a direct connection to Internet for a setup fee of $20-$100, monthly fees as low as $15, and connect charges of around $1 per hour. My goal for this month was to get Mosaic running on my PC at home over a phone line and write an article describing every step taken in the process. The results were mixed: I now have Mosaic access to the Internet from home, but it took me 24.3 hours of effort involving many more steps (not to mention back alleys and blind alleys) than can be documented here. And although I had never used Mosaic before this effort, I did take advantage of my Internet connectivity at work to obtain information and software (using e-mail and file transfer protocol--ftp--, respectively). A greater problem for this article is that the most economical service provider may be one that provides local phone access for you, and not the one I chose, so this account may guide, but not describe, your situation. My journey to Mosaic at home involved: 1) asking friends if they knew how to do it and re-reading Wayne Itano's Mosaic article in the June OPN: 0.3 hours; 2) finding service providers and choosing one of them: 4.1 hours; 3) setting up an account with the chosen service provider: 2.2 hours; 4) obtaining and installing software for my PC: 8.5 hours; 5) using the software to connect directly to the Internet: 5.2 hours; and 6) installing and running Mosaic: 4.0 hours. I am not particularly efficient at these activities, so you might spend considerably less time than I did.

Finding a Provider

I learned from friends (none of whom had Mosaic access over a modem) that Mosaic needed a SLIP connection or a PPP connection. These are acronyms for transfer protocols with PPP apparently being the up and coming standard. There was also the suggestion that the Tuesday science section of the New York Times (and presumably your local newspaper) had ads for service providers. This yielded one provider (PSI, 800/774-3031). I next turned to Internic and their electronically accessible list of service providers. Send e-mail to mailserv@is.internic.net and use "send /faq/internic-long" as your message. A file will be mailed back to you containing useful information including a list of service providers. Limit your search to those providers for which SLIP or PPP appears in the services line. Then look at costs, which include the start-up fee, monthly rate, and hourly access and telephone charges (if a number local to you is not available). I chose Colorado SuperNet, 303/296-8202, a provider that offered toll-free 800 dialup access in addition to dialup access local to Colorado. The fees for my dynamic SLIP/interactive account were $20 startup, $15 monthly minimum, $1-$3 per hour access fees depending on the time of day, and an $8 per hour surcharge for using 800 access. Dynamic SLIP meant that my Internet address was assigned from a pool each time I logged on, rather than being permanently mine. This option was inexpensive and could be activated quickly. If you want to provide full Internet connectivity for the employees in your company, you can obtain a permanent SLIP account, an Internet domain name, and an Internet Class C Network address. In this case, members of your company will have sub-addresses to the company domain name.

Obtaining Software

Once the account has been established, you must acquire software and load it into your PC or Mac. Some service providers include software as part of their start-up fee. If well documented, this could be a faster, albeit more costly, route to follow than the one I used, which was to obtain software by ftp. You need a program to handle the SLIP or PPP interface at your end, and you need application programs to handle e-mail, ftp, gopher, Mosaic, and so on. Several programs handle the local end of a SLIP or PPP connection. For a PC, there is the commercially-available Chameleon from NetManage, or the shareware Trumpet Winsock by Peter Tattam. For Macs, you need to obtain MacTCP by Apple and then use something like the freeware InterSLIP by InterCon Systems Corp. You can learn more about service providers by reading the Internic file and the references it contains. You can obtain a lengthy description of SLIP and PPP by ftp from ftp.digex.net in the file /pub/access/hecker/internet/slip-ppp.txt. Robert Sutterfield presents a comparison of SLIP and PPP in "Low-Cost IP Connectivity" available compressed and in Postscript format by ftp from ftp.MorningStar.com in file /pub/papers/sug91-cheapIP.ps.Z.

Bob Jopson is a member of technical staff at AT&T Bell Laboratories, Holmdel, N.J. He can be reached at virgin@pochs.att.com.

THE IEEE WORLD-WIDE-WEB COMES TO LIFE

This is an abridged version of the article by Bob Alden which appeared in the January'95 issue of the IEEE "Institute".

There are two levels of access to the Web. Both require full Internet access--which means more than an E-mail connection. If you are using a personal computer and have one with a 486/33MHz processor with 8 Mb RAM, or a Mac of equivalent capability, with a local area network (LAN) or dial-up Serial Line Internet Protocol (SLIP) connection, then you can use the Mosaic graphics-oriented browser. You can get a copy of Mosaic using the file transfer protocol (FTP) from ftp.ncsa.uiuc.edu:/PC/Mosaic (the part before the colon is the site address and the part after is the directory). Then you install it on your PC and run it under Windows. Please see my August 1994 column in The Institute for more information about Mosaic and the Web. There are also versions for Mac and workstation users. Mosaic allows you, if you have all the bells and whistles, to connect to any Web server, read hypertext, view graphics, listen to sound clips and move around the Web by using a mouse to click on highlighted key words.

If you have a simpler personal computer that does not run Windows, or if you cannot connect to the Internet using a LAN or by dialing up using SLIP, then you may be able to use Lynx to access the Web. Lynx is a text-only browser developed at the University of Kansas. Lynx runs on the host computer where you have your log-in ID, not on your PC. I got a copy of Lynx from ftp2.cc.ukans.edu:/pub/WWW/lynx. Don t forget that upper and lower case characters are different in Unix, so type carefully. My system administrator installed the Lynx software in about five minutes. I logged in and typed lynx at the system prompt. It worked like a charm. Let's see what Lynx does and why it may be for you. You may want to see if Lynx is available on your host computer, and if not, ask your system administrator to get and install it.

With Lynx you cannot view graphics or listen to sound clips, but you can read hypertext, place the cursor on highlighted words using the arrow keys and move around the Web by pressing the enter key. Lynx is much faster than Mosaic because it does not transfer the large files needed to display graphics or produce sound on your computer. Some people who have both Mosaic and Lynx choose to use Lynx because of its speed. In many cases, the text content is much more significant than the graphics and sound.

All Web servers have what are called "home pages". The Web home page corresponds to the root directory in gopher. To connect to the IEEE Gopher, we type gopher gopher.ieee.org from the system command prompt after logging in. To access the IEEE Web server with Lynx, we type lynx http://www.ieee.org/ from the system command prompt after logging in. Using Mosaic, we start up Mosaic in Windows, click on File, Open URL, and enter http://www.ieee.org/ into the window. The http stands for HyperText Transfer Protocol. URL stands for Uniform Resource Locator and is the equivalent of the Web server address.

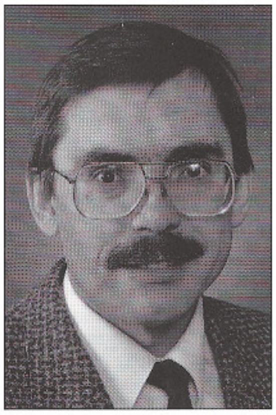
What do we see next--the IEEE Web home page. We view this page and using either mouse or arrow keys (depending on whether we are using Mosaic or Lynx) we can move around the screen or scroll to see more. The text is displayed in an attractive manner because it is written in HTML (HyperText Markup Language). Some words are highlighted and if we click (or hit enter if we are using Lynx), we see the screen contents change as we are taken through the Web to view a different file. There may be a time delay as the next file may be on a computer in another country (anywhere on the Internet) and that file has to be downloaded to your PC where you are running Mosaic (or to your host running Lynx). There may be some graphics, an IEEE logo, a photograph, a pie chart, for example. These we will not see if we are using Lynx.

The highlighted words may take us to view other files - such as the various articles in The Institute - or they may take us to other home pages, such as home pages for IEEE societies that have created their own Web servers. Each of these will have their own URL so that you can go directly to the home page of your choice or see the variety of home pages that will develop over time. The Institute has its own URL http://www.ieee.org/ti.html. Browsers have the capability to store lots of different URLs so that you can select as needed. Some of these URLs can be very long and difficult to type in correctly.

Text files containing previous articles on E-mail and other aspects of IEEE's information highway are available via E-mail. To find out more, send a message to fileserver@ieee.org and place the file name info.E-mail by itself at the start of the first line in the message.

Robert T.H. (Bob) Alden is the chair of the IEEE Electronic Communications Steering Committee, and a former IEEE vice president. He welcomes your input via e-mail at r.alden@ieee.org.

About the authors



Jacek Chrostowski received his M.S. degree in Electronics Engineering and Ph.D. in Physics from the Warsaw University of Technology, Poland. After work at the University of Warsaw and at Laval University, he joined the National Research Council in Ottawa in 1982 where he is currently Project Leader, Photonic Systems, in the Institute for Information Technology. His technical interests include fibre optic networks and applications enabled by them. He has published over 80 journal and conference papers, and holds 4 US patents in photonic systems.

The CCRS Synthetic Aperture Radar System: a Canadian national facility

by C. E. Livingstone
Canada Centre for Remote Sensing

The CCRS C- and X-band airborne Synthetic Aperture Radar (SAR) system is a Canadian national research facility for SAR remote sensing. The existing radars were designed and built in Canada from 1982 to 1987 as part of a program to develop Canadian expertise in SAR and have their roots in earlier CCRS experience in operating and modifying U.S. built equipment. Research based on the current and predecessor systems has won international recognition for Canadian SAR remote sensing expertise and the current CCRS radar system is considered to be one of the best research facilities in the world. This paper describes the CCRS SAR system, its history, properties and uses.

Les systèmes de radar d'aperture synthétique (SAR) en bande C et X du CCRS font partie de l'infrastructure de recherche en télédétection au Canada. Les deux systèmes ont été conçus et réalisés de 1982 à 1987 dans le cadre d'un programme visant le renforcement de l'expertise canadienne en SAR, suite aux premières expériences d'amélioration du matériel américain. Ainsi les travaux de développement et de recherche ont permis au Canada d'afficher un savoir-faire de premier plan reconnu mondialement. Cet article présente le système SAR du CCRS en faisant le point sur son historique, fonctionnement et applications.

Since 1978, the Canada Centre for Remote sensing (CCRS) has operated an airborne Synthetic Aperture Radar (SAR) as a national research facility. Initially based on older analogue technology, this system as evolved into a modern, C- (5.3 GHz) and X-band (9.25 GHz), remote sensing research tool that has been at the heart of Canada's international reputation in SAR for civilian applications. This paper provides an overview of the facility, and some insight into both the system and the research and development that has been conducted with it.

HISTORICAL BACKGROUND

In 1978, the Canada Centre for Remote Sensing (CCRS) had the opportunity to install a two frequency (X-band, 9.35 GHz; and L-band, 1.25 GHz), multi-polarization SAR, built by the Environmental Research Institute of Michigan (ERIM), in the CCRS Convair 580 aircraft. The initial objective of this work was to investigate civilian uses of SAR as part of the very successful SURSAT program[1]. Following SURSAT, CCRS purchased part of the radar system from ERIM and the jointly owned radar was upgraded and operated in the CCRS CV 580 aircraft as a Canadian national SAR research facility until 1985. This facility was used to support research in a large number of remote sensing disciplines and to develop Canadian expertise in the acquisition and interpretation of SAR imagery. In addition, CCRS established policies that allowed the national SAR facility to be leased by the Canadian remote sensing industry to develop domestic and foreign markets for Canadian SAR expertise and services. The CCRS / ERIM SAR was leased to explore the sea-ice remote sensing markets that fostered the development of the world's first modern commercial SAR described in the previous issue of this magazine. Leases in support of international research projects opened European markets for Canadian SAR remote sensing expertise and helped to develop the reputation for excellence in SAR remote sensing that Canada enjoys today.

Early in the SURSAT program it became apparent that although the CCRS / ERIM SAR produced valuable data for manual interpretation, the 1960s analogue technology used to build the radar was inadequate for quantitative analysis. Concurrent work with non-imaging radar systems showed that the quantitative analysis of radar returns could be used to measure physical properties of materials on the earth's surface and that radiometrically calibrated SARs were needed for future remote sensing tools. Over the period 1979 to 1981 CCRS supported a number of study contracts by the Vancouver firm, MacDonald Dettwiler and Associates (MDA), to evaluate the technology of the day and to define a Canadian built, airborne remote sensing SAR system that would replace the CCRS/ ERIM SAR with calibratable instruments for ongoing SAR research.

1. See the previous issue of the IEEE Canadian Review, Fall and Winter 1994.

From 1982 to1987, MDA and their subcontractor Canadian Astronautics Ltd. (CAL), designed and built two airborne SARs under Unsolicited Proposal contracts sponsored and monitored by CCRS. This article describes the development of the CCRS C- and X-band SARs, their specifications and their evolution.

SYSTEM DESCRIPTION

The CCRS SAR system was designed as a state-of-the-art tool (1982) for research and development in SAR remote sensing and is based on two, two channel, coherent radars, one at C-band (5.30 GHz) to support research associated with the European ERS-1 SAR satellite (launched in 1991) and one at X-band (9.25 GHz) to support research at the frequency used for commercial SAR reconnaissance. It was expected that the radars would support SAR research needs until the mid 1990s. The system performance specifications were defined from the knowledge available at the design date, from the projected needs of the remote sensing industry and from the projected SAR research directions for the next decade. CCRS uses a large (58000 lb), two engine turbo-prop aircraft (CV 580) for radar research, thus, the radar design was optimized for performance accuracy and flexibility but was not strongly constrained by weight.

Each radar was designed to transmit either H (horizontal) or V (vertical) linearly polarized radiation and to capture radar returns with both the transmitted polarization and the orthogonal linear polarization in two identical, phase-coherent receivers. The C- and X-band, dual polarized radar antennas were designed and built by Comdev Ltd (Cambridge, Ontario) using waveguide technology and a shared horn aperture to minimize radiation pattern differences between the transmitted polarizations, to maximize the polarization isolation, to minimize polarization phase centre separations and to maximize the antenna tolerance to peak transmitter power (> 64 kW). Azimuth aperture weighting was used to constrain antenna 2-way azimuth sidelobes to be less than - 40 dB and horn aperture weighting was used to similarly constrain elevation sidelobes. The antenna patterns used are symmetric in both azimuth and elevation. In the original design, the antennas were mechanically steered in azimuth and elevation to compensate for aircraft attitude changes and to illuminate a swath normal to the mean track of the aircraft. The antennas could be turned to map on either the port or starboard side of the aircraft.

To compensate for the large systematic variation in signal strength caused by the combination of antenna pattern, imaging geometry and incidence angle dependence of terrain reflectivity, the receiver gains are varied systematically during signal reception (sensitivity-time control or STC) using invertible models whose parameters are preset. The received signals are coherently down converted to base-band in-phase (I) and quadrature (Q) components and are digitized to 6 bits for digital processing and recording. Outputs from precision calibration signal generators can be injected into the receiver inputs at the end of each data acquisition flight line to aid in radiometric calibration of the radar returns.

Each radar has two concurrent signal processing and recording paths: raw signal recording and real-time processed image recording. Both paths share a selectable real-time motion compensation system that can correct for non-ideal aircraft motions, measured at the antenna mount by an inertial navigation system (Litton LTN-92). Data in the raw signal recording path are combined with aircraft motion and radar setting data and are recorded by high speed digital recorders. These data are converted to image products using ground processors. Data in the real- time image recording path are formed into 7 look, detected, strip images by the SAR real-time processor using custom boards designed by MDA. The real time processor outputs are displayed on-board using a quality-control video system, are recorded as dry-silver paper strip images in flight and are recorded as unsigned Byte data streams for ground display and analysis. In the original design, either of the received polarizations could be processed in real time and the 4096 recorded cells of raw signal data could be selected from the full swath of either receiver channel or a half swath of both receiver channels.

The CCRS SARs have two range resolutions: high resolution operation produces images with 6 m range resolution sampled at 4.0 m over 4096 cells to yield a 16.4 km slant range swath, and low resolution operation produces images with 20 m range resolution sampled at 15 m over 4096 cells to yield a 61.4 km slant range swath. For high resolution operation, the radars can be used in two image swath modes: a nadir mode that creates images from nadir out to the swath limit and a narrow swath mode that creates images from 450 incidence angle (plane earth model) to the swath limit.

The radar range gate delay is controlled by the radar motion compensation system to automatically compensate for cross-track aircraft motions and the radar pulse repetition frequency is slaved to the aircraft ground speed by selectable scaling constants 2.32 Hz/m/s and 2.57 Hz/m/s to maintain nearly constant power density on the ground in the flight direction. To permit the radars to be operated as calibrated instruments, all radar parameters and settings are logged automatically (including the key elements of the STC functions).

USES AND EVOLUTION OF THE CCRS SARS

Although the CCRS SAR system is a research tool and has been primarily used to investigate the radar properties of terrain types and terrain covers; it has also been used extensively to model expected results from spaceborne radars, to demonstrate radar remote sensing applications and to develop markets for Canadian remote sensing technology. In addition to these functions, the CCRS radars have been used to investigate the impact of radar system parameters on remote sensing measurements and to provide baseline parameter sets for the design of other radars. Throughout the life of the radars, the pressures of research have driven a continuing evolution of the instruments, their auxiliary equipment and the signal processing software needed to exploit their full potential. The information acquired, capabilities developed, and the processing tools created have been made available to the Canadian remote sensing industry to enhance its ability to compete internationally.

Early in the lifetime of the CCRS radars, a series of calibration experiments at CCRS and related refinements to the radar systems established the relative radiometric calibration errors in precision processed imagery to be less than 1 dB and the absolute calibration errors to be less than 2 dB. Radiometrically calibrated SAR images have been combined with measured surface parameters to investigate the geophysical processes responsible for the appearance of the radar images and to develop algorithms to extract geophysical information from the image data. In other work simultaneous multi-polarization, calibrated C- and X- band images of sea ice were combined to show that at least 5 of the 6 independent radiometric radar channels in these data are required to preserve the available information content. No single polarization or frequency channel is dominant.

Ever since the first (C-band) radar was commissioned in late 1986, the CCRS SARs have been used to provide two very different kinds of research data: real-time processed imagery for semi-quantitative and qualitative analysis; and precision processed imagery for quantitative analysis and advanced SAR applications.

Semi-quantitative uses of real-time processed imagery

The cross-swath radiometric leveling provided by the radar STC and the stable radar performance allows classical image analysis operations to be used on real time processed imagery for the extraction of semi-quantitative relative contrasts and textures. Analyses of this type have been widely used by researchers in agriculture, hydrology, forestry and geology to extract information of importance in their disciplines and to investigate the radar signatures of known test areas.

In geological studies, the main interest in SAR remote sensing has been triggered by the ability of radars at large incidence angles to detect subtle variations in terrain relief and thus surface expressions of geological structures. The low resolution, wide swath mode of the CCRS SAR has been used to map large scale geological structures such as the ancient meteor crater at Sudbury and the associated fracture structures. In other work, mosaics have been made from multiple flight lines of high resolution imagery and these have been overlaid with maps of geophysical data to aid mineral exploration.

In forestry, radar imagery at moderate to large incidence angles highlights clear-cuts and has been used in conjunction with optical imagery for mapping cutting practices and forest regeneration. Radar image texture and intensity variations have also been used as forest parameter indicators.

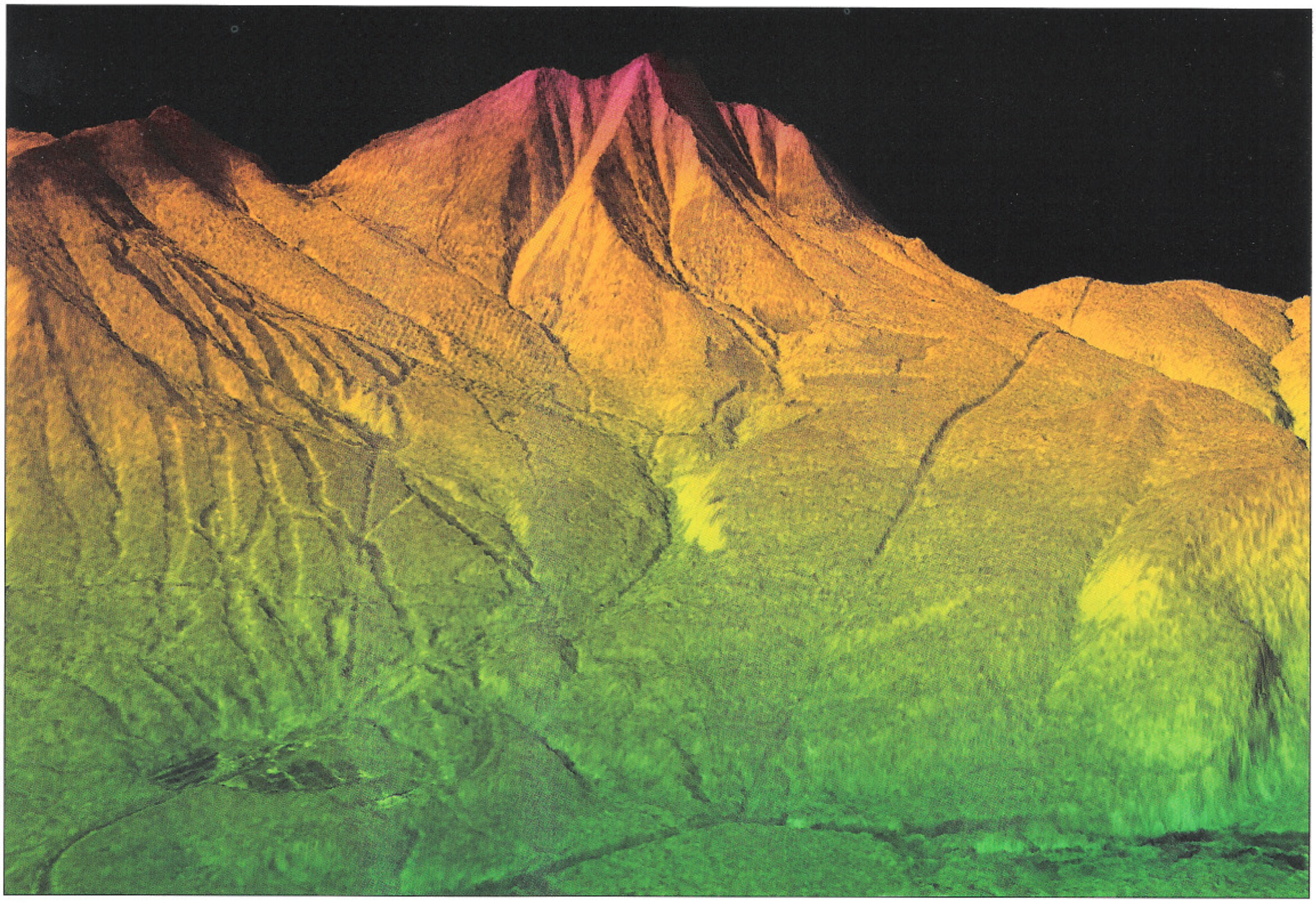


Figure caption: This scene shows the Nakiska ski area, site of the 1988 winter Olympics, in the Kananaskis Valley, Alberta. The ski runs are clearly visible on the mountain side as are tree cutting patterns and hydro lines. The river is visible on the valley floor. This image was created using interferometric data from a single pass of the CCRS C-band airborne SAR on February 9, 1992. Although the radar was flown at 6.7 km (22,000 ft) and looked northwards, it is possible to create images which view the terrain from quite a different perspective, as in this westward looking view apparently taken from across the Kananaskis valley. Using computer processing, different views (or even animations) of the data can be created. This perspective includes a vertical exaggeration factor of 1.65. The image source is a digital elevation model with RMS height errors less than 5 m, sampled on a 5 m grid, derived from the SAR interferogram.

In agriculture, the polarization and frequency dependence of the terrain reflectivity at radar frequencies has provided information on crop types, soil types, farming practices and crop development stages.

CCRS has acquired data in all provinces and territories of Canada to support research in these areas by government scientists, university scientists and remote sensing companies. In addition CCRS scientists have gained international recognition for their work in extracting information from SAR image data in these application areas as well as in oceanography and sea ice studies.

Two major international demonstration programs have been conducted with the CCRS SAR: SAREX'92 and GLOBESAR'93. The SAREX program in 1992 imaged areas in Brazil, Venezuela, French Guyana, Colombia and Costa Rica to support projects of interest to national remote sensing agencies and the European Space Agency (ESA). SAREX was funded by ESA to support the ERS-1 SAR program and the RADARSAT program. The GLOBESAR program in 1993 was a Canadian funded project that imaged areas in Morocco, Tunisia, Jordan, Kenya, Malaysia, Thailand, Vietnam and China to support projects of interest to national agencies and to promote the Canadian RADARSAT program. Both demonstration programs had commercial SAR components and both programs involved national agencies, CCRS scientists, and Canadian companies in the planning and execution of the experiments as well as in the analysis of the data acquired. The unqualified success of both programs has reinforced Canada's international reputation for excellence in SAR remote sensing and has opened doors for future work in the host countries.

Quantitative uses of SAR data and the evolution of the CCRS SARs

In parallel with the development of the quantitative uses of the radar system, the equipment was modified to improve its performance. From 1987 to 1990 much of the effort concentrated on improving the radiometric properties of the radar and the antenna control, STC accuracy, and automatically logged radar parameters were refined. During this period accurate measurements of the antenna patterns were made, the real-time processor was modified to process both received channels, and initial tests of the radar as a SAR polarimeter were performed.

From 1990 to 1992 the focus shifted to the use of the phase coherence of the system and the antenna steering was changed to 3 axis control (pitch, azimuth, elevation), the motion compensation system of the radars was redesigned, the imaging swath modes were changed to allow images to start at any selected incidence angle, a C-band high power switch was built for polarimetric SAR operation, a side mounted antenna system was built for SAR interferometry, Global Positioning System (GPS) receivers were installed in the aircraft for precision positioning, and a specialized software SAR processor was developed to generate topographic information from interferometric SAR data.

From 1992 to 1994 development work has focused on the use of the phase measurement capabilities of the CCRS radar system and on the data recording subsystems. Several digital elevation models and associated geometrically corrected images and three dimensional projections of the radar scenes have been created from interferometric SAR imagery. Terrain height accuracies better than 5 m RMS are obtainable on a 5 m grid in high relief terrain.

Antennas for along-track (temporal) interferometry have been developed and this mode has been used to generate preliminary images of the tidal currents in the Bay of Fundy and the orbital velocity fields of ocean waves.

Phase calibration studies have been conducted for SAR polarimetry, a specialized software processor and calibration software set has been developed for this radar mode, and SAR polarimetry application studies are in progress for sea ice, forests and agriculture. In parallel with the preceding activity, the SAR data recording systems on the CCRS CV 580 aircraft have been changed so that real-time processed images are now recorded on 8mm cassette tape for direct transfer to client computing/ analysis systems and the full swath of both received raw data channels is now recorded on a high bandwidth helical scan tape recorder.

The ability of the CCRS SARs to be operated as calibrated measurement instruments has driven most of the commercial applications of this system. Since 1988, the CCRS SAR system has been used in international SAR remote sensing projects, with strong or dominant Canadian commercial remote sensing components, in Norway, Sweden, UK, Germany, France, and Taiwan. In all cases, the client countries funded the data acquisition and data processing required. The CCRS SAR system was chosen for this work because of its measurement accuracy and the international reputation of the CCRS SAR system and the Canadian contractors for the quality and accuracy of their services. As the CCRS radars have evolved, client interest has tracked the growth in measurement capability.

SUMMARY OF THE PAST AND DIRECTIONS FOR THE FUTURE

The Canadian designed, Canadian built CCRS SAR system has acquired international recognition as one of the best SAR research facilities in the world. SAR remote sensing expertise acquired by CCRS and by Canadian companies using the CCRS facility is widely recognized for its depth and excellence and Canada is considered to be a world leader in many areas of SAR remote sensing research. Current research trends world-wide stress the quantitative relationships between SAR measurements and geophysical properties of the earth's surface. These are expected to continue and Canadian companies are in a good position to use the national SAR facility to investigate and capture markets that evolve from this work and to establish client bases. In particular, the complementary capabilities of spaceborne and airborne SARs need to be investigated. As typical time lines to move from initial research activities to marketable products and services range from 5 to 20 years, the next decade should be a period of opportunity for interested Canadian companies.

For the next 15 to 20 years there will be a continuing need for a national airborne SAR research and development facility to support Canada's international competitive position. Development of new airborne systems and techniques will be required and the synergy between government research and industrial activities will need to be maintained. CCRS is presently considering a redesign of the existing airborne SAR system to fill this role. This will be essential to maintain Canada's position, especially in the era following the launch of RADARSAT later this year. Without an ongoing commitment to the continuation of the research that has led to RADARSAT, the success of this national venture will be compromised.

Canada's remote sensing industry is knowledge based and is functioning in an increasingly sophisticated international market place. In the past, industrial access to the national SAR research facility and first hand experience in working with it have enabled Canadian industry to gain an international competitive advantage from Canadian R&D. In the future, a close coupling between current, world-class R&D, a national airborne SAR facility, and vigorous industrial implementation of the knowledge gained will be even more important in securing markets for Canadian industry.

About the author

He received the B.Sc. degree in physics in 1965 and the M.Sc. degree in geophysics in 1967 from the University of British Columbia. He received the Ph.D. degree in physics in 1969 from the University of Western Ontario. He joined the Canada Centre for Remote Sensing in 1976 and is currently a senior research scientist at this institute. He has conducted a number of research and engineering programs in sea ice and oceans remote sensing and in the development, extension and calibration of airborne synthetic aperture radars. He is currently completing calibration work on the CCRS SAR polarimeter. Dr. Livingstone is a member of the IEEE Geoscience and Remote Sensing Society and is registered as a Professional Engineer in the Province of Ontario.